

CONCEPTUAL UNDERSTANDING OF SCIENCE
THROUGH ARCHAEOLOGICAL INQUIRY

by

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A dissertation submitted in partial fulfillment
of the requirements for the degree

of

Doctor of Education

in

Education

MONTANA STATE UNIVERSITY
Bozeman, Montana

April 2011

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DEDICATION

This work is dedicated to the 27 students who shared their ideas and knowledge with me, so willingly and so honestly.

ACKNOWLEDGMENTS

I was fortunate to have embarked on my doctoral work in the good company of a collegial cohort of other doctoral candidates. Their professionalism and good humor got us all off to a good start. In particular, I thank Kim Boehler, Micki Abercrombie, Shane Doyle, and Jess Krim for their unflagging support and their willingness to listen to my trials and tribulations as I've made my way through the grind of graduate school. I hope that I can provide the same support to them in some way.

This study would not have been possible without the full cooperation of two fifth grade teachers, the school where they work, and the 27 students who devoted extra time to sharing their ideas and knowledge with me. My thanks to all involved with the project.

Crystal Alegria generously donated several hours to checking my research findings; I thank her for her time and for her thoughtful insights on my research. Many other colleagues provided good sounding boards for my ideas and the issues encountered during research and writing. Ivy Merriot and Rob Bargatze helped me think through the use of science inquiry concepts in other areas of science. Joelle Clark helped me devise approaches for assessing conceptual understanding of science inquiry. Linda Clark helped me consider the significance of the work for broader issues in learning and assessment. Savannah Barnes graciously offered to edit the final draft and her excellent work greatly improved this manuscript. Lastly, I thank Dean Littlepage who has the finest mind, the warmest heart, and best sense of humor I have ever encountered. His encouragement, his brilliant insights into the research, and his support have made this project a joyful experience.

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ABSTRACT

Since the launch of Project 2061 in 1985, an effort to improve science education, educators have searched for engaging ways to teach science inquiry in the classroom. While archaeology is inherently interesting, it is an underused vehicle for teaching to national standards, especially science inquiry, in pre-collegiate education. This case study examined students' conceptual understanding of five science inquiry concepts (observation, inference, classification, context, and evidence) and the Nature of Science (NOS), the differences between science and history, and the similarities in science inquiry and historical inquiry through the study of archaeology.

This qualitative case study included 27 subjects, all fifth grade students who were studying American history through archaeological inquiry. Data was collected through a series of learning assessment probes and a performance task designed specifically for this study. Interviews, observation of the performance task, and examination of classroom work completed data collection.

With only minor exceptions, students were conversant in all five of the inquiry concepts, however, their understanding of each concept was highly individual. In many cases, students retained some misconceptions, misunderstandings, or incomplete understandings of the concepts. Identification of the cognitive processes underlying student understanding helped trace the origin of misconceptions, misunderstandings, and incomplete understandings. All of the students demonstrated some understanding of the Nature of Science and the relationships between science, history, and archaeology.

The study has implications for learning, for curriculum development, and for teaching and teacher preparation. Students can easily retain misconceptions throughout a course of study or can fail to reach complete conceptual understanding. Identification of misconceptions and their source can provide teachers with a clear starting point to dispel misconceptions and to create deeper and more accurate conceptual understanding of science processes. Results can be used immediately to improve the curriculum used in this study and to design better science inquiry curricula. Future research could be designed to confirm the results of this study and to expand the sample to a larger and more diverse group of subjects.

CHAPTER ONE

INTRODUCTION

Most people in North America find archaeology to be a fascinating subject (Ramos & Duganne, 2000). Despite a widespread interest in archaeology, it has been little used in pre-collegiate education in the United States and Canada primarily due to a lack of widely available and pedagogically sound curricular materials keyed to national standards in science, social studies, history, and other school subjects (Smardz & Smith, 2000). Over the last decade, archaeology educators have redoubled their efforts to fill this void (e.g., Letts & Moe, 2009) and to do the research that will demonstrate the effectiveness of archaeology in the classroom (Davis, 2005; Levstik et al., 2005; Moe & Clark, 2008).

Archaeology is not only interesting; it can be an engaging way to teach national standards in science, history, and social studies (Davis, 2000). Because archaeology is by nature an interdisciplinary field, it can be used to integrate subjects in pre-collegiate education. Through this qualitative case study I examined students' conceptual understanding of science inquiry concepts (observation, inference, evidence, classification, and context), the Nature of Science (NOS), the differences between science and history, and the similarities in science inquiry and historical inquiry through the study of archaeology.

Conceptual Framework

According to the seminal book *Science for All Americans* (Rutherford & Ahlgren, 1990), most Americans are not scientifically literate. Specifically, Americans lack working knowledge of science content in life sciences, earth sciences, and physical sciences; they do not understand the nature of science or how science works; and they do not have the habits of mind to understand the results of scientific studies. The *National Science Education Standards* defines scientific literacy as follows:

Scientific literacy is the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity. ... A literate citizen should be able to evaluate quality of scientific information on the basis of its source and methods used to generate it. Scientific literacy also implies the capacity to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately. (NRC, 1996, p. 22)

One of the most important habits of mind for understanding science is understanding how science inquiry works and to be able to use it to design and perform investigations. What is science inquiry? The *National Science Education Standards* explains inquiry as follows:

Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. (NRC, 1996, p. 23)

In the 15 years since the publication of the *National Science Education Standards* (NSES) in the mid 1990s (NRC, 1996; NRC, 2000), we have seen few gains in science

literacy (Gabel, 2006). The publication of the *Standards* gave educators their marching orders: teach science inquiry as part and parcel of science education in grades kindergarten through twelfth. Shifting the paradigm to science inquiry, however, has not been an easy task (Gabel, 2006). According to Gabel (2006), the difficulties may be attributed to two main reasons. First, it is very difficult to teach inquiry effectively. Second, most teachers are ill-prepared to teach inquiry and therefore, are reluctant to teach it and/or are unable to do it effectively.

Real science inquiry has been sparsely implemented; therefore there have been few opportunities to assess it (Gabel, 2006). Only recently has a body of research on the efficacy of science inquiry in the classroom begun to emerge. Some studies show positive results from assessment (Beeth et al., 1999; O'Neill & Polman, 2004; Metz, 2004; Gabel, 2006). Lee and Aukyx (2006) measured gains in scientific literacy among students whose first language was not English and found that cultural as well as language barriers seemed to limit their achievement in science inquiry. Other researchers (Trumbull et al., 2005) have found inquiry-based curricula very difficult for students to perform and, consequently, found very little improvement in science inquiry skills. Others (e.g., Hume & Coll, 2008) have found much recent inquiry-based instruction to be mechanistic and simplified rather than creative and critical. Still others (Kirschner et al., 2007) have flatly stated that students cannot learn content through inquiry-based instruction because children are not cognitively able to learn both content and process at the same time.

Understanding of the Nature of Science (NOS) is often considered to be a critical component of scientific literacy (Lederman, 2007). An understanding of how science works is necessary to make sense of scientific knowledge, the value of science to society, and how science can inform everyday life (Driver et al., 1996). The Nature of Science is difficult to define succinctly because it essentially asks the question: What is science? Clearly, one important aspect of NOS is understanding science inquiry concepts, especially the distinction between observation and inference and how scientific knowledge is derived from systematic inquiry (Lederman, 2007, pp. 833-834).

While there is a growing body of research on learning outcomes from science inquiry instruction, there is little research on the processes that underlie successful performance of science inquiry tasks and understanding of science concepts and constructs. Pellegrino, Chudowsky, and Glaser (2001, p. 194) note that assessments tend to be *task-centered* rather than *construct-centered*. Task-centered approaches tend to measure how well students do on specific tasks without specification of the underlying constructs that are the targets of inference. By contrast, construct-centered approaches start with the knowledge, concepts, skills, or other attributes to be assessed which are derived from a clear model of learning. Assessment design should focus on the “cognitive demands of task (mental processes required for successful) performance” (Pellegrino et al., 2001, p. 194). Pellegrino and his colleagues call for more construct- or concept-centered assessment to better understand the underlying processes involved in understanding new concepts and integrating them into existing knowledge for future use.

Because concept-centered assessments are not readily available, new assessments were developed for this study to examine student understanding of inquiry concepts. The new assessments were based on recent research on formative learning assessment probes designed to bridge the gap between standards and student learning (Keeley, 2005).

Archaeology and Science Education

Because of the profession's deep interest in epistemological questions and emphasis on rigorous procedures, archaeology has considerable potential to make significant contributions to science inquiry education. Few, if any archaeological interpretations of the past are beyond question. For example, new evidence and new research questions have recently challenged the long-held belief that the Western Hemisphere was peopled at the end of the last Ice Age via the Bering Land Bridge, a piece of land now covered by the Bering Sea (Bradley & Stanford, 2004).

Additionally, archaeology bridges three school subjects: science, social studies, and history (Figure 1). Situated at the confluence of science and history, archaeology provides a place for both historical and scientific reasoning. Educators need compelling ways to teach both (Sunal, 2006). Archaeology is a branch of anthropology and is technically a member of the social sciences, however, archaeologists routinely use tools and evidence from biology, geology, soil science, and chemistry to analyze data and draw inferences about past environments and human lifeways.

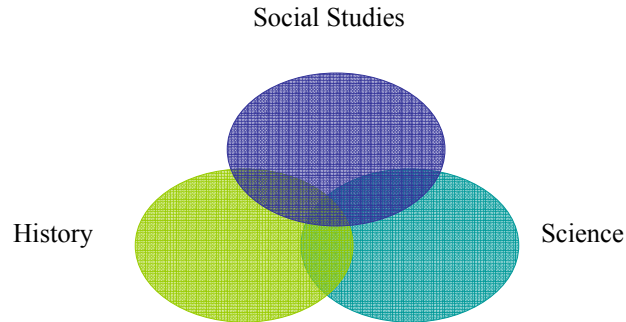


Figure 1. Archaeology as the Link between Science, History, and Social Studies.

As a branch of anthropology, archaeology focuses largely on understanding cultures of the past through material remains, thus it contains a significant cultural aspect. Because of its cultural connections, archaeology may provide a means for engaging students of diverse cultural backgrounds in the study of science (Brody et al., 2009). Archaeology often studies the history of cultural groups such as African Americans or Native Americans and, hence, may provide a connection for these students to engage in science inquiry through the study of their own history. Culturally relevant science curricula may help these students cross the borders between their own family or peer groups and the culture of school science (Aikenhead, 1996; Aikenhead & Jegede, 1999).

In North America, the subfield of archaeology education got its start in the late 1980s, largely in response to federal laws in the United States and Canada which mandate the protection of archaeological sites through education (Smardz-Frost, 2004). While archaeology education has been available to classroom educators for nearly 30 years, it has seldom been assessed for its ability to teach concepts of science inquiry. It has long been thought that archaeology could contribute to learning science concepts (Hawkins, 1987; McNutt, 1988; Devine, 1990; Smardz, 1990; Smith et al. 1992, 1996; White, 1998;

MacDonald & Burtneiss, 2000), but no published evaluations of archaeology as a means for teaching science inquiry were found for this study.

Elaine Davis (2005) studied how students use archaeology to construct history and Levstik, Henderson, and Schlarb (2005) studied how students understood the nature of historical knowledge and how to use it through archaeology. Both are important studies in the emerging field of archaeology education, but neither study specifically addresses science learning.

A new archaeology curriculum, *Project Archaeology: Investigating Shelter* (Letts & Moe, 2009) was designed using recent findings in learning research (Bransford et al., 2000; Donovan & Bransford, 2005). National science standards in inquiry formed the basis of lessons designed to teach science inquiry concepts and for investigations using authentic archaeological data. The curriculum is a complete investigation of a historical shelter through the process of archaeological inquiry. It contains nine complete lessons and assessment is built into all aspects of student learning. *Investigating Shelter* is a comprehensive and challenging supplementary curriculum (Moe & Clark, 2008; Moe et al., 2008), which integrates science with social studies and language arts and also some basic mathematics. Formative evaluations of the curriculum during development show that archaeology may be effective at engaging students in science inquiry and increasing positive dispositions towards science (Brody et al., 2009).

Based on recent research, archaeology is a promising but underused avenue for teaching science inquiry in classrooms. *Project Archaeology: Investigating Shelter* was used as a curriculum intervention for this study to examine how students learn and use

science inquiry concepts, their views of NOS, and their understanding of the integration of science and history through archaeology.

Research Problem

To meet the goals outlined in *Science for All Americans* (Rutherford & Ahlgren 1990) and in the *Benchmarks for Science Literacy* (AAAS, 1993), American students will need to learn science content, better understand the Nature of Science (NOS), and acquire the values and habits of mind including science inquiry skills and concepts to effectively employ science in the 21st Century and beyond. To accomplish this goal, educators will need compelling, effective, and doable ways to teach inquiry and to provide practice (repetition) for their students to grasp science content fully and to understand the results of scientific studies.

To develop and provide effective teaching materials, curriculum designers need more knowledge of how students understand inquiry concepts such as observation, inference, classification, context, and evidence and how they construct their understandings (Bransford et al., 2000; Pelligrino et al., 2001). We all use mental “tools” to help us process new information on a daily basis. Examples include observation, inference, classification, context, evidence, prediction, modeling, and perhaps, experimentation. These same tools are routinely used in science inquiry. Observation, inference, classification, context, and evidence are the main “tools” of archaeological inquiry, as presented in *Project Archaeology: Investigating Shelter* (Letts & Moe, 2009). The Enduring Understanding, the main learning goal, for the four lessons that teach

observation, inference, classification, context, and evidence is: “Using tools of scientific and historical inquiry, archaeologists study shelters and learn how people lived in them” (Letts & Moe, 2009, p. 10).

All five “tools” are abstract and complex concepts, and all carry specific meaning in the context of archaeological inquiry. All five of these tools or concepts are classified as nouns in English (Table 1). All five nouns are ultimately derived from Latin verbs, but only three of the “tools” (observation – observe, inference – infer, classification – classify) have verb forms in English. The English definitions for all five words include some notion of process or of doing something (see below), thus retaining some of their original Latin meanings. While observation, inference, classification, context, and evidence are all general concepts, the first three can be specific; for example, an observation, an inference, or a classification. Importantly, not all observations, inferences, or classifications are equal; some are better than others because of the strength of the reasoning processes behind them. Both context and evidence need another modifier to be specific, for example, a piece of evidence or the environmental context of five Archaic sites, hence the five concepts are not completely parallel.

Table 1. Science Inquiry Concepts and their Etymology.

English Noun	English Verb	Latin Root(s)	Latin Meaning
observation	observe observing	<i>observare</i> (v)	to watch or to look at to attend to
inference	infer inferring	<i>inferre</i> (v)	to bring in or to place on to conclude
classification	classify classifying	<i>classis</i> (n) <i>facere</i> (v)	division to make or to do
context		<i>con</i> (p) <i>texere</i> (v)	together to weave
evidence		<i>ex</i> (p) <i>videre</i> (v)	out to see

Source: *The New Oxford American Dictionary*, 2001.

In *Investigating Shelter*, each of these tools also encompasses an associated skill: observing, inferring, classifying, identifying context, or using evidence. Because context and evidence do not have English verb forms, another verb is required to make them into skills. Performing each skill is an application of the concept underlying it, i.e., observation, inference, classification, context, and evidence. If the concept is understood correctly, then the skill can be applied with productive results. If the concept is not understood correctly or is misunderstood, then the application of the accompanying skill will not be productive. When the underlying concept is fully understood, the investigator can build rules for applying the concept to inquiry. The “tools” taught in *Investigating Shelter*, should more properly be called “conceptual tools” because they encompass both the concept (e.g., observation) and the skill (e.g., observing) of using the concept to conduct an inquiry and gain knowledge. Observation, inference, classification, context, and evidence will be referred to as conceptual tools or concepts in this study. Observing, inferring, classifying, identifying context, and using evidence are considered to be skills

of science inquiry and were not specifically addressed in the research. Instead, this study concentrated on student understanding of these five concepts of science inquiry.

Definitions for the five conceptual tools and their accompanying skills (Table 2) are drawn from *Project Archaeology: Investigating Shelter* (Letts & Moe, 2009) and from the *New Oxford American Dictionary* (OUP, 2001):

1. Observation is defined as “recognizing or noting a fact or occurrence” in *Project Archaeology: Investigating Shelter* (Letts & Moe, 2009, p. 52).
Observation is the basis for inquiry and is a systematic way to gain information. In science, observation may include definitions and measurements of the subject of inquiry. In archaeology, an example of an observation is stones arranged in a circle on the ground. Observing is a skill and means to notice or perceive something of significance such as the circle of stones described above. An archaeologist might count the number of stones in the circle, measure the diameter, note the presence of interior stones or artifacts, and record gaps in the circle.
2. An inference is a conclusion derived from observations; evidence and reasoning also help build and support inferences. Inferences may be developed into testable hypotheses for further study. An archaeological example of inference might be concluding that the circle of stones is a tipi ring and the stones mark where people pitched their conical shelters known as “tipis” or “teepees” as the word is sometimes spelled. The skill of inferring

means to deduce or conclude from observation, evidence, and reasoning, rather than by drawing conclusions from explicit statements.

3. A classification is a systematic arrangement in groups or categories. More generally, it is a way to group objects or ideas. In science inquiry, classifications or groupings are based on research questions. Classifying is the skill of arranging objects or people or ideas according to shared characteristics, attributes, or qualities; in scientific inquiry classifying is driven by a research question. An archaeologist might want to know how many people lived in tipis and might classify stone circles by their size and infer that larger circles may represent larger family units.
4. In *Investigating Shelter* students learned that context is “the relationship that artifacts have to each other and to the situation in which they were found” (Letts & Moe, 2009, p. 52). The word can also be defined more broadly as “circumstances that form the setting for an event, statement, or idea, and in terms of which it can be [more] fully understood and assessed” (OUP, 2001, p. 371). Correspondently, something that is “out of context” cannot be fully understood. Context occupies a special place in archaeological inquiry and archaeology is often described as “a science of context.” Identifying and using context is critical in the interpretation of the archaeological record; without primary context, artifacts by themselves have very little value in archaeological inquiry. For example, an archaeologist might want to know if larger stone circles are found more often on certain landforms such as river

terraces or high bluffs. If size is associated with landform, an archaeologist might conclude that size has nothing to do with family size. Context is of widely recognized importance in archaeology because loss of context due to looting is both common and detrimental to interpretation. Context is also essential to research and explanation in many other sciences including all of the earth sciences and geomorphology in particular because this discipline relies heavily on environmental context for interpretation (e.g., Parsons & Abrahams, 2009), as well as ecology, biology, and medical science to name a few. Practitioners of other sciences may not be aware of the role of context and may take it for granted.

5. Evidence is the available body of data used to indicate whether an inference is valid or to answer a research question. Science does not associate the words “fact” or “proof” with “evidence,” but these two words are often associated with evidence in legal practice. For example, the New Oxford American Dictionary (OUP, 2001) defines proof as “... evidence or argument establishing or helping to establish a fact or the truth of a statement” (p. 1365) and that evidence may be “... used to establish facts in a legal investigation” (p. 589). An archaeologist might rely on radiocarbon dates or the presence of time-sensitive artifacts as evidence to establish when tipi rings were occupied. In *Investigating Shelter*, students are routinely required to use evidence to support their inferences and to answer their research questions.

Table 2. Summary of Five Inquiry Concepts Including Definitions and Archaeological Examples.

Concept	Definition	Example
Observation	recognizing or noting a fact or occurrence	stones arranged in a circle on the ground
Inference	conclusion derived from observations	concluding that the circle of stones is a tipi ring and the stones mark where people pitched their conical shelters
Classification	systematic arrangement in groups of categories	classify stone circles by their size and infer that larger circles may represent larger family units
Context	the relationship that artifacts have to each other and to the situation in which they were found	larger stone circles are found more often on certain landforms such as river terraces or high bluffs
Evidence	data used to answer a question	radiocarbon dates or the presence of time-sensitive artifacts as evidence to establish when tipi rings were occupied

Source: *Project Archaeology: Investigating Shelter*, 2009

Misunderstandings or misconceptions may hamper acquisition of scientific knowledge and educators need content-specific ways to detect and correct them (von Glaserfeld, 1989; Bransford et al., 2000; Wiggins & McTighe, 2005). Application and transfer of knowledge and fundamental concepts to other subjects and to everyday life is an important goal of education (Bransford et al., 2000) and few tools to assess application and transfer were found for this study. Not all educators agree that content can be learned through inquiry (Kirschner et al., 2006) and researchers need more and better ways to assess inquiry-based learning in diverse educational contexts (Metz, 2004). Archaeological inquiry and content could provide a new context for assessing conceptual

understanding, misconceptions, the application and transfer of knowledge, and content-learning outcomes.

Most science educators throughout the world recognize that people should understand how science works or the Nature of Science (Lederman, 2007).

Understanding of the Nature of Science (NOS) has been an education goal for over 100 years and has recently been receiving additional attention in research (e.g., Schwartz et al., 2004) and instruction (AAAS, 1993).

The observation that NOS has been a perennial goal of science education, and is now receiving increased emphasis, can be construed to mean that high school graduates, and the general citizenry do not possess (and never have possessed) adequate views of NOS. The research reviewed later in this chapter provides clear support for such a notion. (Lederman 2007, p. 831)

Based on 50 years of research on NOS, Lederman (2007, p. 869) concludes that neither K-12 students or their teachers possess “adequate” conceptions of NOS and that conceptions of NOS are better taught through explicit instruction rather than through inquiry. Other researchers are still exploring the relationship between active science inquiry in the classroom and students’ understanding of NOS (e.g., Sandoval, 2005) and think that inquiry is essential for personally connecting students to science, so they are able to grasp the larger picture of what science is and is not. The ability of archaeological content and inquiry processes has been only minimally tested for its ability to assist teachers and students with an understanding of NOS and its ability to increase positive dispositions toward science and careers in science (Brody et al., 2009).

Prominent educators have long called for interdisciplinary learning to help students understand the connections between different kinds of knowledge (Jacobs, 1989;

Jacobs, 2009). It certainly makes sense to integrate subjects whenever possible and archaeology provides a natural link for integrating science, social studies, and history. While integrating subjects to save classroom time and to demonstrate how different types of knowledge are complementary is a worthy goal, teachers need guidance to help them integrate subjects and knowledge, and students need ways to organize their new interdisciplinary knowledge (Jacobs, 1989; Champagne & Cornbleth, 1991). Archaeology educators (e.g., Devine, 1990; Smith et al., 1992; Davis, 2000) have long thought that lessons in archaeological content and processes could provide teachers with a ready-made way to integrate science and history. With a few exceptions (Champagne & Cornbleth, 1991; Scoville, 1994; Sunal, 2006) little research on the efficacy of integrating science and history is available and there is no known research on the efficacy of archaeology as an avenue for curriculum integration.

Purpose of the Study

The purpose of this case study was to uncover students' understandings and misunderstandings of five science inquiry concepts (observation, inference, evidence, classification, and context). The cognitive processes by which they acquire their understanding were of particular interest to me. I examined how students apply the concepts within the study of archaeology and how they transferred the concepts to other subjects and to everyday life. Specifically, I identified misconceptions and erroneous or incomplete preconceptions about archaeology and the nature of scientific knowledge. I

also examined students' understanding of the Nature of Science and the relationships between science and history.

Research Questions

This study examined the affect of archaeological inquiry on the scientific literacy of 27 fifth grade students who learned about archaeological content through guided inquiry instruction. My main question was: How do students understand and use science inquiry concepts through the study of archaeological inquiry? Specifically, I studied how students understood science inquiry concepts while they were engaged in a curriculum on the archaeological investigation of shelter and how archaeological inquiry contributes to an understanding of the nature of science and the relationships between science and history. Figure 2 illustrates the relationships between the various aspects of the research.

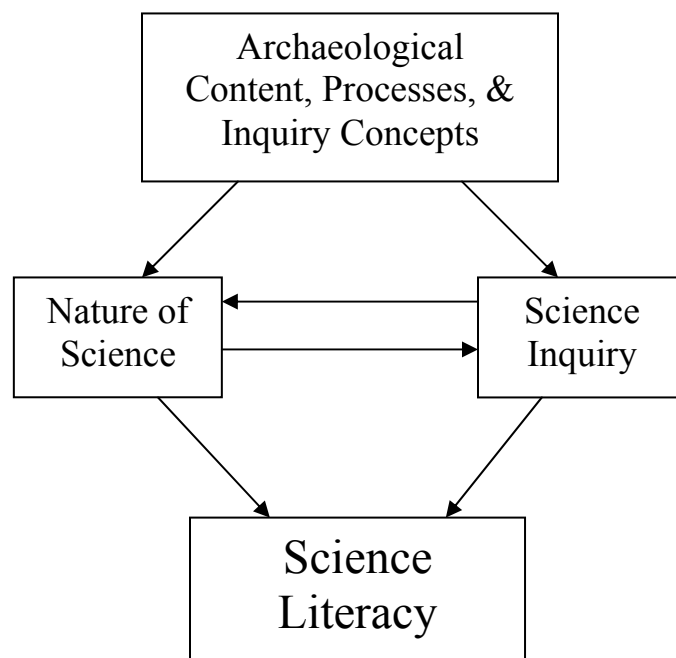


Figure 2. Relationships between Research Elements.

The new archaeology curriculum, *Project Archaeology: Investigating Shelter*, was used as a learning intervention in two fifth grade classrooms. While instruction was in progress, I collected data on student learning of science inquiry concepts through observation, interviews, written learning probes, and examination of student classroom work as needed. Specifically, I addressed the following research questions:

1. How do students understand the concepts of observation, inference, classification, context, and evidence as a result of instruction in archaeological inquiry? Do they misunderstand these concepts? If so, how?
2. How do students construct (logical progression of thought) their understandings or misunderstandings of these concepts?
3. How do students apply these concepts to archaeological inquiry?
4. How do students transfer and apply these concepts to other school subjects or to everyday life?
5. What do students think science is? How do students understand the relationships between science, history, and archaeology?
6. What are the best data collection methods for examining conceptual understanding of science inquiry through archaeological investigations?

These questions were addressed through a qualitative case study approach. The case selected was all of the fifth grade students in one elementary school who received instruction in archaeological inquiry from one teacher. I was integral to the study and designed a series of formative assessment probes, structured interviews, and a performance task to collect data about student understanding. Field research occurred

during the same time the students were engaged in archaeological inquiry learning. I analyzed and interpreted all data.

Significance of the Study

There are few studies of students' conceptual understanding of science inquiry concepts, and none have employed archaeological content or inquiry. This study is the first to use archaeology to examine student conceptual understanding of science and the Nature of Science. The study could be used as a baseline from which to compare similar case studies. Archaeology may provide an engaging way to teach science literacy and a new and largely untried place in the curriculum to provide students with practice in guided inquiry.

A series of formative learning assessment probes were developed for this study and can be used for similar case studies examining the efficacy of archaeology in teaching science inquiry concepts and NOS. The probes could also be used by classroom teachers to enhance assessment of archaeology, in general, and of *Project Archaeology: Investigating Shelter*, in particular. The probes could become part of continuous assessment of learning in general, and assessment of conceptual understanding of archaeological inquiry, in particular. The probes could also be adapted for other science content.

This study provided an opportunity for me to step back from curriculum development and program evaluation and conduct assessment of actual student learning and conceptual understanding. In this sense, the study provided superb professional

development for me, which will profoundly influence all future curriculum production and evaluation that I perform. Others who work in curriculum development may want to consider similar work to hone their understanding of learning processes, misconceptions, and potential pitfalls in curriculum design.

Project Archaeology: Investigating Shelter is currently in use in approximately 20-25 states the United States and could easily be used in Canada. A similar case study could be conducted in similar situations throughout the United States and Canada because there are relevant curricular materials for both countries.

Definition of Terms

Definitions for the five concepts examined in this study and other archaeology education terms were taken directly from the curriculum, *Project Archaeology: Investigating Shelter*. Below, additional explication has been added to some of the terms and the five inquiry concepts that are the focus of this study (observation, inference, classification, context, and evidence) are more fully explained above.

1. Archaeological site: a place where people lived and left objects behind (Letts & Moe, 2009, p. 162)
2. Archaeology: the scientific study of past human cultures through artifacts and sites (Letts & Moe, 2009, p. 162)
3. Artifact: any object made or used by people; usually not modern (Letts & Moe, 2009, p. 162)

4. Classification: systematic arrangement in groups or categories (Letts & Moe, 2009, p. 162)
5. Classify: the process of arranging objects in groups in categories (Letts & Moe, 2009, p. 162)
6. Context: the relationship artifacts have to each other and the situation in which they were found (Letts & Moe, 2009, p. 162)
7. Data: facts and figures, information; especially information that can be analyzed (Letts & Moe, 2009, p. 162)
8. Evidence: data which are used to answer questions or to confirm an inference or a conclusion (Letts & Moe, 2009, p. 162)
9. Inference: a conclusion derived from observations (Letts & Moe, 2009, p. 162)
10. Inquiry: an organized investigation to learn new information or solve a problem (Letts & Moe, 2009, p. 162)
11. Question: something that is asked to guide the inquiry process (Letts & Moe, 2009, p. 163)

This study uses several complex terms and ideas. All of these terms are briefly defined below, but are addressed in greater detail in Chapter Two of this document.

1. Misconception: a failure to understand a certain concept correctly (Bransford et al., 2000)
2. Nature of Science (NOS): what science is and how it works (Rutherford & Ahlgren, 1990; Lederman, 2007)

3. Science inquiry: the processes of investigation employed by scientists (NRC, 2000)
4. Science literacy: comprehensive understanding of science content and processes, and the nature of scientific knowledge (Rutherford & Ahlgren, 1990)
5. Transfer of knowledge: the ability to use knowledge in diverse contexts and situations (Bransford et al., 2000)

Limitations of the Study

As a qualitative case study, the results of this study cannot be generalized to the entire population. Demographically, Riverside Elementary School, where this study was conducted, does not resemble most of the rest of the United States. Enrollment at Riverside Elementary is primarily students of white, middle-class background. Results may be transferable to places with similar demographics and results could also be used as a baseline from which to compare data from less similar cases.

The formative learning assessment probes developed for this study were field tested prior to the study. While they seemed to work quite well for this study for the most part, they will be revised and improved based on the results of this study. Better probes may improve the dependability of results in future studies.

Summary

This study addressed the question: How do students understand and use science inquiry concepts through the study of archaeological inquiry? Concomitantly, how does an understanding of archaeological inquiry increase understanding of science literacy? Science literacy has been a main focus of science education since the publication of the *National Science Education Standards* in the mid-1990s (NRC, 1996). Inquiry is an important part of the standards, but widespread implementation and testing has lagged behind nationwide. Educators are looking for engaging and productive ways to teach inquiry and to guide students to a deep understanding of the nature of scientific knowledge. Similarly, conceptual integration of history and science, a worthy goal, has received little attention in the research literature and actual implementation seems to elude most educators. Archaeology provides a natural link between science and history and could provide a compelling vehicle for integrating the two disciplines, for teaching science inquiry concepts and processes, and for teaching the nature of scientific knowledge.

CHAPTER TWO

LITERATURE REVIEW

Introduction

This chapter examines science literacy more deeply including its theoretical roots in cognitive psychology and human constructivism. The research conducted on science literacy learning including inquiry and the nature of science since the publication of *Science for All Americans* and the *National Science Education Standards* is summarized. Because archaeology is an interdisciplinary field combining science and history, a section on interdisciplinary learning is included. Finally, the new field of archaeology education is outlined and the potential for archaeology to provide an engaging way for teaching science inquiry and integrating science and history is discussed. Figure 3 illustrates the theoretical bases for the research and the major research areas for this study and the relationships between them. Novak's (1977) Integrated Theory of Education unites cognitive psychology and human constructivism to provide the basis for learning through inquiry and understanding the Nature of Science as outlined in *Science for All Americans* (Rutherford & Ahlgren, 1990). This research examines science learning through archaeological inquiry, specifically through a curricular intervention.

Scientific Literacy

The inclusion of scientific literacy (or science literacy) in American school curricula has a long history (Gabel, 2006), beginning in the late 1800s through 1900,

especially during the 1960s when the United States was involved in the Space Race. The biggest recent push is Project 2061 which is the educational system's response to the *Nation at Risk* report (National Commission on Excellence in Education, 1983). The report found that the United States is lagging behind much of the rest of the world in science education.

In response, the American Association for the Advancement of Science (AAAS) launched Project 2061 in 1985. During the 1990s, Project 2061 completed three seminal works: *Science for All Americans* (Rutherford & Ahlgren, 1990), which lays out the basic philosophy and foundation for scientific literacy; *Benchmarks for Scientific Literacy* (AAAS, 1993), which provide measurable benchmarks for scientific literacy and the research behind them; and *National Science Education Standards* (NRC, 1996), which serve as the national standards for science education.

In *Science for All Americans* (SfAA) Rutherford and Ahlgren describe the need for scientific literacy:

Education has no higher purpose than preparing people to lead personally fulfilling and responsible lives. For its part, science education ... should help students to develop the understandings and habits of mind they need to become compassionate human beings able to think for themselves and face life head on. It should equip them also to participate thoughtfully with fellow citizens in building and protecting a society that is open, decent, and vital (1990, p. xiii).

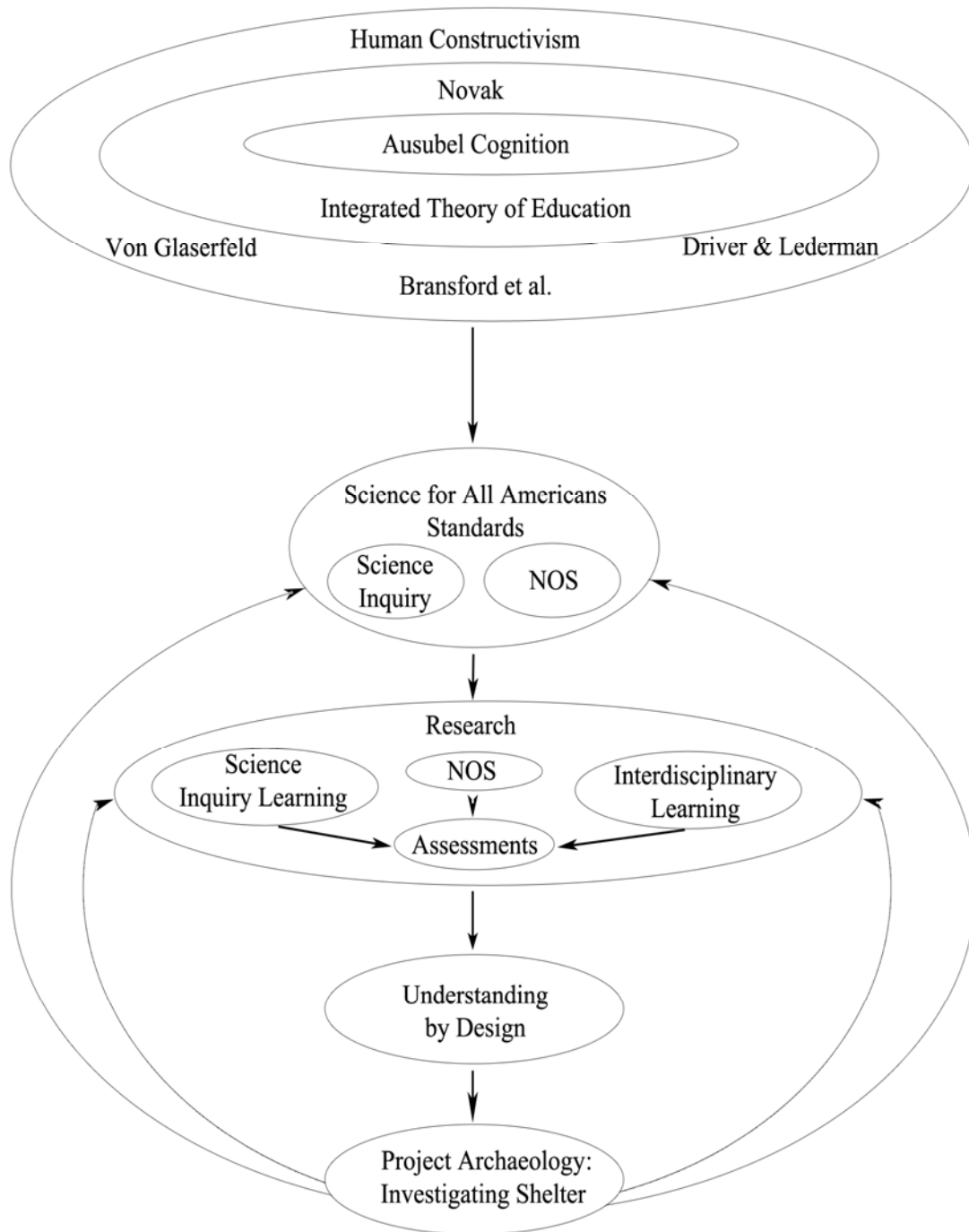


Figure 3. Literature Review Chart.

When SfAA was first published in 1989, international studies of educational performance ranked US students near the bottom in both science and mathematics (Rutherford & Ahlgren, 1990). Project 2061 was launched to reverse this trend and make science education both pervasive and effective, nationwide. Project 2061 developed a set of recommendations based on what “understandings and ways of thinking are essential for all citizens in a world shaped by science and technology” (Rutherford & Ahlgren, 1990, p. xiii).

A scientifically literate person is one “who is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes” (Rutherford & Ahlgren, 1990, p. xv). Scientific literacy is important not only for the American enterprise, but also essential for solving the global problems that humans now face. It is essential to make informed personal and collective decisions (Lederman, 1998; NRC, 1996).

Science inquiry is a set of thinking skills necessary for scientific work (Rutherford & Ahlgren, 1990). In *NSES*, it is defined as:

... a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. (NRC, 2000, 13-14)

The Montana Standards for Science (OPI, 2006) closely mirror the *NSES* standards for science inquiry. Science Content Standard 1 states, “Students, through the inquiry process, demonstrate the ability to design, conduct, evaluate, and communicate the results and form reasonable conclusions from scientific investigations.” By the end of the eighth grade, students should be able to identify questions, determine relevant variables and a control, formulate a testable hypothesis, plan and predict the outcome of an investigation, conduct an investigation, and compare and analyze data. Additionally, students should be able to communicate and defend their results, to consider alternative explanations, to evaluate the strengths and weaknesses of an investigation, and to create models and graphics illustrating concepts and results.

The Nature of Science (NOS) refers to the way science works and knowledge of the way science works is a prerequisite for scientific literacy.

Over the course of human history, people have developed many interconnected and validated ideas about the physical, biological, psychological and social worlds. Those ideas have enabled successive generations to achieve an increasingly comprehensive and reliable understanding of the human species and its environment. The means used to develop these ideas are particular ways of observing, thinking, experimenting, and validating. These ways represent a fundamental aspect of the nature of science and reflect how science tends to differ from other modes of knowing. (Rutherford & Ahlgren, 1990, p. 1)

Rutherford and Ahlgren (1990, pp. 2-12) outline three basic components of the nature of science: (1) the scientific worldview, (2) scientific inquiry, and (3) the scientific enterprise. The scientific worldview is a set of values and beliefs that scientists share. The world is understandable through systematic study. While scientific ideas are subject to change because of new discoveries or new questions, scientific knowledge is durable;

ideas are usually not completely rejected, but are instead, changed to fit new evidence or knowledge. Despite the power of science to help us understand our world, science cannot answer all questions, especially those involving beliefs such as the existence of supernatural powers or the meaning of life. In the study of humans who lived in the past, for example, archaeologists can learn what people ate and what kinds of shelters they lived in from material remains, but they usually do not try to determine what languages people spoke through archaeological data.

All scientists engage in some type of systematic inquiry, but methods and data vary tremendously. It is difficult to describe inquiry except in terms of actual investigations. All scientific inquiry requires evidence which is usually obtained through observation, measurement, and experimentation. Archaeologists use artifacts and their locations both vertically and horizontally within archaeology sites as their main source of evidence.

The scientific enterprise is a complex social activity; scientists do not always work alone in laboratories as is commonly thought, but often work on large research teams. Many scientists regularly work with scientists outside of their own profession. Archaeological research is often conducted by interdisciplinary teams of archaeologists, geologists, botanists, and zoologists. Most scientists maintain strict ethical guidelines, especially regarding the well-being of human and animal subjects while conducting their research, and reporting findings accurately is paramount to professional success and the advancement of the discipline. Archaeologists must consider rights and interests of descendant communities in conducting research and distributing results. Like other

scientists, archaeologists are sometimes called upon to provide expert testimony in court cases or to participate in civic dialogue regarding historic preservation issues.

This study focused primarily on science inquiry concepts, how students understand these concepts, how they acquire their understanding or misunderstandings, how they apply these concepts, and how they transfer the concepts to other subjects and to everyday life through the study of archaeological inquiry. The study also addressed students' understanding of the Nature of Science and the relationships between science, history, and archaeology as a result of instruction in archaeological inquiry.

Organizing Concepts and Theories

This study is rooted in the principles of constructivist teaching and learning and in Novak's (1977) Theory of Education. The concept of cognition is an important consideration in this study and also informs constructivism. Several additional key terms (application; assessment and evaluation; concepts and constructs; inquiry; interdisciplinary learning; learning probe; Nature of Science; transfer of knowledge; understanding, misunderstanding, misconceptions, and preconceptions) are discussed below.

Cognition

Cognition is "the mental action or process of acquiring knowledge and understanding" (OUP, p. 332). It is the internal act of knowing and is, therefore, not directly observable. The relationship between the knowing mind, external reality, and the exact nature of cognition have been debated from many perspectives (epistemological,

linguistic, psychological, etc.) since antiquity. Cognitive psychologists, especially Jerome Bruner and David Ausubel (Good & Brofy, 1986), applied a cognitive approach to understanding human learning in formal (school) education. Unlike the behaviorists who were interested primarily in the results of learning, the cognitivists are concerned with how learning occurs and what type of knowledge is stored. Under the cognitive approach, learning is centered on the learner rather than on the content to be learned.

The human nervous system as a data-processing and storing mechanism is regarded as so constructed that new ideas and information can be meaningfully learned and retained only to the extent that appropriately relevant and typically more inclusive concepts or propositions are already available to serve a subsuming role or provide ideational anchorage. Subsumption thus accounts for the acquisition of new meanings (the accretion of knowledge); for the extended retention span of meaningfully learned materials; for the very psychological organization of knowledge as a hierarchical structure in which the most inclusive concepts occupy a position at the apex of the structure and subsume progressively more highly differentiated subconcepts and factual data; and for the eventual occurrence of forgetting. (Ausubel, 1965, p. 8)

Ausubel's notion of meaningful reception learning occurs when, "the entire content of what is to be learned is presented to the learner in final form" in a way that he or she can make sense of it (Good & Brofy, 1986, pp. 216-221). Ausubel famously said, "the most important factor influencing the meaningful learning of any new idea is the state of the individual's existing cognitive structure at the time of learning" (Ausubel & Robinson, 1969, p. 143). The goal of instruction is to allow learners to integrate new knowledge with existing knowledge structures for longer retention and the ability to apply it and transfer it to other contexts.

Cognitive theorists ... not only agree that the learner's acquisition of clear, stable, and organized bodies of knowledge is the major long-term objective of education. but also insist that these bodies of knowledge, once

acquired, constitute in their own right the most significant *independent variable* influencing the meaningful learning and retention of new subject-matter material. Hence, control over meaningful learning can be exercised most effectively by identifying and manipulating significant cognitive structure variables. (Ausubel 1965, pp. 9-10; emphasis in original)

For Ausubel, all knowledge is organized in hierarchical cognitive structures unique to each individual. Within these cognitive structures, minor elements of new knowledge are linked or subsumed under larger more inclusive concepts (Novak, 1977). The most important piece of instruction is to provide cognitive bridges to make it possible for learners to assimilate new knowledge; usually these are in the form of advance organizers such as graphs, concept maps, or photographs of the phenomenon to be studied. Within the hierarchical structures of knowledge that learners create for themselves,

...specific details called subordinate concepts are not only related to one another but subsumed under higher level cognitive structures called subordinate concepts. Even if we gradually forget details, we tend to remember key ideas and principles associated with a particular scaffolding that supports retention of the information as an organized body of knowledge and provides a frame within which to interpret related new knowledge or efficiently relearn forgotten knowledge. (Good & Brophy, 1986, p. 217)

Joseph Novak (1977) used Ausubel's assimilation theory to develop a comprehensive learning theory and a theory of education. The main concepts of the theory as used by Novak (1977) are: subsumption, progressive differentiation, integrative reconciliation, and superordinate learning.

In the course of meaningful learning, new information is linked with existing concepts in existing cognitive structures through an interactive process in which the new information changes slightly; the new information is subsumed. Similarly the existing

concept (subsuming concept or subsumer) may change as well. As more information is assimilated, concepts (subsumers) become differentiated.

Development and elaboration of subsuming concepts or progressive differentiation occurs during meaningful learning. For example, children of two often call everything with four legs and a tail “doggie,” but soon learn to differentiate between dogs, cats, horses, cows, and all other four-legged animals.

Sometimes new information does not fit with existing concepts and *cognitive dissonance* results. Learners must use Integrative Reconciliation to assimilate or subsume the new information. Novak (1977, pp. 89-90) uses the categorization of beans as being both a plant fruit and a vegetable to illustrate the point. Similarly, in the United States, 95% of the population conflates paleontology and archaeology believing they are one and the same thing (Ruganne & Dumos, 2000). Many learners have difficulty in reconciling the new view of the two concepts, i.e., paleontology and archaeology are not the same, and differentiating between the two disciplines.

Superordinate learning occurs when previously learned concepts are recognized as elements of a larger, more inclusive concept such as “mammals” or “scientific inquiry.” This type of learning requires beginning with more general and inclusive concepts such as “plant fruit” and adding the subordinate concepts later and showing the relationships between the subordinate concepts and the higher order concepts.

The primacy of “concepts” in learning and in educational theory is evident throughout Novak’s work (e.g., 1977, p. 18). While Novak recognizes that each learner

constructs his or her own knowledge, there is enough overlap in construction that knowledge and meaning can be shared.

The almost infinite number of permutations of concept—concept relationships allows for the enormous idiosyncrasy we see in individual concept structures, and yet there is sufficient commonality ... that discourse is possible, and sharing, enlarging and changing meanings can be achieved. It is this reality that makes possible the educational enterprise. (Novak, 1993, p. 190)

Constructivism and Science Inquiry

The Human Constructivist era of science education began in 1978 and is based in large measure on Novak's Theory of Education. Novak's Human Constructivism encompasses both a theory of learning and an epistemology of knowledge building and, at present, offers the most useful framework available for science teaching and for science curriculum development (Mintzes & Wandersee, 2005).

It is my view that the psychological processes by which an individual constructs his or her own new meanings are essentially the same epistemological processes by which new knowledge is constructed by the professionals in a discipline. (Novak, 1993, p. 168)

Constructivism as a theory of knowledge asserts two main principles: (1) knowledge is not passively received but actively built up by the cognizing subject (learner); and (2) the function of cognition is adaptive and serves the organization of the experiential world, not the discovery of ontological reality (von Glaserfeld, 1989, pp. 162). Constructivism as a theory of knowledge has been translated into a constructivist theory of learning and as such has had a profound effect on teaching and learning in the United States. In the constructivist view, "learners are seen as constructing meaning from input by processing it through existing cognitive structures, and then retaining it in

long-term memory in ways that leave it open to further processing and possible reconstruction. Constructivists view learning as depending to the degree to which learners can activate existing structures or construct new ones to subsume the input” (Good & Brofy, 1986, p. 229).

As a theory of teaching and learning, constructivism holds a particular place in education (von Glaserfeld, 1991). In summary, teaching and training are not the same. The former focuses on student understanding while the latter focuses on the students’ observable actions. Knowledge is a network of conceptual structures and cannot simply be transferred from teacher to student; knowledge must instead be built by the student. Teaching is a social activity while learning is a private activity; therefore the teacher must have some idea of what the students already know in order to guide new learning. A teacher or researcher can only infer what students understand and cannot directly observe understanding. Language itself cannot transfer concepts or conceptual structure from one person to another; it can only call up representations of experiences that the listener (or reader) associates with what is said or written. Misconceptions should be of great interest in teaching because they represent what the learner thinks is correct at that moment in time.

The national science education standards in inquiry were built on the constructivist view of learning. “Students build new knowledge and understanding on what they already know and believe” (NRC, 2000, pp.115-127). The seminal work of Bransford et al. (2000) guided much of the development of the science standards, especially in inquiry.

Wiggins and McTighe (1998, 2005) also relied heavily on Bransford et al. (2000) in producing and refining their Understanding by Design curriculum development model. Recent research in cognitive psychology shows that students learn best when knowledge is connected around broad concepts or “big ideas” (Bransford et al., 2000). Students must also have the opportunity to uncover these ideas for themselves through questioning, analyzing, and applying concepts in other domains. Disconnected facts or superficial coverage of a discipline do little to build understanding. Finally, learners need to reflect on their own learning and improve their work based on their own reflections and feedback from others.

The Understanding by Design model is sometimes called “backward design” because it begins with the end in mind. When using Understanding by Design, or UbD, the curriculum designer begins by identifying the desired learning results. These are broad concepts or “big ideas” such as the Rule of Law or photosynthesis that students should remember well into the future. These big ideas are called “enduring understandings.” Students uncover these enduring understandings through a series of essential questions. Next, the designer determines what constitutes evidence of understanding and designs assessments accordingly. Finally, the designer decides what knowledge and skills the student will need to uncover the enduring understandings, then plans learning activities and events.

While the above may seem like common sense, Understanding by Design provides a rigorous process for ensuring that all elements are included and the resulting whole actually helps students achieve the desired results. It almost forces designers to

employ many of the hallmarks of proven pedagogy including interactive instruction, advance organizers for learning, non-linguistic representations of information, student reflection, transfer of knowledge to other contexts or domains, performance assessment, and constructivism.

Terms

Application. The importance of application is not a new idea in education. Bloom (1956) included application in his hierarchy of knowledge and Wiggins and McTighe (1998, 2005) included application as one of their Six Facets of Understanding. The latter define application as the “ability to apply knowledge and skill in diverse situations.” Applying new learning in a different context provides good evidence of understanding.

Assessment and Evaluation. In this study, assessment and evaluation are differentiated. Evaluation refers to the processes involved in determining the value of something; in educational practice, it is usually the value of an educational program or curriculum or innovation. By contrast, assessment refers to the processes of determining what students actually know and understand based on specific goals and criteria (Wiggins & McTighe, 2005). This study was primarily concerned with assessment of student understanding, rather than with evaluation of a program or a curriculum.

Concepts and Constructs. According to Novak (1977), concepts (or constructs) are “*what we think with*.” If we cannot get our concepts clarified and organized, our

thinking remains muddled and we are successful neither in solving problems nor in generating new concepts that would help us solve them” (p. 18, emphasis in original). Wiggins and McTighe (2005) define concept as “A mental construct represented by a word or phrase” (p. 340). Concepts can be tangible objects (e.g., chair , rabbit, artifact) or abstract ideas (e.g., democracy, bravery, inquiry). Observation, inference, classification, context, and evidence are concepts that scientists often use to investigate and are the main focus of this study; they are defined on pages 10 through 14. The terms, concept and construct, are used interchangeably in this study, however, concept is used most often.

Inquiry. As previously discussed in Chapter One, *NSES* defines science inquiry as follows:

Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. (NRC, 1996, p. 23)

Defined as such, science inquiry is wide-ranging and encourages interdisciplinary investigations within science disciplines and may extend to other disciplines such as the social sciences (psychology, economics, sociology, etc.), history, language, mathematics, and the humanities (e.g., Tchudi, 1993; Alvarado & Herr, 2003). For example, historical inquiry shares many similarities with scientific inquiry (Levstik & Barton, 2001). Historians construct historical knowledge by asking compelling questions, finding

relevant information, evaluating sources, and building interpretations based on evidence. There is no single story of the past, but many stories based on who is telling the story, when it is being told, and what evidence is used. In classrooms, history can certainly be taught as inquiry, however, it rarely is because few teachers are willing or able to teach inquiry-based history (Linda Levstik, 2006; personal communication).

Similarly, social studies educators have long advocated the use of inquiry to make social studies learning more meaningful for students (e.g., West, 1971; Sunal & Haas, 2002). Social studies inquiry skills include observing, inferring, and classifying and social studies educators define the terms similarly to the definitions provided in Chapter One. Sunal & Haas (2002) emphasize respect for evidence in developing and testing ideas including the consideration of conflicting evidence when confirming or disconfirming a hypothesis. Similarly, they encourage the use of question-driven investigations in social studies instruction.

The Montana Standards for Social Studies (OPI, 2000) emphasize the role of inquiry in social studies learning as do the Science Standards (see Appendix B). Social Studies Content Standard 1 states, “Students access, synthesize, and evaluate information to communicate and apply social studies knowledge to real world situations.” By the end of the eighth grade students, should be able to apply the steps of an inquiry process including identifying a question or problem, locating and evaluating relevant data, and gathering and synthesizing information. Additionally, they should be able to assess the quality of the information and apply information to support conclusions.

Interdisciplinary Learning. In her seminal work on interdisciplinary curriculum design, Heidi Hayes Jacobs defines the term “interdisciplinary” as “A knowledge view and curriculum approach that consciously applies methodology and language from more than one discipline to examine a central theme, issue, problem, topic or experience” (Jacobs, 1989, p. 8). Interdisciplinary instruction can range from parallel discipline designs in which content in various subjects simply coincides in time to complete programs in which the students’ lives are synonymous with schooling (Jacobs, 1989). In the former, reading a book on World War I might be timed to coincide with social studies lessons on the same topics. In the latter, students create the curriculum out of their daily lives and the issues that may confront them. Intermediate design models include complementary discipline-based units in which certain disciplines are brought together to investigate a theme or issue, interdisciplinary units in which the full range of disciplines is combined for some period of time, and the integrated day model in which full days are based on themes and problems relevant to children’s lives and incorporate all the disciplines. Archaeology integrates scientific and historical inquiry by its very nature, thus it does not fit neatly into any of these categories.

Learning Probe. In this study, formative learning assessment probes or Learning Probes are a type of assessment designed to probe for student understanding and the logical processes the student used to arrive at an understanding or a misunderstanding (Keeley, 2005). They are particularly helpful to teachers for monitoring changes in student thinking and to curriculum designers for developing effective curricula and

instruction that focuses on students' thinking and ultimately, encourages conceptual change.

Nature of Science (NOS). The Nature of Science (commonly abbreviated as NOS) is defined in various ways. It can be defined simply as what science is and how science works (Lederman, 2007). The term also refers to the epistemology of science, science as a way of knowing, or the values and beliefs inherent in scientific knowledge. The wide range of definitions is not surprising given that science itself is a wide-ranging subject (Abd-El-Khalick et al., 2001). While there is little agreement on a specific definition of the term, most researchers do agree that the lack of an exact and widely used definition is not necessary for K-12 education. Several widely-recognized aspects of scientific knowledge and practice are relevant for this study (from Abd-El-Khalick et al., 2001). Scientific knowledge is tentative, empirically-based, and subjective; is the product of human inference, imagination, and creativity; it is socially and culturally embedded. Scientific practice distinguishes between observation and inference and employs multiple methods for gathering and analyzing data.

Transfer. A major goal of schooling is to prepare students to learn in new and diverse contexts (Bransford et al., 2000). The ability to apply concepts to new situations such as other school subjects, other types of knowledge, or to everyday life is evidence that significant learning has occurred. Ability to transfer concepts depends on several factors: learning with understanding rather than memorization, active practice or repetition, and learning the concept in a variety of contexts (Bransford et al., 2000, pp.

235-236). Transfer of learning to new situations also provides good evidence of understanding.

Understanding, Misunderstanding, Misconception, and Preconception. The word “understanding” is difficult to define and is notably absent from the indexes of many books on science learning (e.g., Novak, 1977; Driver et al., 1994, 1996; Kuhn et al., 1988). Other works include the word but only in conjunction with qualifiers such as “student competencies” (Pellegrino et al., 2001) or “understanding of a domain” (Klahr, 2000). Bransford, Brown, and Cocking (2000) discuss understanding extensively, but only in relation to a variety of other topics such as assessment, problem solving, and transfer of learning. None of these authors made an attempt to define the term. Understanding is such a basic word (it comes from Old English) that the Thesaurus (Merriam-Webster, 1989, p. 599) offers only “apprehend” as a synonym. In *Understanding by Design*, authors Grant Wiggins and Jay McTighe (2005) begin Chapter 3 with a striking observation about their own seminal work: “Up to now, we have presented understanding as if we understood it. The irony is that though we all claim, as teachers, to be after understanding we may not adequately understand our goal.” They devote an entire chapter to “understanding understanding” and discuss understanding extensively in relationship to inference, transferability, and misunderstanding. Evidence of understanding involves “assessing for students’ capacity to use their knowledge thoughtfully and to apply it effectively in diverse settings” (Wiggins & McTighe, 2005, p. 48).

Pre-existing knowledge is widely recognized as one of the most important considerations in learning (Ausubel, 1965; Novak, 1977; Bransford et al., 2000; Wiggins & McTighe, 1998, 2005). If pre-existing knowledge is correct, the learner will be in a good position to acquire and assimilate new, related knowledge. If pre-existing knowledge is incorrect and is not detected and dispelled, the learner may not be able to acquire new knowledge. Preconceptions or misconceptions can be persistent and research shows that usually the learner will return to preconceptions outside the classroom (Bransford et al., 2000, pp. 14-15).

Misunderstandings of concepts are valuable to teachers and to curriculum designers and should not be viewed simply as mistakes to be corrected (Wiggins & McTighe, 2005, pp. 50-51). Because any student of any age can acquire unintended misunderstandings from instruction or from any new information, the evidence of misunderstandings can provide powerful insights into learning. Misunderstandings may indicate deeply covered misconceptions which may impede learning. Similarly, misunderstandings or misconceptions may indicate flaws in curricular materials or inadequacies in delivery. For example, it is easy to understand why most people in the US conflate archaeology and paleontology; both use similar methods and both study the past. However, if students still confuse archaeology and paleontology at the end of a college course on archaeology as Dr. Lauren Ritterbush, a Kansas State University archaeologist (2008, personal communication), clearly demonstrated through pretests and posttests at the beginning and end of the semester, both the curriculum and teaching methods should be examined.

Previous Research

The literature on research in science education generally and in both science inquiry and the Nature of Science in particular is vast (Mintzes & Wandersee, 2005; Abell & Lederman, 2007). By contrast, literature on the integration of science and history or social studies is scant. Research on science inquiry, Nature of Science, and content knowledge integration relevant to this study are summarized below.

Research in Science Education

Efforts to assess science for deep conceptual understanding have been gaining momentum since the publication of the *NSES* (Mintzes et al., 2005, Sunal & Wright, 2006). Mintzes and Wandersee (2005) estimate that about 3500 articles on science education research had been published at the date of their writing. They make twelve knowledge claims based on these studies; seven of these claims are relevant to this study (Mintzes & Wandersee, 2005, pp. 76).

Learners are not “empty vessels” or “blank slates.” Learners bring with them to their formal study of science concepts a finite but diverse set of ideas about natural objects and events. Often these ideas are incompatible with those offered by science teachers and textbooks. The ideas that learners bring with them to formal science instruction are often tenacious and resistant to change by traditional teaching strategies.

As learners construct meanings, the knowledge they bring with them interacts with knowledge presented in formal instruction. The result can be a diverse set of unintended learning outcomes. Because of limitations in formal assessment strategies,

these unintended outcomes may remain hidden from teachers and from students themselves. Alternative concepts (those not specifically intended) are products of a diverse set of personal experiences, including direct observation of natural objects and events, peer culture, everyday language, and the mass media as well as formal instructional intervention.

Successful science learners possess a strongly hierarchical, cohesive framework of related concepts and they represent those concepts at a deeper, more principled level. Understanding and conceptual change are epistemological outcomes of the conscious attempt by learners to make meanings. Successful science learners make meanings by restructuring their existing knowledge frameworks through an orderly set of cognitive events (i.e., subsumption, superordination, integration, and differentiation). Instructional strategies that focus on understanding and conceptual change may be effective classroom tools. Similarly, strategies that focus on misunderstandings and misconceptions may be particularly effective instructional tools.

Research on Learning through Science Inquiry

With the publication of the *National Science Education Standards* (NRC, 1996), educators received their marching orders to include inquiry throughout the science curriculum. *Inquiry and the National Science Education Standards* (NRC, 2000) clarified and guided the use of inquiry in science. The inclusion of science inquiry throughout the science curriculum is nothing short of a massive paradigm shift (Gabel, 2006). What is the result of these efforts? How well are we doing at teaching science inquiry concepts? Have we increased scientific literacy?

Research shows that students come to school with a diverse array of beliefs and knowledge about science and how science works (Bell & Linn, 2002). These beliefs are typically tied to specific disciplines within science and vary according to specific contexts or problems (Driver et al., 1996). Students typically do not view science as an integrated way of knowing and as an enterprise which shares many similarities across science disciplines and with other non-science disciplines such as history. While inquiry certainly does differ within science as whole, teaching inquiry tied solely to a specific discipline may lead students to hold multiple or incorrect views of the scientific enterprise (Bell & Linn, 2002). For example, when asked if he or she would like to be a scientist, the student may answer, “No. I want to be a veterinarian,” apparently not understanding that a career as a veterinarian requires a considerable background in science.

For students to develop a cohesive and coherent perspective on scientific inquiry they need to integrate, connect, sort out, and combine their repertoire of ideas as well as incorporate the different images of science they encounter. From this perspective, effective science instruction adds new ideas to the mix held by students and encourages them to compare, prioritize, link, and evaluate their ideas as well as to seek a cohesive view of science inquiry. We call this process knowledge integration... (Bell & Linn, 2002, p. 322)

The call for the inclusion of science inquiry in the *NSES* (NRC, 2000, pp. 124-126) is backed up by considerable research on the effectiveness of inquiry-based instruction and research has continued since the publication of the science standards.

If one accepts the full sweep of content in the *National Science Education Standards*, including conceptual understanding of science principles, comprehension of the nature of scientific inquiry, development of the abilities for inquiry, and a grasp of applications of science knowledge to

societal and personal issues, this body of research clearly suggests that teaching through inquiry is effective. (NRC, 2000, p. 126)

Studies show that students who are taught through inquiry methods score higher on mathematics and science tests than those who receive expository instruction (Scott et al., n.d.). Gabel (2006) analyzed scores from the *Colorado Student Assessment Program* and found that students did their best work in science on Standard 1, Scientific Investigation, particularly in the area of data analysis; the mean percentage score for Standard 1 was 69.1% as compared to 61.4% for all science standards combined.

Exposure to a diverse suite of inquiry activities in a variety of contexts (in school subjects and connected to relevant issues in everyday life) seems to help students understand the larger scientific enterprise. Inquiry-based instruction can help students understand science concepts, processes of science, and science content.

Research also shows that when students participate in science courses that offer a broad array of inquiry practices combined with opportunities for synthesis, their understanding of science inquiry is enhanced. Students develop a more coherent set of images of science when specifically supported in connecting diverse examples Courses that help students sort out, prioritize, and organize these ideas can enhance understanding of inquiry and promote a disposition to make sense of inquiry. (Bell & Linn, 2002, p. 342)

Many other researchers have examined the efficacy of using science inquiry to teach science literacy and science content (e.g., Howe & Rogers, 1991; Klahr, 2000; Hsin-Kai & Chou-En, 2006; Anderson, 2007; Zion et al., 2005; Zion, et al., 2007). In a case study of students in two classrooms, Kathleen Metz (2004) used a combination of video tapes of self-guided inquiry tasks, written student work, and notes from classroom discussions to study children's understanding of science inquiry. She found that fourth

and fifth grade students were capable of designing and conducting their own investigations in animal behavior. Additionally, they were capable of evaluating the quality of the evidence they used to draw their conclusions. Success depended on strong knowledge of the domain (insect biology and behavior in this case) and considerable practice in designing and conducting investigations before they could embark on self-guided inquiry projects.

O'Neill and Polman (2004) examined the potential of practice-based inquiry to teach science literacy. They used data from three case studies of high school science students and concluded that “involving students in the formulation of research questions and data analysis strategies results in better spontaneous use of empirical data collection and analysis strategies” (O'Neill & Polman, 2004, p. 234). Conversely, failing to involve students in the design and conduct of science investigations may result in students' loss of their sense of agency as learners and therefore, interest in the project and, perhaps ultimately, in science education.

A five-year ethnographic study of science inquiry (Jennings & Mills, 2009) evaluated science literacy at a public magnet elementary school (Center for Inquiry) where all instruction is centered on inquiry. Specifically, they examined the role of social discourse in the inquiry process (Jennings & Mills, 2009), “Through their academic work, these teachers and learners were constructing working relationships that supported genuine inquiry and a sound learning community. They constructed together a humanizing discourse of inquiry that students could draw on in learning and in life” (p. 1612). This type of inquiry is not easily transferable to other schools and settings, but

clearly demonstrates the potential for holistic, inquiry-based instruction as an organizing structure for all learning.

Despite the requirements of *NSES* and the generally positive results in science inquiry learning, making the paradigm shift to inquiry-based science learning nationwide has not been an easy task (Gabel, 2006). Several factors may apply (Gabel, 2006). First, very few schools have actually implemented inquiry-based science curricula. Second, teaching inquiry effectively is very difficult and few teachers are prepared to implement it. Third, very few well-researched and tested inquiry-based curricula are widely available to teachers. Fourth, inquiry-based instruction is difficult to assess and therefore, few assessments have been completed, thus leaving little research to guide further implementation.

Authentic science inquiry is difficult to actually implement for students of any age. Through a case study in New Zealand, Hume and Coll (2008) encountered the realities of implementing classroom-based inquiry learning in science as framed in a national curriculum. Using classroom observations, formative and summative assessments of performance on investigations designed specifically for the study, and scores on a standardized test, results were disappointing at best. “The findings showed purposeful and focused learning occurring, but students were acquiring a narrow view of scientific inquiry where thinking was characteristically rote and low-level.... Thus, the resulting student learning was mechanistic and superficial rather than creative and critical...” (Hume & Coll, 2008, p. 1201). Administrative decisions to concentrate on testing outcomes required a didactic approach to instruction rather than authentic

learning. Abandonment of authentic inquiry may have contributed to the disappointing results.

Internationally, most information about student understanding of science inquiry comes from broad surveys rather than from detailed case studies about the complex interplay of variables in classrooms such as student interactions, teacher abilities, and student conceptual understanding (Hume & Coll, 2008). More detailed case studies of inquiry-based instruction should help clarify the relations between complex variables and elucidate student conceptual learning of inquiry processes and science content.

Evaluation of an inquiry-based curriculum in ornithology demonstrated little or no improvement in student learning outcomes (Trumball et al., 2005). This study relied on data from pretests and posttests to assess student gains in knowledge about birds and changes in attitudes about conducting science, including aspects of inquiry. The researchers attributed the disappointing results to insufficient knowledge on the part of both teachers and curriculum designers about the work of ornithologists and ornithology content. Additionally, critical questions such as “Why should students learn this?” and “What does someone have to understand in order to succeed at this activity?” were never resolved before instruction began (Trumball et al., 2005). These researchers suggested that better integration of content knowledge about birds and models of inquiry would help students successfully plan and conduct ornithological investigations themselves.

An international team of researchers (Paul Kirschner, John Sweller, and Richard Clark) question the ability of elementary-aged students to learn both content and processes at the same time through inquiry-based teaching, especially minimally-guided

investigations. “The past half-century of research on this issue has provided overwhelming and unambiguous evidence that minimal guidance during instruction is significantly less effective and efficient than guidance specifically designed to support the cognitive processing necessary for learning” (Kirshner et al., 2006, p. 76). Minimally-guided instruction does not work because working memory is limited and the transfer of knowledge to long-term memory is complicated and difficult to achieve. Additionally, they think that inquiry-based disciplines such as science or history do not need to be taught as inquiry and are actually better taught initially through strong instructional guidance. Kirschner and his colleagues cite the body of empirical research on discovery, problem-based, experiential, and inquiry-based teaching as evidence for the failure of constructivism.

In the United States, Lee and Aukyx (2006) addressed cultural considerations in inquiry-based science teaching and learning and found that students of diverse cultural and language backgrounds struggle with science literacy more than do their white, native English-speaking peers. They found, however, that students from different cultures and languages actually learn better through inquiry methods than they do through more traditional, didactic approaches. Their findings contradict Kirschner et al.’s (2007) statement that while minority students prefer less guided approaches to learning, they learn less from it.

A literature search revealed few effective science inquiry curricula that are widely available to teachers. Also, it is little understood that there is a continuum of inquiry-based instruction ranging from teacher directed (teacher-led demonstrations) to student

directed (discovery inquiry) with several levels in between the two (Gabel, 2006).

Gabel's (2006, p. 233) continuum of inquiry instruction is as follows:

1. Teacher demonstration – completely directed by the teacher; inquiry is most often taught this way, if it is taught at all.
2. Structured inquiry – teacher directs the inquiry; considerable structure is needed for difficult content and for younger grades; students can design their own questions for investigation (some of *Project Archaeology: Investigating Shelter* falls under this category).
3. Guided inquiry – teacher directs most aspects of the inquiry; it is possible for older students to guide some of their own inquiry activities including asking questions and determining appropriate methods for investigation such as classifying or using context (some of *Project Archaeology: Investigating Shelter* falls under this category).
4. Open inquiry – student directs the inquiry with minimal guidance from the teacher; open or self-guided inquiry may be possible (in archaeology) for older students.
5. Discovery – all aspects are controlled by the students including choice of topic, research questions, and determination of results.

It is clear that the experience of inquiry alone is not enough (Driver et al., 1994, pp. 7-8). Experience must also be negotiated through an authority; for students, the authority is usually the teacher. Students may make fundamental mistakes when conducting an inquiry and may need additional direction to find more productive paths or

better guiding questions for their investigations. Students certainly need considerable scaffolding and practice to have the ability to conduct largely independent inquiries (Metz, 2004; Jennings & Mills, 2009).

Similarly, widespread and effective professional development for teachers in science inquiry is not yet available (Gabel, 2006). Jennings and Mills (2009) recognize that the inquiry-based pedagogy at the Center for Inquiry magnet school cannot be neatly packaged and transferred to other contexts. Instead, they recommend that teachers seek professional development that will equip them with the resources and skills to become active inquirers of their own practices.

Research on Learning about the Nature of Science

In the United Kingdom (Driver et al., 1996), Canada (Aikenhead et al., 1987) and many other countries (Lederman, 2007), educators' views of the nature of science and its importance in science learning mirrors that of educators in the United States. A comprehensive study of children's images of the nature of science in the UK shows that while there is progress in this arena, students still lag behind expectations. Driver, Leach, Miller, and Scott (1996, pp. 113-114) devised a three-level framework for characterizing students' reasoning in science. The lowest level is phenomenon-based reasoning where students focus on observing a phenomenon as the basis of inquiry and make no distinction between description of the phenomenon and actual explanation. Relation-based reasoning involves correlating variables and explanation and is characterized by noting the relation between observable features of a phenomenon. Students at this level recognize that description and explanation are different, but explanation is seen as

emerging from the data. Scientific knowledge is unproblematic and theories can be proven. Students at the third level, model-based reasoning, recognize that inquiry can involve evaluation of a theory or a model through evidence because theories and models are conjectural. They make a clear distinction between description and explanation and recognize that explanation goes beyond mere observational data and involves conjecture about theories. Driver et al. (1996, p. 117) recognize that the three levels are not necessarily better or worse than one another, but noticed that most of the younger students (elementary age) were phenomenon-based reasoners, students ages 12 to 16 were mostly in the relation-based level, and only a few older students were in the model-based level.

Writing in 2007, Lederman concludes that after nearly 100 years of emphasis on NOS education and 50 years of research, K-12 students throughout the world still have inadequate understanding of the Nature of Science. Reasons for inadequate learning in this area are fourfold (Lederman, 2007, p. 869): K-12 teachers themselves do not have adequate conceptions of NOS, teacher's conceptions of NOS are not automatically translated into effective classroom practice (even when their own conceptions are adequate), teachers do not regard NOS as an important instructional outcome of equal status with other subject matter, and NOS is better learned through explicit NOS instruction rather than through simply "doing" science. Sandoval (2005) argues that there is a gap between what is known about students' inquiry practices and their beliefs about science. He thinks that inquiry connects students personally and is, therefore, an essential component of a robust understanding of NOS.

Lederman (2007) proposes eleven sets of questions to guide future research in NOS, two of which are relevant to this study: “Is the nature of science better learned by students and teachers if it is embedded within traditional subject matter or as a separate ‘pull out’ topic?” and “What is the effectiveness of the various interventions designed to improve teachers’ and students’ conceptions?”

Research on Learning through the Integration of Science and History

Interdisciplinary instruction has long been thought to provide students with the opportunity to learn without the fragmentation of knowledge into disciplines that is typically found in public schools (Jacobs, 1989).

While many claims have been made about the benefits of interdisciplinary approaches to science education, the contention is that little empirical data exist to either support or refute the claims. The demands of integrated approaches on students and teachers have not been subjected to either theoretical or empirical assessment. (Champagne & Cornbleth, 1991, p. 1)

The statement holds true today; searches of the ERIC database for this study yielded only four additional articles on the subject of integrating science with history or social studies (Bybee et al., 1991; Scoville, 1994; Tzanakis & Thomaidis, 2000; Nikitina, 2006). Scoville’s (1994) article addresses outcome-based, interdisciplinary study at the college level that will enhance critical thinking. Bybee, Powell, Ellis, Giese, Parisi, and Singleton (1991) call for a mechanism to integrate the history of science into social studies, but recognize that no conceptual framework exists for doing so. Tzanakis and Thomaidis (2000) developed a series of conceptual frameworks for integrating history into physics and mathematics education from elementary school through graduate study.

Their frameworks are based on the rich relationship between the three disciplines.

Nikitina (2006) outlines three strategies (contextualizing, conceptualizing, and problem-centring) for interdisciplinary teaching based on the perspective of the primary discipline (humanities, science, and applied fields respectively). She uses data from studies of university and pre-university to determine the strengths and weaknesses of each of the strategies. Sunal (2006) explores the intersection of scientific and historical reasoning and inquiry. She developed a model for argumentation in inquiry using the perspectives of both disciplines. Results show that students aged 13-15 years are capable of recognizing limitations in both historical and scientific evidence using this approach.

The task of assessing the affordances and constraints of interdisciplinary approaches to science education is difficult (Champagne & Cornbleth, 1991, pp. 1-2). Actual specifications for interdisciplinary approaches are non-existent and outcomes or benefits are stated in broad terms that cannot be easily measured. The absence of empirical data makes new analytical studies difficult to design and opportunities to compare results simply do not exist. Champagne and Cornbleth (1991) limited their analysis to the integrated study of the natural sciences, history, and philosophy. They began with the demands interdisciplinary study places on both teachers and students and designed probable learning outcomes from three approaches: conventional organization of content, the historical case study approach, and problem/issue approaches. Beyond content knowledge, Champagne and Cornbleth (1991, p. 12) found that interdisciplinary study requires a second level of knowledge, i.e., knowledge about the disciplines

themselves. Students may need assistance in creating a schematic diagram of the relationship between disciplines so that new information can be added when encountered.

Thus, a schema for discipline serves to organize information about the common features of a number of disciplines and serves as a guide for learning about an unfamiliar discipline. A schema for discipline knowledge contains places for the discipline's concepts, principles, and theories. A nature-of-the-discipline schema contains places for the discipline's goals, philosophical basis, and modes of inquiry. (Champagne & Cornbleth, 1991, p. 12)

In one of the few studies of the use of archaeological content and conceptual understanding in classroom learning, Davis (2005) studied how students understand the past through instruction in archaeology. "Historical knowledge can be structured in at least two ways: narrative understanding and logical/scientific understanding" (Davis, 2005, p. 119). For the students in this study, narrative was an important vehicle for understanding the past, but student narratives did not always follow accepted chronological sequences. Davis found that children construct the past in some surprising ways probably because of deeply held preconceptions. Consequently, what teachers believe they are teaching may not be what students are learning. For this reason, constant monitoring of students conceptual understanding of their learning is essential.

Several other conclusions (Davis, 2005, pp. 119-120) are relevant to this study. If learners are to make meaning of the past, the past must have relevance for them. Relevance is a difficult task for both history and archaeology educators. Learners become more engaged in studies of the past when they are actively involved in constructing it. Active involvement may provide some form of relevance for learners. Objects (artifacts, shelters, etc.) contribute to a learner's understanding of life in the past

in a way that words alone cannot convey; authenticity and accessibility to the learner (e.g., close personal examination of real artifacts) may greatly affect learning potential. Again, objects, especially those of personal significance, may contribute to relevance for learners. Finally, the context in which instruction takes place is an important and powerful part of instruction (e.g., museums, natural landscapes, classrooms, etc.). Learning outcomes in different contexts may be profoundly different. Learning history and archaeology in a variety of contexts may optimize both relevance and conceptual understanding.

Archaeology as Science Inquiry

Archaeology studies the length and breadth of the human past (Trigger, 2006). Bill Rathje (1984), an archaeologist at the University of Arizona, studied the recent past by coring landfills. He and his team of graduate students found “mummified” newspapers from the 1950s, still readable decades later, entombed in anaerobic landfills. To the surprise of sanitation engineers, the paper had decomposed only minimally. Other archaeologists (e.g., Bradley & Stanford, 2004; Straus et al., 2005) are currently debating the peopling of the Western Hemisphere. Did they arrive through the Bering Land Bridge or via a coastal route? Did some people move through Greenland before arriving in North America? Others study the distant evidence of human origins throughout the world (Fagan, 1999; Sutton & Yohe, 2003). Because of archaeology’s length and breadth, it provides the framework for all other social sciences (Trigger, 2006).

Whether studying landfills deposited in the 1950s or a cave where some of the first residents of the Western Hemisphere lived, archaeologists employ science inquiry and regularly use inquiry concepts such as observation, inference, classification, context, and evidence to structure their investigations and to interpret their findings. Contrary to popular belief, archaeology is not just discovery; it is, instead, more like careful detective work guided by questions about the past. Archaeological inquiry is like any other scientific inquiry except that it studies past human cultures.

Archaeology Education

While most major archaeological museums in North America have always included education as part of their missions, archaeologists first extended their interest to the education of the general public in the late 1970s and early 1980s (Jameson, 2004; Smardz-Frost, 2004). In the United States, laws such as the Archaeological Resources Protection Act protect archaeological sites from vandalism and looting; however, the destruction of sites and the theft of artifacts continues. Much of archaeology education is driven by the belief that if people understand their role in protecting millions of archaeological sites from coast to coast, there will be a noticeable decrease in damage.

Public archaeology was perceived as a real and viable solution; if people could be made to feel that the loss of archaeological resources somehow impinged upon their own quality of life, upon their pride in their respective national heritages, and that site stewardship was the responsibility of every citizen, perhaps the tide of cultural resource destruction could at least be slowed. (Smardz-Frost, 2004, p. 61)

Archaeology has been used as a tool to teach citizenship, civic dialogue, ethics, and personal character while teaching stewardship of archaeological sites (Moe, 2000;

Moe et al., 2002). Many archaeology educators think that archaeology could and should be used to teach much more than stewardship (e.g., Smith et al., 1996; Jeppson & Brauer, 2003; Letts & Moe, 2009). For nearly three decades, archaeology educators capitalized on the processes of archaeological inquiry to design engaging science and social studies activities for students (Hawkins, 1987; McNutt, 1988; Devine, 1990; Smardz, 1990; Wheat & Whorton, n.d.; Smith et al., 1992, 1993, 1996, 1997; White, 1998) which meet national, state, and district educational standards (Davis, 2000). Archaeology has long been viewed as a vehicle for teaching science inquiry (e.g., Hawkins, 1987; McNutt, 1988; Devine, 1990; Wheat & Whorton, n.d., Smith et al., 1992; White, 1998), but archaeological content has never been evaluated for its ability to teach science inquiry concepts and processes in elementary classrooms. Archaeology, by its very nature, integrates science and history and provides a powerful way to study the past (Sutton & Yohe, 2003; Kosso, 2001). Just as archaeology has never been evaluated for its ability to teach science inquiry concepts and processes, it has never been evaluated for its ability to conceptually integrate history and science knowledge in elementary classrooms.

More recently, archaeology educators (Alegria, 2009; Letts & Moe, 2009) have used the national standards in science, social studies, and history to design activities and lessons. *Project Archaeology: Investigating Shelter* (Letts & Moe, 2009) is a complete archaeological inquiry of a historic or prehistoric shelter site and directly addresses the Content Standard A: Science as Inquiry of the NSES (NRC, 1996, 2000). It was developed using *Understanding by Design* (Wiggins & McTighe, 1998, 2005) and Lynn Erickson's (2001) Conceptual Learning Model. This curriculum guide teaches the basic

concepts of archaeological inquiry (observation, inference, evidence, classification, and context) and the basics of gathering data and analyzing it through a series of active learning lessons. Students then apply these concepts to analyze and interpret authentic archaeological data (drawings of artifacts, site maps, historic photographs or drawings, and oral histories). They describe their conclusions in a final essay about the archaeological site they studied and support their conclusions with evidence. Finally, students apply their knowledge through civic dialogue concerning the protection of an archaeological site similar to the one they studied.

Uncovering Conceptual Understanding

Most of the case studies of science inquiry learning reviewed for this study, developed their own instruments and observation or interview protocols. Assessing inquiry-based instruction is an enormous and complex task (Mislevy & Baxter, 2004; Pellegrino et al., 2001). For this reason, it is probably the least likely area of science education to be adequately assessed. Writing in 1999, Michael Beeth and his colleagues noted that there was very little information available on how to assess the science process skills that students are expected to learn through science instruction. Beeth et al. (1999) developed a continuum for assessing process knowledge for elementary school students. Results were promising, but several implementation problems arose such as the number of interactions required to collect sufficient evidence and a way to separate ability in reading and writing from science understanding.

Progress has been made, for example, in embedding assessments in technology-supported learning environments, creating complex

performance-based tasks, tracking student reasoning during problem-solving (e.g., strategy use, metacognition), and evaluating multiple aspects of student performance or products over time. However, much of this work has been localized or experimental in nature and generally not cost effective, not easily adaptable for large-scale use, and not re-usable for other purposes or in other contexts. As such, research and development have produced very little in the way of a shared, practical, and instructionally informative set of tools and strategies to assess learning. (Mislevy & Baxter, 2004, pp. 1-2)

The *NSES* (NRC, 1996, 2000) call for assessment that is broad in perspective, diverse, and as authentic as possible. Based on research in learning theory, student cognition, standards, and instructional expectations, Mislevy and Baxter (2004) developed an evidence-centered framework for assessing science inquiry learning known as the Principled Assessment Design for Inquiry (PADI). The framework is guided by “four critical questions: (a) What does it mean to know and do inquiry? (b) What constitutes evidence of knowing? (c) How can that evidence be elicited from students? (d) What are appropriate techniques for making valid inferences about what students know, from what students do?” PADI shows great promise for assessment of science inquiry learning, but has not yet been implemented widely.

The Curriculum Topic Study (CTS) procedure provides a way to bridge the gap between standards and actual teaching and evaluating the results in terms of student understanding of science benchmarks (Keeley, 2005). The CTS procedure grew out of Project 2061 and correlates to *Science for All Americans* (Rutherford & Ahlgren, 1990), the *Benchmarks for Science Literacy* (AAAS, 1993), the *NSES* (NRC, 1996, 2000), and the *Atlas of Science Literacy* (AAAS, 2001). CTS was designed as a methodical study process to help teachers translate state and district science standards into classroom

practice, but it is also useful for designing context-specific assessment of science inquiry learning and understanding of NOS based on national standards.

Formative Assessment Probes (Keeley et al., 2007; Keeley et al., 2008) are particularly promising for eliciting students' ideas about scientific investigation, e.g., that scientists investigate the world in a variety of ways and there is no fixed scientific method. Keeley and her colleagues developed a series of assessment probes for all areas of science content in *NSES* and for the science as inquiry standards. The probes are based on the most current research on learning about the topic under consideration (e.g., hypothesis or plant growth or magnetism). They are designed to elicit students' preconceptions about the topic or to assess understanding of the topic. Keeley (2005) provides a step-by-step procedure for designing assessment probes based on state or district standards.

Summary of the Literature

While science literacy has occupied an important place in American education for more than 100 years, it received renewed interest in the 1990s following the publication of *Science for All Americans* (Rutherford & Ahlgren, 1990) and the national implementation of Project 2061 goals. Science inquiry and the Nature of Science have played important roles in the broader goals of achieving universal science literacy and both have been extensively researched for their efficacy in science classrooms.

Inquiry-based science education is firmly based in well-researched theories of education (Novak, 1977; Bransford et al., 2000), cognition and cognitive processes

(Bransford et al., 2000; Pellegrino et al., 2001), and the principles of constructivist teaching and learning (vonGlaserfeld, 1989 & 1991; Bransford et al., 2000). Similarly, understanding the nature of scientific knowledge is dependant on individually constructed concepts of inquiry (Sandoval, 2005)

The inquiry portions of the *National Science Education Standards* (NRC, 1996, 2000) are nothing short of a paradigm shift in American science education. Although research generally shows that the benefits of inquiry-based science education are significant, actual implementation of widespread inquiry has lagged behind expectations for several important reasons (Gabel, 2006). Very few well-researched and tested inquiry-based curricula and effective professional development are readily available to teachers nationwide. Additionally, it is difficult to implement authentic, inquiry-based curricula effectively and even more difficult to evaluate learning outcomes (Mislevy & Baxter, 2004). While science inquiry has been extensively assessed in classrooms, there are few broadly applicable instruments available. The Curriculum Topic Study process (Keeley, 2005) provides a practical way for teachers and curriculum designers to bridge the gap between standards and classroom practices.

Archaeology, because of its emphasis on epistemological considerations and its ability to integrate science and history seamlessly, provides a promising way to teach both scientific and historical inquiry in classrooms. However, the ability of archaeology to contribute to science education and to effective ways to integrate scientific and historical knowledge has not been assessed.

Rationale for the Study

Science inquiry instruction clearly fits within the Human Constructivism model outlined by Novak (1993) and his colleagues. It would be difficult to teach science inquiry without a grounding in the idea that individuals build or construct their own knowledge based on their preexisting knowledge and their own processes of making meaning. Human Constructivism and Novak's (1977) Theory of Education provide the foundation for this study.

The goal of universal science literacy has not yet been reached. Most studies of learning through science inquiry show generally positive results, however, some of the researchers included in this review reported mixed or even disappointing results. Not all researchers think that inquiry-based education is productive or even cognitively feasible for elementary age students. Some researchers, especially Metz (2004), found that students can learn both science content and processes through inquiry-based instruction.

Archaeology may provide an engaging way to help educators teach science inquiry and NOS. Additionally, because of its interdisciplinary nature, archaeology may provide effective and seamless ways to integrate science and history. Thus far, however, archaeology has not been assessed for its ability to teach science inquiry, NOS, and the integration of knowledge. This study examines the ability of archaeological content and processes to teach conceptual understanding of science inquiry, NOS, and the conceptual integration of knowledge across disciplines.

While learning through numerous but isolated inquiry-based curricula has been assessed, there are no widely used instruments. Thus far, most information has come

from broad survey studies rather than detailed case studies. Recently, researchers have been applying case study approaches and most of these researchers have developed their own data collection methods and tools to assess learning and understanding in specific situations. Some widely used interview protocols are available to assess NOS, but often must be adapted for particular learning situations.

The CTS procedure offered the best avenue for producing effective learning assessment probes for this study. The probes developed for this study were developed to elicit learning in science literacy, specifically inquiry concepts and understanding NOS, and for examining how students understand the relationships between science, history, and archaeology. The Performance Task and the accompanying observation protocol were similar to the data collection tools that Metz (2004) used in her study of students' self-guided investigations of animal behavior.

CHAPTER THREE

METHODS

Introduction

This study examined the “scientific thinking” of fifth grade students during the instruction of a unit on archaeological inquiry. Two classes of fifth grade students in the small southwestern Montana town of Riverside (not its real name) experienced a supplementary social studies and science curriculum, *Project Archaeology: Investigating Shelter* (Letts & Moe, 2009). The students used “Investigating the Poplar Forest Slave Cabin” (Heath et al., 2007), which is an archaeological investigation of a slave cabin in Virginia. The unit was included in a year-long social studies curriculum on American history and geography. Instruction and field research occurred over an eight-week period in April and May 2009. The students studied science through the Full Option Science System (FOSS), an inquiry-based science curriculum from the Lawrence Hall of Science at the University of California-Berkeley (<http://lhsfoss.org/introduction/index.html>), throughout the academic year.

Rationale and Assumptions for the Qualitative Design

The purpose of this study was to uncover how all of the fifth grade students in Riverside Elementary School understand and use science inquiry concepts. Data collections techniques were designed to uncover and interpret the perceptions of the students within their normal school environment. The researcher was an integral part of

the study. For these reasons, the study fits well within the qualitative paradigm of research in education (Key, 1997; Patton, 2002).

Case Study Design

The research question for this study was, How do students understand and use science inquiry concepts through the study of archaeological inquiry? To adequately address this question, the following specific research questions were developed:

1. How do students understand the concepts of observation, inference, classification, context, and evidence as a result of instruction in archaeological inquiry? Do they misunderstand these concepts? If so, how?
2. How do students construct (logical progression of thought) their understandings or misunderstandings of these concepts?
3. How do students apply these concepts to archaeological inquiry?
4. How do students transfer and apply these concepts to other school subjects or to everyday life?
5. What do students think science is? How do students understand the relationships between science, history, and archaeology?
6. What are the best data collection methods for examining conceptual understanding of science inquiry through archaeological investigations?

This study can best be described as a case study (Stake, 1995; Merriam, 1998) because it is bounded by the sample, i.e., the entire fifth grade at Riverside Elementary School. In other words, the purposefully selected sample (N=27 students) and their experience with archaeological inquiry is the unit of study or the “case.” Case studies

facilitate insight, discovery, and interpretation of the phenomenon in question within a certain context, often as it unfolds over time (e.g., Brody, 2005). Case studies are not tied to particular research methods and may draw from the full spectrum of data gathering techniques (Stake, 1995; Merriam, 1998). A case study approach is appropriate for this study for the following reasons:

1. The case is the entire fifth grade in a small elementary school; the students experienced a curriculum that is widely available nationally. While the number of participants was small, the research illuminates the larger issue of teaching science literacy. The findings should be transferable to similar contexts throughout the United States and perhaps, to other nations where science literacy is an important part of education.
2. Besides the stated research questions, several additional questions were considered through this research. For example, Why did the curriculum intervention work in the way that it did? How could it work better in similar contexts? Would different teaching strategies change the results? Would additional learning activities or additional graphic organizers assist with learning?
3. The approach allowed me to consider a variety of variables such as the ability of the teacher and the previous learning experiences of the students. Additionally, the relationships between variables can be considered within a bounded context. Description can be “thick” and filled with the “voices” of the participants in both written and verbal form. Rather than providing a

cursory view of each student's understanding at one moment in time, as would be obtained through a multiple choice instrument, I had the opportunity to interact with students multiple times and in several different ways (e.g., reading classroom work, reading written responses, analyzing verbal responses, observing a self-guided inquiry, and observing classroom instruction).

Because the sample size is small ($N = 27$), I developed data collection tools to gather specific data (see below). Additionally, I obtained all of the students' class work and used them to check research findings against the probes and interviews (Patton 2002, pp. 293-295). Together, these data sources provided sufficient data to examine the science inquiry concepts that students used to manipulate archaeological data and the processes they used to perform an inquiry task. Data analysis involved interpretation of these data to "get a picture" of students' experiences in learning and using science inquiry concepts through archaeology.

Role of the Researcher

I came of age as an archaeologist in the mid 1970s when the discipline was exploring the role of science inquiry in archaeological practice. A group of archaeologists, led by Lewis Binford who was heavily influenced by Thomas Kuhn's work, especially *The Structure of Scientific Revolutions* (Kuhn, 1962), advocated the hypothetico-deductive model for archaeological inquiry, which became known as processualism. Basically, this meant that if archaeologists followed "the scientific method" rigorously, they could build better explanations, formulate laws that would be

useful for interpreting material remains, and make predictions about the archaeological record in the present (Binford, 2002). They recognized that while archaeology seeks to understand the past, the archaeological record itself (sites and artifacts) are always in the present and archaeologists are constructing the past at this moment in time. The processual model did not deliver all that archaeologists hoped for and the profession has struggled with its identity within the social sciences since then (Trigger, 2006).

Archaeology has since expanded to include, for example, post modern theories of feminism and engendering the past, the search for individual agency in the past as opposed to emphasis on cultures and systems, and the role of oral history in interpretations (Hegmon, 2003; Moss, 2005). Archaeologists still ask compelling epistemological questions (Hegmon, 2003). For example, What constitutes adequate evidence for an explanation of the archaeological record? Or, How should formal scientific method be applied to explain the archaeological record?

My favorite classes throughout my graduate and undergraduate education were the history of anthropological theory, the history of archaeology, and archaeological method and theory. I took these types of classes whenever possible. The most interesting question about archaeological practice for me has always been, How do you know? And, an even deeper question, How do you know that you know? These questions still fascinate me. What can we really know about people who lived a hundred years ago? A thousand years ago? Or ten-thousand years ago? What questions could and should we ask about the past? What evidence should we gather to answer these questions and how should we interpret the evidence?

In 1988, Congress added an amendment to the Archaeological Resources Protect Act of 1979 instructing federal land managing agencies to educate “the public about the significance of archaeological resources on public and tribal lands and the need to protect these resources” for present and future generations to learn from and enjoy (41 United States Code 470). In early 1990, the Bureau of Land Management (BLM) began an archaeology educational program for teachers and their students in Utah. I was working for the BLM in Salt Lake City at the time and had just completed a secondary teaching certificate in history at the University of Utah. My professional background in archaeology and my new credentials in education landed me a spot on the new archaeology education team. Luckily, I was in the right place at the right time and have been working as an archaeology educator for the past 20 years.

The new team began work in January 1990. We knew that teachers would not be interested in simply teaching students about the “significance of archaeological sites” and the “importance of protecting them” as required in the new amendments to ARPA. We knew that we had to give them a way to use archaeology to teach what they were already required to teach. We thought that archaeology might offer an engaging way to teach the basics of science inquiry and developed a series of lessons to model how archaeologists use observation, inference, classification, and context to construct the past (Smith et al., 1992).

Thirty-some years after completing my education in archaeology, the deep, epistemological questions of archaeology still intrigue me. As an archaeology educator, I want to find out, How do students know and understand science inquiry through the study

of archaeology? Since 1990, I have been developing educational materials (Smith et al., 1992, 1993, 1996, 1997; Letts & Moe, 2009) and training teachers to use archaeology in their classrooms to teach social studies, science, and history. I have written and published extensively about the subject (Moe & Letts 1998; Moe 2000a, 2000b, 2002; Moe et al. 2002; Moe & Heath 2005; Moe & Clark 2008; Brody, Clark, & Moe 2009; Franklin & Moe, 2011). In all this time, I have never been able to talk directly to children about their learning through archaeology. Through this study I finally had the opportunity to ask kids what they know and understand about archaeology. It was a transformative experience; I will never see archaeology education the same again.

I guided the planning, development, and production of *Project Archaeology: Investigating Shelter* (Letts & Moe, 2009). Archaeology education is my calling and my life's work and *Investigating Shelter* is unquestionably my best effort to date. In this study, I am clearly not an "objective" outside evaluator. There is very little research on the efficacy of archaeology education materials in the classroom and I embarked on a doctoral degree in education to prepare myself to begin filling this void. I have devoted most of my doctoral study to the question: How can I adequately position myself to research the efficacy of my own work?

As one of the authors of *Project Archaeology: Investigating Shelter* (Letts and Moe, 2009) and the national leader of the Project Archaeology education program, I have a vested interest in the outcomes of the research. For this reason, I chose a research topic that does not "test" learning outcomes of the curriculum. Instead, I examined the students' understanding of inquiry concepts and the processes underlying student learning

of science inquiry concepts. I tried to narrow my focus and interest to the interpretation of students' understanding of science inquiry through archaeology, their ability to use these skills in studying archaeological materials, and their ability to transfer their knowledge to other science subjects. During both field research and data analysis, I continually monitored my position within the research.

This study was certainly a journey for me. As the students were uncovering archaeological concepts and content, I was uncovering their understandings and misunderstandings by examining their writing and some of their classroom work. I was lucky enough to be able to interview all of the students about almost all of the concepts we were studying together. They gave their time so willingly and a few students even missed parts of their recesses to finish interviews. Several times their teacher told me, "They work harder on your learning probes than they ever have on anything that they do for me." I only hope that I can do justice to the contributions they have made so willingly to science education.

Context of the Study

Site and Sample

In 2000, 1,396 people lived in Riverside, Montana; by 2005 the population had grown to an estimated 1,465 residents (<http://www.citytowninfo.com>). As reported in the 2000 census, 97.4% of the population was white and the remaining residents were Asian, American Indian, and Mixed Race (people of Hispanic ancestry are included within these three categories). Riverside is located in a large agricultural valley in

southwestern Montana. A land grant university is within commuting distance of the town.

Riverside Elementary School is the only elementary school in the town of Riverside and approximately 250-260 students are enrolled each year. The high school and junior high school occupy adjacent wings of the same building. The campus is situated on the edge of town with an excellent view of open agricultural fields, pasture land, and mountains in the distance. The school building is not new, but is in very good repair and was always clean during field research. A small computer lab contained enough computers in good working-order for all students in the fifth grade to work together in pairs. A pleasant, well-stocked library completed the core learning areas in the school. Each of the grades, kindergarten through sixth grade, are divided into two classrooms. In 2009, there were 27 fifth grade students and they were taught by Ms. Martha Jones (14 students) and Ms. Rachel Smith (13 students). These names are pseudonyms.

Ms. Martha Jones has taught fifth grade at Riverside Elementary School for 10 years. While she likes science and mathematics and likes to teach both subjects, she prefers to teach English, social studies, and history. Martha said that she stopped teaching science when she had the opportunity because she does not like teaching science “out of a book,” and did not have adequate supplies and curricula to teach science properly. She has never had any training in science inquiry and has never taught science as inquiry, but has always encouraged her students to approach social studies and history from the questions they have about the past.

All of the fifth grade students had a “homeroom” where they studied language and literacy, but Martha teaches social studies and history, while Rachel teaches science and mathematics. The two classrooms were immediately adjacent, so the students could move easily between the rooms. Students from the two home rooms were assigned to one of two groups based on their abilities in mathematics: Black or Orange, which were the school colors. The Black group contained 13 students who were higher-level performers in math. The Orange group had 14 students who performed at a lower level in math. The same groups received their science and social studies instruction together. Martha taught *Project Archaeology: Investigating Shelter* as social studies, rather than science.

As a whole group (N=27), Martha described the students as average to low performing based on her previous teaching experience and her personal opinions. Eight of the students needed extra help with reading or mathematics. Dan, Roger, Edison, and Brezy received extra help with reading under the Title I program. Antwan and EJ were pulled out of their classrooms for a special reading program and Jack was pulled out for math instruction. English is EJ’s second language. While Fred does not have any academic problems, he was diagnosed with Asperger’s Syndrome. With only a few exceptions, all students regardless of abilities or disabilities completed all of the learning probes and interviews. All of the students completed the performance task.

Curriculum Intervention

Project Archaeology: Investigating Shelter is a supplementary science and social studies curriculum unit for grades three through five. It consists of an introduction to

archaeological thinking, nine comprehensive lessons, and a final performance of understanding, all of which guide students through the archaeological study of shelter including a toolkit of archaeological and scientific concepts and a final performance of understanding. Following *Understanding by Design* (Wiggins & McTighe, 2005), *Investigating Shelter* teaches six enduring understandings and all learning is guided by essential questions (Table 3).

Table 3. Outline of Project Archaeology: Investigating Shelter by Enduring Understanding.

Enduring Understanding	Essential Questions	Learning Activity
		Warm-up Lesson: Thinking Like an Archaeologist
All people need shelter, but shelters are different from one another.	How are shelter the same and how do they differ? Why do they differ?	Lesson One: Knowing Shelter—Knowing People
We can learn about people by exploring how they build and use their shelter.	What does the study of shelter teach us about people? How important is this way of knowing?	Lesson Two: By Our Houses You Will Know Us
Everyone has a culture and our lives are shaped by culture in ways we may not even see.	How is culture expressed in the ways people meet basic human needs?	Lesson Three: Culture Everywhere
Using tools of scientific inquiry, archaeologists study shelters and learn how people lived in them.	How do archaeologists study the past?	Lesson Four: Observation, Inference, and Evidence Lesson Five: Classification Lesson Six: Context Lesson Seven: Every Picture Tells a Story
Studying a shelter can help us understand people and cultures.	How can investigating shelters help us understand people and cultures? How can we use what we learn about shelter in the present and the future?	Lesson Eight: Being an Archaeologist
All enduring understandings		Final Performance of Understanding: Archaeology Under Your Feet

Lessons One through Three set the stage for the unit, hook student interest by looking at contemporary shelters, and ground students in the study of cultures through archaeology. Lessons Four through Seven teach the scientific concepts of observation, inference, evidence, classification, and context that archaeologists use to gather, analyze, and interpret data. (Lessons Four through Seven and Assessment for these three lessons are shown in Appendix A). Lesson Eight is a complete archaeological investigation of a shelter, which models how archaeologists analyze and interpret data. Teachers choose a regionally appropriate shelter investigation from an online database to help them teach history and social studies standards. Each investigation contains as much authentic primary data as possible for students to manipulate and analyze. Lesson Nine shows students that everyone is responsible for protecting archaeological sites because they represent the cultural legacy of all Americans. In addition, students learn that archaeological sites can be affected when land is developed for highways, subdivisions, or mining and they examine the federal and state laws that preserve sites and the information they contain.

Each shelter investigation includes a Final Performance of Understanding specific to the shelter studied. The students take roles in a preservation issue and debate their point of view. The performance activity shows students that archaeology is everywhere and in constant need of protection from theft and vandalism. Table 4 shows where and how specific science inquiry concepts are taught in *Project Archaeology: Investigating Shelter*.

Table 4. Science Inquiry Concepts and *Project Archaeology: Investigating Shelter*.

Science Concept	Investigating Shelter Lesson	Instruction
How archaeologists work	Warm-up Lesson: Thinking Like an Archaeologist	Speculate about the nature of archaeological sites and archaeological inquiry
Data collection and analysis	Lesson Two: By Our Houses You Will Know Us	Collect data about how people use space where they live
Observation, inference, and evidence	Lesson Four: Observation, Inference, and Evidence	Observe artifacts, make inferences, use evidence to confirm their inferences
Classification	Lesson Five: Classification	Classify everyday objects based on questions, apply the concept to artifacts
Context	Lesson Six: Context	Uncover the concept of archaeological context through a game using modern objects, apply context to archaeological site protection
Observation, inference, evidence, classification, context, how archaeologists work	Assessment: Lesson Four - Six	Apply all concepts to the study of a modern living space
Observation, inference, evidence	Lesson Seven: Every Picture Tells a Story	Apply all concepts to the study of a modern photograph and a historical photograph
Observation, inference, evidence, classification, context, how archaeologists work	Lesson Eight: Being an Archaeologist	Apply all concepts to the study of a historic cabin occupied by enslaved people using authentic archaeological data; report conclusions through an essay
Observation, inference, evidence, classification, context, how archaeologists work	Final Performance of Understanding: Archaeology Under Your Feet	Debate about preservation of an archaeological site similar to the one they investigated; students play the roles of archaeologists, members of the descendant community, families who need homes, and developers respectively

Martha rated *Project Archaeology: Investigating Shelter* as a very high-quality curriculum. She chose the curriculum for teaching American History, but she also thought that it incorporated tasks that are consistent with investigative science and that it would have a positive affect on students' understanding of science. She thought the unit was well planned and supplied sufficient resources to accomplish the learning objectives. The lessons encouraged a collaborative approach to learning and students of all abilities were able to participate effectively. Her students struggled with writing the definitions, so she gave them the written definitions and instructed them to match words with definitions, instead of using the more constructivist approach in the curriculum in which students construct their own definitions based on instructional activities. Many of the words were review from science and mathematics. Martha said the students were "somewhat perplexed by the fact that they were using 'math and science words' in the history classroom." The vocabulary integration and "the questions and discussion it prompted was a very powerful learning opportunity for students to see that words and concepts are often connected in many parts of life, not just in each individual discipline" according to Martha. She found that teaching the eleven learning activities in the curriculum took more time than estimated by the curriculum designers and she had to slow some sections down to ensure adequate learning by students of all abilities.

Martha chose *Investigating Shelter* because of her interest in history and her desire to add more hands-on lessons to her curriculum. The curriculum fit well with Montana Standards in social studies, technology, world languages, arts, mathematics, and science (Appendix B). Riverside School District did not have district standards, but

rather had a scope and sequence that coincides with the Montana Standards.

Investigating Shelter was officially accepted by the Riverside School District.

While Martha did not feel particularly well-prepared to teach science, she felt well-prepared to teach *Project Archaeology: Investigating Shelter*. In college, Martha took courses in anthropology, sociology, and history as well as one class in archaeology. She attended a professional development workshop at Montana State University using a different curriculum, *Intrigue of the Past* (Smith et al., 1996), in 2006. Martha attended a second professional development workshop offered by Montana State University to learn how to use *Investigating Shelter* in June 2008 where she studied “Investigating a Plains Tipi” (Alegria et al., 2007). She took another workshop in August of the same year and studied “Investigating the Tinsley Homestead” (Adams et al., 2008). Martha thinks that she could be a good science teacher with training and proper materials and supplies.

It was truly a pleasure to be in Martha’s classroom. Based on Martha’s own assessment and my observations, Martha is an excellent teacher and was particularly well-suited and well-prepared to teach this unit. She described her experience with *Project Archaeology: Investigating Shelter* as follows:

Very little time was spent on lecture. Other than giving general directions for task, my role became less information delivery and more facilitator to information discovery. I also asked questions of students if they seemed lost or stuck to get them going in some direction and conversing with one another. My other role was in facilitating discussions including times when they seemed to need more help understanding a concept, however, the great discussion taking place between the students made it clear that they were learning from one another and the questions and hypotheses they were formulating.

Martha said that she thoroughly enjoyed teaching the curriculum and was amazed at how “on task” the students were throughout the unit. The school principle visited the class while students were placing artifacts in their original context on a large floor map of the slave cabin site. He was impressed with how focused the students were. Martha got a stellar evaluation for her teaching that day.

Data Collection Techniques

This study employed several types of data collection tools (Appendix C). I collected data in four ways: (1) observation of an inquiry performance task and a brief interview following the performance task, (2) a series of five formative learning assessment probes adapted from existing science learning probes and a complementary interview protocol to elicit further information on student ideas about the specific concept in question, (3) a formative assessment probe on the Nature of Science and dispositions toward science and a complementary interview, and (4) a final interview with the cooperating teacher at the end of the research. In addition, I checked samples of student work produced during instruction of the curriculum and correlated them to data gathered from the seven data collection tools.

Formative Assessment Probes on Concepts

Five formative assessment probes (titled “Learning Probe” in Appendix C) were used to elicit student thinking on: (1) the nature of archaeological inquiry, (2) classification, (3) the use of evidence, (4) context in archaeology, and (5) the difference between observing and inferring. These assessment probes closely follow those

developed by Keeley (2005; see also Keeley et al. 2007 & 2008) and published by National Science Teachers Association Press. Learning assessment probes are called “probes” because they are intended to probe for student conceptual understanding. Following Gabel’s (2006) advice that assessment data collection techniques must be content specific, I designed probes specific to archaeology and to the *Investigating Shelter* curriculum. The formative assessment probes and an explanation of each can be found in Appendix C. The Learning Probes were field tested by two adults, both knowledgeable about archaeology and the *Investigating Shelter* curriculum, before research began; both were generally familiar with archaeology and the curriculum.

Learning Probes 2-5 were administered to all students by the teacher at appropriate times during instruction, usually immediately following the lesson or lessons teaching the concept(s) specific to the assessment probe. Martha and I mutually decided on the best time to administer the assessment probes. I interviewed all of the students about their responses on the learning probe using the interview protocols for each probe as shown in Appendix C. The protocols were designed to provide more information about underlying cognitive processes that the students used to arrive at their responses for each of the questions or statements. The interviews were digitally recorded.

Learning Probe 1: How an Archaeologist Works, was administered as a pretest to obtain baseline information on students’ understanding of archaeological inquiry before instruction and again as a posttest following all instruction. The purpose of the pretest and posttest was to look for changes in understanding, rather than to determine if the student got the “correct” answers. The data collected from Learning Probe 1 seem to be

flawed. Many students performed better on the pretest than they did on the posttest. Martha explained that the students received the posttest on a chaotic day near the end of the school year and probably did not give it their full attention. For this reason, data from this learning probe was used to address Research Question 6 regarding the efficacy of data collection methods only.

Performance Task

Students were presented with archaeological data (a map, artifacts, and basic background information) from an unfamiliar archaeological site (one that they did not study during the unit) and were asked to investigate the site using a written guide (Appendix C). The performance task was field tested with two of the fifth grade students who were available to leave their other work before beginning the research. Martha and I agreed that students who had recently completed the *Investigating Shelter* unit would provide a better test of the performance task than would adults who were unfamiliar with the specific inquiry processes involved. The procedure was modified and a “worksheet” to provide structure for the inquiry was developed in consultation with Martha before research began. The exercise was recorded on a digital audio recorder. The performance task was used to identify how students applied inquiry concepts in a self-guided inquiry and how they structured an investigation under their own volition. The performance task was set up in a separate room (the school computer lab) and administered using the following procedure:

1. Students worked in dyads as they did during instruction of the unit. Martha selected the teams based on how well they would work together and sent them to the computer lab. I explained the task to the two students.
2. I observed students while they were performing the task and took notes on their performance, e.g., classification methods, investigation methods, silent interactions.
3. I asked probing questions about each team's investigation procedures, the concepts they used, and their inferences, as needed and appropriate, to better understand how they arrived at their conclusions. Their responses were digitally recorded.

Interviews on the Nature of Science and Dispositions toward Science

Learning Probe 6: The Nature of Science (Appendix C) was designed to allow students to outline their thoughts about the Nature of Science and the relationships between science, history, and archaeology before their interview. The Learning Probe was developed in consultation with Martha to fit the context of her classroom and the students' background in science and history. All students, except one, completed the probe and were interviewed about their understanding of the Nature of Science (following Abd-El-Khalick et al. 2001; Lederman 1998) and their own dispositions toward science. Interview questions, which closely followed the assessment probe, were as follows:

- What, in your view, is science?
- How is science different from history?
- How are science and history similar?
- Could you be a scientist? Why or why not? Would you like to be a scientist?
Why or why not?
- How has the study of archaeology changed your view of science?

Student Work

Several of the activities in *Project Archaeology: Investigating Shelter* involved collecting data through observing and inferring. Students also analyzed the data in various ways such as through graphing and drew conclusions based on the archaeological evidence they encountered. Martha photocopied all of these student activity sheets and gave them to me during instruction of the unit. Students were required to write an essay describing what they learned in their archaeological investigation of shelter. Martha photocopied all of the essays and submitted them to me for analysis at the end of unit. Copies of all classroom work were collected and analyzed while instruction proceeded. In some cases, these documents provided immediate insight into learning processes which helped refine interview questions or pointed to other avenues of research.

At the end of the unit, students played the roles of archaeologists, members of the descendant community, new families who needed a home, or developers respectively in the Final Performance of Understanding. The students demonstrated their comprehensive knowledge of the curriculum unit while debating the protection of an archaeological site similar to the one they studied. The students worked in groups and presented a

persuasive speech from their assigned point of view. I observed the debate and recorded instances of the inclusion of science inquiry concepts, understanding of the nature of science, and dispositions toward science in the persuasive speeches.

Teacher Interview

I completed data collection by using the Inside the Classroom: Observation and Analytic Protocol (Horizon Research, Inc. 2000) found in Appendix D, to examine the community of learning in which study subjects were engaged in social studies and science education. Martha and I completed most of this protocol together following the instructions for data collection included in the document. Martha completed Part One: Sections F(1) and Part Two: Sections A.1.a and 5.b, and Section B alone. The portions of the protocol regarding curriculum development were not completed because the curriculum for this project had already been chosen. This protocol identifies various aspects of classroom learning communities such as management strategies and observations about science instruction strategies such as active participation versus individual reading. Much of the form is designed to elicit information about the teacher's ability to choose or develop effective science curriculum. For this reason, the form could not be completed entirely because the curriculum was already set, but partial completion provided useful baseline information about the learning community.

Martha completed the 2000 National Survey of Science Questionnaire (Horizon Research, Inc. 2000) found in Appendix E, for basic information on her background in science education and interest in teaching science. A final interview with Martha in July 2009 completed the collection of data for the study. Interview questions were as follows:

- What previous instruction have the students experienced this academic year that might affect the results of this study. For example, have you completed other instruction on science inquiry or historical inquiry?
- What training have you had in archaeology education? Do you have a particular interest in archaeology?
- What training have you had in science inquiry?
- Do you consider yourself to be a good science teacher? Are you confident in teaching science inquiry?

The relationship between the research questions and the data sources is summarized in Table 5.

Table 5. Relationship between Research Questions and Data Sources.

Research Question	Data Sources
How do students understand the concepts of observation, inference, classification, context, and evidence as a result of instruction in archaeological inquiry? Do they misunderstand these concepts? If so, how?	Student classroom work Learning Probes 1-5 Student interviews Teacher interview & consultations Performance Task
How do students construct (logical progression of thought) their understandings or misunderstandings of these concepts?	Learning Probes 2-5 Student interviews
How do students apply these concepts to archaeological inquiry?	Learning Probes 1-5 Student interviews Student classroom work Performance Task
How do students transfer and apply these concepts to other school subjects or to everyday life?	Learning Probes 2-5 Student interviews
What do students think science is? How do students understand the relationships between science, history, and archaeology?	Learning Probe 6 Student interviews Teacher consultations & interview
What are the best data collection methods for examining conceptual understanding of science inquiry through archaeological investigations?	All Learning Probes Student interviews Performance Task Teacher consultations & interview

Informed Consent

An application to conduct research on human subjects was submitted to the Institutional Review Board at Montana State University. Dr. Art Bangert, Department of Education, signed the application and guided the data collection phase of the project. The application including an Informed Consent Form for students can be found in Appendix F.

Data Management

All data was coded by pseudonyms to preserve the anonymity of the subjects. Separate folders were maintained for each subject and contained all student work, completed learning probes, classroom work, and other data as applicable.

Transcripts of the digital recordings of interviews with students were also coded for anonymity. The recordings were transcribed by a professional transcriber and will be stored in a secure place in the researcher's home. I coded my field notes to help correlate data with individual subjects and the coded notes will be stored in a secure area along with other project data and records.

Data Analysis Procedures

Preliminary analysis began as soon as field data were available (per Merriam, 1998). Initial observation of the data helped detect problems in research design and/or assessment probes while field work was still underway. Early identification of problems

made it possible to alter strategies and/or probes as necessary before the research was completed. Table 6 summarizes all of the data collected for the study.

Table 6. Summary of Data Retrieved for All Students.

Probe	Complete Data	Written	Interview	Interview Notes	Interview Transcript
1	0	Pre = 27 Post = 27	0	0	0
2	25	27	25	25	25
3	0	27	0	0	0
4	22	27	26	26	22
5	25	26	26	26	25
6	25	26	26	26	25

All data collected was qualitative in nature and was analyzed inductively as described by Patton (2002; also Coffey & Atkinson, 1996; Merriam, 1998). The purpose of data analysis was to ferret “out the essence or basic structure of [the] phenomenon” (Merriam, 1998, p. 158). In this case, I was looking for understanding of the science inquiry concepts and the underlying processes involved in learning and using the concepts.

Using the Inside the Classroom: Observation and Analytic Protocol (Appendix D) and follow-up interviews with Martha, I outlined a description of the classroom community. This portion of the research provided an *emic* perspective (an insiders’ perspective) of the learning community (Patton, 2002).

After all data were collected, I examined the data from an outsider’s perspective (an *etic* perspective). I grouped all of the data by the collection method: Learning Probe or Performance Task. I inductively searched for key themes or core meanings such as understanding; misconceptions; cognition; application of concepts to archaeological

contexts; transfer of concepts to other subjects and to everyday life; or application of observation, inference, classification, context, researchable questions, or use of evidence. Using this information as a base, I coded the data and searched for patterns, links, and/or correlations in the data. The final step was to draw conclusions about the patterns and correlations identified. I also identified unique responses to interview questions and the written probes. Martha and I conferred about unique cases and I designed some follow-up questions to better understand these cases. Outlying cases can provide good insight into patterns and themes (Patton, 2002).

Methods for Verifying Trustworthiness

To verify the trustworthiness of the results, I used four criteria: credibility, transferability, dependability, and confirmability (Shenton, 2004).

Credibility

To establish the credibility of the study, I triangulated the data in several ways. Following Merriam (1998, p. 204-205), triangulation was aimed at finding an understanding of the situation (case) to construct plausible explanations of student understandings. Multiple sources of data (student class work, verbal explanations of concepts, written explanations of concepts) gathered through a variety of methods (writing, interviews, observations) allowed for several checks and cross-checks to answer the question: How well do the results capture what really occurred during the course of this study? Specifically, I:

1. Compared written assessment probes with and interview transcripts with student class work.
2. Compared observations (notes) of the performance task with student class work and with written assessment probes and related interviews.
3. Periodically checked results and initial interpretations with the cooperating teacher for consistency and to identify disagreements in interpretation of the data. Checked the final results with the cooperating teacher for dependability in interpretation of the data.
4. Checked interpretations of written assessment probes for accuracy with the subjects themselves through the interviews as needed.

Research was conducted over the entire period of unit instruction and each student was observed and interviewed on multiple occasions to ensure adequate representation of his or her understandings. At the beginning of the unit and the research period, I encouraged the students to be as honest as possible in describing their understanding of their own thinking processes. I encouraged the students to think of themselves as “co-researchers” in the project. All students had the opportunity to decline participation in the study. Qualitative data, especially sections of interview transcripts, are presented in considerable detail and depth in Chapter Four, so the reader may examine the data and my interpretations of the data for him or herself.

Transferability

Data was collected throughout the period of instruction and all students were interviewed multiple times. Additionally, all student classroom work was examined for

consistency with data from interviews and learning probes. Thus the research does not represent a brief moment in time, but rather, a complete investigation of the curriculum intervention.

A complete description of the research findings is presented in Chapter Four and in Appendix G. Extensive quotes from all of the students are included and in some cases complete transcripts of interviews are included for the reader to evaluate.

The formative assessment probes developed by Page Keeley and her colleagues (e.g., Keeley et al. 2007; Keeley et al. 2008) have been well-researched and tested. The probes developed for this study were modeled closely after the CTS process and probes. A major goal of this study was to develop and test probes similar to the CTS produced probes for assessing understanding of science concepts through the study of archaeology; no such instruments for archaeological content existed. While the new probes had not been previously tested with students, they would still have had the potential to produce similar results in a similar study. The curriculum, *Project Archaeology: Investigating Shelter*, and the six formative assessment probes are available to teachers throughout the nation. This study could provide a “baseline understanding” from which to compare similar case studies of conceptual learning through archaeological inquiry (Shenton, 2004), using the same curriculum and assessments.

Dependability

Research methods have been described in detail. Methods and data were triangulated in several ways (see above) to ensure the dependability of research findings.

I used the interview process and examination of student classroom work to check my interpretations of the students' conceptual understanding and cognitive processes.

Because of the qualitative nature of this study, research results could never be replicated exactly (Merriam, 1998, p. 205), however, to ensure the consistency and dependability of content analysis, I designed an intercoder-reliability sample following Lombard (2008). I omitted three students (Antwan, Dan, and Fred) from the possible selections of the sample because I found their work difficult to code; all three students have significant learning disabilities. From the remaining pool of 24 students, I randomly selected the names of three students (Matthew, Lane, and Sally) by writing the names of the students on small pieces of paper and selecting them from a hat. I assembled copies of all the written work submitted by these students and transcripts of their interviews. Transcripts of the work of two Performance Task teams (Walt and Kate; Jake and Reed) were also randomly selected for review through a similar process.

Ms. Crystal Alegria, National Project Archaeology Coordinator and the state coordinator of the Montana Project Archaeology Program, agreed to code the sample data to check for consistency and dependability of the results. Crystal assisted with preparation of *Project Archaeology: Investigating Shelter* and has taught the curriculum or portions of it to teachers on approximately ten or twelve occasions. She was intimately familiar with the guide and its learning goals at the time of the study. I provided Crystal with a copy of Appendix C and relevant guides for coding the data in the assessment probes, the interview transcripts, and the performance task transcripts.

Crystal spent approximately seven hours of unpaid time examining and coding the sample.

Lane was absent the day that all of the data about Nature of Science learning was collected, therefore, I selected the work of two additional students to be included in the intercoder-reliability sample for NOS. Jake, Bella, and Mazy all demonstrated good understanding of the relationship between science and history; I selected Jake randomly from these three students for further evaluation by Crystal. Similarly, Amelia and Luna both demonstrated a good understanding of science and Luna was randomly selected for further evaluation. Crystal's coding matched mine in approximately 75% of the instances.

Ms. Martha Jones, the cooperating teacher, reviewed the results at the completion of the study and concurred with the findings. She provided additional explanation in some cases to assist with accurate interpretation of the results.

Confirmability

Confirmability in qualitative research is similar to the concept of objectivity in quantitative research. A key criterion for confirmability is "the extent to which the researcher admits his or her own predispositions (Shenton, 2004, p. 72). The Role of the Researcher section of this chapter includes a complete description of my background and professional connection to this research. Additionally, all project records are available for inspection by other observers to trace the course of this research and the conclusions.

Summary of Methods

This qualitative study involved the development and testing of six learning assessment probes and one largely self-guided performance task, all specific to the curriculum, *Project Archaeology: Investigating Shelter*, which was used for instruction. I devoted 14 field sessions to the project and consulted with the cooperating teacher twice before beginning research and conducted a closing interview at the end of the research project. A total of 27 students and one cooperating teacher participated in the study. Data was analyzed by coding it for evidence of student understanding or misunderstanding of the concept in question, the underlying processes the student used to arrive at his or her understanding, how the student applied the concept to archaeological inquiry, and how the student transferred the concept to another school subject or to everyday life.

The four criteria for trustworthiness (credibility, transferability, dependability, and confirmability) were applied to the entire project. Data was triangulated through collection of multiple forms of data through multiple methods, all research methods are described in detail in this chapter, dense description of raw data and interpretations are provided in Chapter Four, and all project records are available for audit. An intercoder-reliability sample was selected and was coded by a knowledgeable colleague to ensure the consistency and dependability of the data analysis.

CHAPTER FOUR

RESULTS

In this research project, I studied how students build scientific literacy through participation in a series of inquiry-based learning exercises and how they apply these inquiry concepts in a performance task. I also looked at how students thought that scientists (archaeologists in particular) work and what they think science is and how science, history, and archaeology are related. Additionally, an important part of the project was to develop and test the efficacy of a set of formative learning probes for assessing student science learning through the context of archaeological inquiry.

The previous chapter outlines the setting of the study and data collection methods. This chapter presents the results of analysis of qualitative data and how the results of the study answer the six research questions. Chapter Five presents my interpretation of the data, how these findings relate to previous research, and the relevance of the research for curriculum design. The specific research questions I examined were:

1. How do students understand the concepts of observation, inference, classification, context, and evidence as a result of instruction in archaeological inquiry? Do they misunderstand these concepts? If so, how?
2. How do students construct (logical progression of thought) their understandings or misunderstandings of these concepts?
3. How do students apply these concepts to archaeological inquiry?

4. How do students transfer and apply these concepts to other school subjects or to everyday life?
5. What do students think science is? How do students understand the relationships between science, history, and archaeology?
6. What are the most effective data collection methods for examining conceptual understanding of science inquiry through archaeological investigations?

In this chapter, research results are presented under each of the six research questions. Within the discussion of Research Questions 1 - 4, I present results about students' conceptual understanding of the five inquiry concepts. I combined discussion of observation and inference because Learning Probe 5 asked students to differentiate between the two concepts. The discussion of Research Question 5 concentrates on students' understanding of the Nature of Science and does not include results specifically about the five inquiry concepts. The discussion of Research Question 6 presents findings about the efficacy of each of the Learning Probes and the Performance Task. A brief discussion of unexpected outcomes follows analysis of the research questions. The reader will need to examine the Learning Probes and the Performance Task (Appendix C) to understand the results of the study.

Throughout the chapter, quotes from both written learning probes and from interviews are included to illustrate student understanding, cognitive processes used, and examples of application and transfer of knowledge. Additional quotes supporting my conclusions may be found in Appendix G and are coded by Appendix (G), Research Question (1-5), and the order they appear in the text (1 through the highest number for

that section), thus, G.1.1, G.1.2, etc. Student understanding of the five inquiry concepts was very individual and no one student is representative of all research subjects or even of a subset of subjects.

Research Question 1: Understanding, Misunderstanding, and Misconceptions

How do students understand the concepts of observation, inference, classification, context, and evidence as a result of instruction in archaeological inquiry? Do they misunderstand these concepts? If so, how?

Observation and Inference

The *Investigating Shelter* curriculum teaches the concepts of observation and inference in one lesson and Learning Probe 5: Observation and Inference asks students to differentiate between the two concepts. Eleven students gave “correct” answers for all six of the statements on Learning Probe 5. Thirteen of the students thought that Statement F (“The image on the coin is a representation of the nation’s king.”) was an observation rather than an inference, but were “correct” on all of the other statements. Two of these students decided that Statement F was actually an observation during their interviews. Two other students gave “incorrect” responses on at least one of the other statements.

Most of the students understood observation to be something that they could “see,” a “fact,” or something that “can be proven” (G.1.1). For example, Jake said, “It’s a (*sic*) observation because it can be proven. There is a picture of a face on one side; it’s

true.” Most students understood inference to be something that “cannot be proven” or “you don’t know” (G.1.2). Inferences could also be a “guess.” Luna made a clear connection between observation and inference, “To know if the people were deeply religious you would have to observe their acts.” For the most part, the students seemed to understand that inferences needed to be based on observations, but other than Luna’s statement, there was not much direct evidence for their understanding of the relationship between observation and inference. Walt explained his choice of inference for Statement F, “It was an inference because from my observation I could tell that they were religious people.” Walt had some understanding of the relationship between observation and inference, but in this case he thought that one observation was sufficient to confirm his inference.

Roy chose inference for Statement C (“The words ‘We Trust the Gods’ are printed on the coin.”) and made a good case for his choice. He said, “It’s an inference because you can’t tell if it’s print or non-print.” In other words, using only the data at hand (a picture on a piece of paper) the viewer cannot be sure that the words are actually printed on the coin.

Misconceptions about Observation and Inference. An erroneous preconception about the face on the coin caused 13 students to decide that Statement F was an observation rather than an inference. Most of the students who chose observation rather than inference seemed to have done so because they reasoned that anything that looks like a king on a coin, must, indeed, be the king of that nation. Reed’s reason for his choice of observation was: “Because he has a crown and he looks like a king because he

has long hair like a king usually does.” Perhaps, this comes from the fact that most of the currency in the United States, has a representation of one of the Presidents. Two notable exceptions are the presence of Alexander Hamilton on the ten-dollar bill and Benjamin Franklin on the fifty-dollar bill. Hamilton and Franklin were both early US statesmen, but neither was ever President.

One student (Walt) said that Statement F was an inference, but his explanation for the answer indicates some confusion about inference and observation. “I put inference because it’s known that it’s the king of that nation so I inferred it from looking at it.”

Dan assumed that the artifact could somehow tell the how’s and why’s of past human behavior by itself without the benefit of human interpretation. “It (the coin) tells why they were religious and how they were religious and peaceful people and respect the Gods.” When I asked him what “they” means, he responded, “The people of the city probably or someone really religious like a fortune teller or something.”

Several students thought that the statement rather than the coin contained the relevant information about the past. I could not discern if this misconception arose from an inadequate reading of the instructions or a deeper misconception about observing objects and making inferences about them.

Classification

In *Project Archaeology: Investigating Shelter*, Lesson Four: Classification stresses the importance of asking questions to guide the classification of artifacts. The majority of the students (N=17) recognized that questions should guide the classification of artifacts (G.1.3). George clearly stated the relationship between questions and

classification, “I think River is right because you need to ask a question in order to know how to sort the artifacts.”

Some of the students (N=10) thought that the use or function of the artifacts was more important than a guiding question (G.1.4). In other words, function trumped any other possible way of classifying artifacts. Matthew chose Crystal, “... because you’re supposed to do it by how they were used because that is the main way of getting proof.” While some of them recognized that questions produce different conclusions, they thought that artifacts should always be classified by how they are used.

Roger understood that “... you should classify facts (artifacts?) based on questions,” but he could not provide an example that would work. Edison thought that artifacts definitely should not be classified based on a question, but contradicted himself. “If someone asked you a question and you did it, it would make more sense to them than if they didn’t ask you a question and you did it on what you want to know. They might not understand.” He seemed to think that if you ask a question, you should already know the answer.

Misconceptions about Classification. I identified some misconceptions about classification in the interview transcripts. Some of the students seem to think that classification and context are the same concept. Lane’s interview illustrates the misconception.

Lane: Um, you can’t really classify something right away just by looking at it, you need more information about the artifact.

Jeanne: And, what do you mean by needing more information?

Lane: Like you need more evidence or objects around it.

Jeanne: Okay, and what would that tell you?

Lane: It would tell you what the use of it was.

Some of the students confused individual artifacts and their uses or functions with classes of objects. This misconception seems to come from the statement on the learning probe: “It doesn’t matter how you classify artifacts. They will still tell you the same thing.” For example, Mia conflated the use of an artifact with how it is classified, “She (Ivy) is not right because not all artifacts tell you the same thing. Some might tell you how ... like a pot could be holding corn or carrying water and...” Walt stated, “... artifacts shouldn’t be classified the same way because they have different uses.” Shirley was puzzled about the statement and said, “I don’t get that because they won’t tell you the same thing because they are different things maybe.” Shirley’s statement may indicate that the statement on the instrument needs revision.

Some students chose Crystal over River because they thought that most archaeologists used “function” to classify artifacts most of the time. Matthew recognized that while questions will produce different conclusions, artifacts should always be classified according to how they were used. “I chose Crystal because you’re supposed to do it by how they were used because that is the main way you are going to get your proof.” He did not seem to recognize the problem with reconciling the use of questions and the “way you’re (archaeologists) are supposed to do it.” One uses questions within the category of “function,” but questions would never cause an archaeologist to classify artifacts based on anything besides function; material type or evidence of wear, for

example. Bella stated, “Because you classify artifacts according to how they are used. I think Crystal is more right because River, he is kind of right because you can classify artifacts based on the questions you have, but I don’t think most archaeologists do that.”

Context

The majority of the students (N=12) thought that the pottery jars in Drawings A and B were the same pot as was the intention of the learning probe, but eight thought they were different pots and the remainder either did not know or thought that there was insufficient information for them to differentiate between the two. Despite this unforeseen problem with the probe, most of the students were able to complete it without any difficulties and to apply the concepts of observation and inference.

A majority of the students (N=15) gave a good definition of the word “context” either on their written assessment probe or during the interview (G.1.5). Two students supplied the definition verbatim from the curriculum guide in their written probes: “Context is the relationship artifacts have to each other and to the situation in which they are found.” Both provided additional information to show that they actually understood the definition and could apply it. Walt understood that if an artifact was in a different place, it might have been used for a different purpose. Shirley thought that “the stuff around” an artifact can provide “clues.” Other students successfully translated the concept into their own words; for example, Amelia wrote, “Context is studying artifacts around and archielogical (*sic*) site to understand things about the site. It is important because if you didn’t use context, you wouldn’t understand anything about the site.”

Five of the students defined context primarily in a negative sense; in other words they defined it in terms of what is lost if the context of an artifact is lost or disturbed (G.1.6). Interestingly, all of these students were in the Orange group. Martha, the cooperating teacher, explained that the students in the Orange group had more questions about the importance of context while the Black group students simply wanted the “right” answer. All five students could explain the concept adequately in these terms. Lane’s statement illustrates an understanding of context through the loss of information: “The context is people take things from sites and it takes information from the site and makes it hard (to interpret) without that information.”

All of these 20 students successfully explained context in terms of “surroundings,” “other objects,” “different places equal different meanings,” “clues,” “relationships,” “information,” or “space.” Two students could use and apply the concept of context, but could not explain it as illustrated in a section of Annie’s interview (G.1.7). While Annie could not explain the concept, her inferences for Drawing A (Somebody likes to make pots.) and Drawing B (Somebody probably bought stuff from a pottery store.) were reasonable and defensible. Similarly, Antwan inferred that “They used it (the pot) to store food” in Drawing A and “They used (the pot) for decoration,” in Drawing B, but could not explain the concept of context in writing or in the interview (G.1.7). He may have been confusing or conflating context with both observation and inference.

Misconceptions about Context. At least two of the students clearly conflated classification and context in their written probe and/or in the interview. Interestingly,

three of the four students who conflated the two concepts during the classification probe did not show any evidence of conflating or confusing them on the context probe. Jake continued to connect context to classification as he did in the classification probe:

“Context is having something in its correct place, its group.” He defined context as “an object in its correct place” and the connection to classification did not seem to confuse his responses on the probe and in the interview. In his interview, Matthew seemed certain that context and classification are the same thing.

Context is very important because if you don’t classify your objects in a certain way then you’ll never get the proof that you really need to answer your questions. You will just get the same proof over and over again, so it’s really important, context is really important because you need to sort them out. So you can get a better picture of how they (artifacts) were used and why they were used.

Despite his apparent misunderstanding of context, he applied the concept successfully to the two drawings with the pottery jar. For A he inferred that the pottery jar was used for holding food; for B he inferred that the same jar was used for decoration.

Three students equated the broken-down condition of the structure in Drawing A with the character of the owners; they were either poor or “careless.” They thought that it was a place where poor or careless people lived rather than a long-abandoned archaeological site. Edison’s interview illustrates the correlation of broken-down condition with poverty.

Edison: (Drawing) A is a pueblo and the people were very poor.

Jeanne: How do you know they are very poor?

Edison: Because their house is cracked and it is made out of a pueblo and it’s made out of rocks and wood.

Four students thought that context was a process that archaeologists use to find out about sites (G.1.9).

The *Investigating Shelter* curriculum includes a lesson on analyzing historic photographs as a way to learn about how people may have lived at archaeological sites and to find clues about the uses or ages of artifacts that might be shown in photographs. This may have confused John. Additionally, the assessment for the lesson on context is a series of three pictures of “Dan’s Room.” Students are instructed to determine which of the three pictures provides the most information about Dan.



Figure 4. Context Assessment from *Project Archaeology: Investigating Shelter*.

This exercise may have introduced a misconception for at least one of the students. On his probe, Roger defined context as “... when you have to look at (a) picture and find were (where) it is.” His interview confirms his emphasis on looking at pictures.

Jeanne: What is context?

Roger: It is when you find artifacts and you have to figure out what happened.

Jeanne: And how do you do that?

Roger: You look at pictures.

Jeanne: What do pictures tell you?

Roger: Hmm, what happened back then.

Antwan could not define context except in terms of the inferences he made about context for the two drawings. When interviewed, he did seem to understand that Dan's Room was an exercise to find more evidence (G.1.10).

Evidence

Walt used the definition from *Investigating Shelter* verbatim, "Evidence is data which are used to answer questions." He went on, however, to more fully explain the concept in his own words, "Evidence is something that can prove another situation." Several students provided solid explanations of evidence, but used the words "proof" or "prove" to define or explain the concept, words which are not used to define "evidence" in scientific context. Luna, for example, provided an excellent explanation of evidence, "Evidence is prof (proof) that something happened. Evidence is like seeing something happen or writing that something happened. If you saw a bug eat a leaf you can show evidence by a picture." Most students gave more general explanations for evidence and many used the words "proof" or "prove." Martha explained that some of reliance on the use of the word "prove" came from her; she used television forensics programs' use of evidence as an analogy to help the students understand the concept. Additional examples are in Appendix G (G.1.11). Most of the students understood that there is a connection between evidence and data and cited examples of data such as fingerprints, artifacts, houses, bones, or pictures that could be used as evidence.

Summary of Research Question 1: Understanding,
Misunderstanding, and Misconceptions

With only a few exceptions, all of the students were conversant (in writing or in the interview) with all five of the concepts. In other words, they clearly recognized the concept when it was presented to them on the written probes and, for the most part, they provided reasonable and cogent responses to my interview questions. Students' understanding and misunderstanding of the five science concepts was, however, idiosyncratic. The conceptual understanding exhibited by each student seemed to be completely individual and these understandings were difficult to compare and categorize. If a student did not completely understand one of the concepts, it did not mean that he or she did not understand other concepts.

To get a picture of misunderstanding of the five concepts, I identified all instances of misunderstanding, misconceptions, and incomplete understanding (referred to as "misconception" for this discussion) of each concept (Table 7). Misconceptions were common; 57 misconceptions were identified in 158 possibilities. Only three students (Alex, Shirley, and George) showed no evidence of misconceptions about the five concepts. Six of the students showed evidence of only one misconception, while eight students showed two misconceptions. While Billy did not exhibit any indication of misconceptions about classification and context on his written probes or interviews, he seemed to conflate these two concepts in the performance task. Six students showed evidence of three misconceptions and four students retained four misconceptions. Two of the students who exhibited four misconceptions (Annie and Lane) both seemed to have a good general understanding of archaeological inquiry. Annie worked with Shirley on

the performance task and the team did a good job of generating investigable questions, inferring, and using evidence to answer their questions and support their inferences. Similarly, Lane did a reasonably competent job of conducting an archaeological inquiry. Both Roger and Mia did, however, seem to be conceptually confused throughout the field research. Antwan showed three misconceptions and he also seemed to be conceptually confused throughout the unit. He struggled with Learning Probe 5: Observation and Inference and Learning Probe 4: Context and he could not explain any of the three concepts in the interview. His classroom work, however, shows some understanding of all three concepts and he supplied appropriate inferences and evidence to support them during the performance task.

Eleven of the students used the words “proof” or “prove” to define evidence and explain how it worked. Several of these students (Matthew, Luna, Walt, Jake, and Reed) provided some of the better explanations of “evidence,” but incorrectly resorted to the words “proof” or “prove.” *Project Archaeology: Investigating Shelter* does not use either of these words in reference to “evidence,” hence the students may have picked up the correlation of “evidence” and “proof” from other sources including their teacher. The three students who did seem conceptually confused, in general, did not show any evidence of misconceptions on Learning Probe 3: Evidence, but neither were they able to provide complete and accurate descriptions of the concept. The *New Oxford American Dictionary* (OUP, 2001) defines proof as “evidence or argument establishing or helping to establish a fact or the truth of a statement” (p. 1365). Although scientists typically do

not define evidence in terms of proof, most of the general public probably does because of the strong connection between evidence and proof as seen in legal contexts.

Table 7. Incidence of Misconceptions, Misunderstandings, and Incomplete Understandings.

Name	O	I	C	X	E	PT	Total
<i>Sue</i>	nd	nd	Y Y				2
<i>Matthew</i>			Y Y Y				3
<i>Billy</i>						Y	1
<i>Mia</i>	Y Y		Y	Y			4
<i>Alex</i>							0
<i>Luna</i>					Y	Y	2
<i>Walt</i>			Y Y				2
<i>Fred</i>			nd		Y		1
<i>Shirley</i>							0
<i>Kate</i>	Y	Y	Y				3
<i>George</i>			nd				0
<i>Amelia</i>			Y				1
<i>Annie</i>	Y Y		Y	Y			4
<i>Lane</i>	Y	Y	Y Y				4
<i>Bella</i>	Y Y				Y		3
<i>Jake</i>			Y Y				2
<i>Mazy</i>			Y			Y	2
<i>Roger</i>	Y	Y	Y Y				4
<i>EJ</i>	Y	Y					2
<i>Roy</i>	Y	Y					2
<i>Reed</i>			Y Y				2
<i>Antwan</i>	Y	Y	Y				3
<i>Dan</i>	Y	Y	Y				3
<i>Edison</i>	Y	Y	Y				3
<i>Brezy</i>					Y		1
<i>Sally</i>					Y		1
<i>John</i>			Y				1
Total	11/26	11/26	11/25 9/27	11/27 4/27			57/158

Table Note. O = Observation, I = Inference, C = Classification, X = Context, E = Evidence, and PT = Performance Task; top number represents incidence of misconceptions, bottom number represents the possible number of misconceptions that could occur.

On Learning Probe 5: Observation and Inference, eleven students chose observation rather than inference for the statement referring to the image of the “nation’s king,” which is visible on one side of the Ancient Coin. In this case, the “kingliness” of the image trumped all other considerations of the difference between observation and inference. Only two students provided incorrect or unsubstantiated answers for any of the other four statements.

A few students confused context and classification; they seemed to think that the two were the same thing. The confusion created some problems for two of the teams when they were engaged in the performance task.

In classification, the use or function of artifacts trumped the use of a research question for many of the students (Learning Probe 2: Classification). Lesson Five: Classification of *Investigating Shelter* stresses the importance of using a question to guide classification and Martha emphasized this premise of the lesson. Nonetheless, some students still did not think that a question was as important as the function or use of artifacts. They wanted to classify the artifacts by use first, then ask a question later. Similarly, some students confused individual artifacts with larger classes or categories of objects. In other words, the hypothetical use of an artifact and how it is classified are one and the same.

At least one student (John) retained a fundamental misunderstanding of the nature of the archaeological record throughout the length of the unit and this research. He seemed to think that archaeological sites were places where poor and slovenly people had lived and left a mess behind. This fundamental misunderstanding made it difficult for

him to draw reasonable conclusions from the data that he observed in the performance task.

In the process of data analysis, it was sometimes difficult to separate the categories of understanding, misunderstanding, and cognition because they are similar. It was even more difficult to separate understanding and cognition when students misunderstood the concept or had some other misconception.

Research Question 2: Cognition

How do students construct (logical progression of thought) their understandings or misunderstandings of these concepts?

Observation and Inference

When I asked the students how they arrived at their choice of observation (G.2.1), most responded, “I just looked,” or “you can see it,” or “it’s a fact.” Luna said, “I put observation because you can see there is a face on it. I didn’t put inference because you can’t guess when there is a face there.”

Students explained their reasoning for choosing inference (G.2.2) as “can’t be proven” or “you don’t know.” Several students recognized that further observation would be required to know if the statement is true. For example, Amelia said, “Because you can’t tell that they are religious until you like meet one of them or something.”

Two of the students (Matthew and Annie) thought that Statement F (“The image on the coin is a representation of the nation’s king.”) was an observation, but decided that

it was an inference during the interview. Matthew changed his mind by talking it through himself.

Matthew: Yeah, the face of the coin is a picture of the nation's king because you can't really... because everybody has a different point of Gods or God. You are making an observation because on the coin there is a picture of the king or probably someone else. It has a good chance of being the king because he has a crown and that's making an inference, but I put observation because there is a picture of a face. But, the inference is you don't know who it is so you are basing the facts you have on the coin.

Jeanne: Would you change your answer from what you said?

Matthew: Probably.

Annie came to a similar conclusion during her interview (G.2.3) and also decided to change her answer based on my questions and her reasoning. In both cases, my questions may have been too leading and I may have led the students to changing their answers from observation to inference. A more open question such as, "Observation or inference? Which is it?" might have been better.

Classification

Luna's interview transcript on classification (G.2.4) illustrates her cognitive processes and provides a good example of reasoning. She chose River as being the most correct and said that Crystal's approach was a good way to classify, but "... there are many different ways also." Several students made cogent statements about the importance of questions in the classification process and the reasoning for their choice of either River or Erika as being the most correct (G.2.5). Antwan and Jake provide particularly good examples:

Antwan: Because if you don't have a question you don't know what you are doing. You just sort them out.

Jake: If you don't care (how you classify artifacts), there is no point. All you do is put them in little groups.

Some of the students who chose Crystal as being the most correct did so because they thought that using questions to guide classification was problematic. Edison chose Erika as being the most correct, but did not think that using questions was appropriate (G.2.6). Edison concluded that it was better to group artifacts by how they were used rather than asking a question. Roy concluded, "You can group artifacts based on a question, but you don't always have to, so Crystal is more correct." Reed thought that if you have a question you should already know the answer or if you have a question, you should just ask a friend for the answer. Walt thought that both River and Crystal were correct, but decided that River was more correct during the interview.

Jeanne: Okay, so if you had to choose between River and Crystal, which one would you choose?

Walt: That's hard. I would think Crystal would be better than River because, well River is kind of correct because it says on a question or something you want to know. So, I think River, I think actually.

Jeanne: So you changed your mind?

Walt: Yeah.

Jeanne: Why River?

Walt: Because you should classify artifacts by a question or something you want to know because then you can get more information and learn more about that artifact.

Jeanne: Could you give me an example of that?

Walt: Say somebody asks you a question about all these artifacts on the ground. Say they are like, 'classify these artifacts by their shape.' You can say there is (*sic*) circles and squares by their depth, you could classify by their shape and size. You can classify all these other circles and put them in this circle group, squares in this group, and how big they are in this group.

Context

Most of the students (N=18) used prior knowledge of the Anasazi (more properly known as the Ancestral Puebloans) and the Aztecs, which they had studied earlier in the year, to interpret Drawing A of Learning Probe 4: Context. For most of them, this prior information probably made a big difference in their ability to make inferences about the pottery jar and the structure in which it was found. They knew that it was an archaeological site rather than a "poor person's house." Many students made a reference to "adobe" construction and recognized similarities to Puebloan architecture. Four additional students recognized that the structure in Drawing A was an "archaeological site" or it was "old." This learning probe probably would not have been as successful as it was, if the students had not had this prior knowledge. Virtually all of the students recognized that Drawing B depicted a fireplace in a modern house and based their inferences on that assumption.

All except two of the students (Mazy and EJ) arrived at different inferences for the two drawings. I did not interview Mazy, so I was not able to explore her reasons for arriving at the same inference for both drawings. EJ indicated that his inferences were the same in the third question on the probe, but his inferences under the first two questions are different. When asked, he said that he said "same" because he thought that the pots were the same in the two pictures.

Almost all of the students derived their inferences through analogical reasoning (G.2.7). Analogies have long been recognized as an effective science teaching tool because they can “simplify difficult concepts and render abstract notions concrete by comparing less familiar systems, concepts, or even objects to more familiar ones” (Dagher 2005, p. 195). Hogan and Fisherkeller (2005, p.99) define analogical reasoning as discerning “ similarities between two or more things (and by default to recognize their differences), often to understand or illuminate significant features of a novel situation, idea, or problem by comparison with a more familiar case.” Several students provided good examples of analogical reasoning; Bella’s is particularly cogent: “I got the conclusions because (Drawing) A is more and kind of a hot, dry place with an adult in it. It’s an adobe house. (Drawing) B is in a house like today and it has a fireplace.” I know that because back then they didn’t have fireplaces, they just kind of had a pit where they put a fire. It’s (*sic*) kind of has a clock on top of it and they didn’t have clocks back then.” Reed’s interview provides a good example of analogical reasoning.

Jeanne: Tell me how you arrived at different conclusions, different inferences for A and B.

Reed: (Drawing) A is an Indian’s house probably. (Drawing) B is probably either a family because it has a stove (referring to fireplace).

Jeanne: Because it has a stove?

Reed: Yeah, and Indians don’t really have stoves like that.

Jeanne: You thought A was an Indian’s house probably. How do you know that?

Reed: Because this looks like an adobe and that’s it.

Jeanne: And the family house because it has a stove and Indians don’t?

Reed: To keep them warm. And the Indians have this little fireplace (referring to the fire ring in the center of the drawing).

Most of the students used their analogies to the Ancestral Puebloans and the Aztecs, and to modern life as inferences. In this sense the students used “analogies themselves to do the inferential work and generate the problem solution” (Nercessian 1992, p. 20) and their analogies went beyond being guides to their thinking. Historically, the study of archaeology relies heavily on analogy to build interpretations for evidence. While analogies can produce “multiple meanings that depend on the learner’s prior knowledge and experience” (Mintzes, Wandersee, & Novak 2005, p. 330), the use of analogy in this exercise helped most of the students reach reasonable conclusions about what might have happened in the past based on the evidence they had at hand.

Only one student (Matthew) concentrated more on the process of observing the pictures and drawing conclusions. He described his process as follows: “Well, I just took the steps by looking at the pictures and thinking what this would be used for and what that would be used for. ... I made conclusions by looking at the evidence about why they used it (the pot), what it was used for, and how it was used.” He did use analogy to modern times for his inference for Drawing B: “I came to that conclusion because a pot is just sitting up there and you wouldn’t put food out on a shelf for when people came over.”

Three students assumed that because the structure in Drawing A was “broken down” and “cracked,” poor or careless people lived there. Both Roger and Roy did understand that Drawing A was older than Drawing B, but they did not understand that it was an archaeological site. John and Edison knew that Drawing A was an archaeological

site, but both also assumed that the people who lived there were poor or careless. While all four demonstrated some understanding of context, their preconceptions prevented them from making reasonable applications to archaeological context.

Evidence

In Learning Probe 3: Evidence, students who employed another conceptual tool (observation, inference, classification, or context) seemed to have a better understanding of evidence. Without the use of another conceptual tool, students seemed to equate evidence with sources of data. In other words, “doing” something with data makes it into evidence. Five students used observation in some part of their explanation of evidence as summarized below:

- Luna – observe a bug eating a leaf or a fish jumping and document with a picture to prove that bugs eat leaves and fish jump.
- Walt – observe a body and blood on the ground to prove that a murder was committed.
- Reed – observe an act as a witness and report the act.
- Brezy – observe fingerprints on the handle of a hammer to prove that someone had used it.
- Matthew – observe and document an archaeological site.

Dan used classification to help explain evidence, “Well grouping evidence is like grouping artifacts together (*sic*) and telling if there was a mother or a father or sons or daughters.” The phrases “grouping evidence” and “grouping artifacts” may indicate some confusion, but grouping artifacts certainly provided several of the performance task teams with a way to make inferences about the residents of the earthlodge. Jake inferred

that finding a teepee (tipi) ring would be evidence that someone had lived at a particular place. Four students used context to help explain evidence as summarized below:

- Walt – inferred that the location of sewing needles outside the slave cabin indicated that people did their sewing outside.
- Shirley – concluded that the presence of a bone at a certain location in the forest would be evidence if you took someone there and showed it to him/her.
- George – inferred that the presence of artifacts (nails, pins, and peach pits) indicate that someone lived there.
- Amelia – noted that artifacts located near the slave cabin were evidence.

I did not interview the students about their responses to Learning Probe 3: Evidence, so I do not have any direct data on how the students arrived at their understanding of the concept of evidence.

Summary of Research Question 2: Cognition

Students constructed much of their knowledge by reasoning through analogy to existing knowledge, especially to their knowledge of present-day life. This reasoning process was particularly apparent while students were completing the performance task. The students made numerous references to “we” or “us” when making inferences about what archaeological data might mean. They were comparing less familiar objects and their contexts with more familiar ones to make sense of them (Dagher, 2005). Reasoning through analogy to present-day life is a perfectly reasonable approach especially in the absence of historical data, ethnographic data, or the results of previous archaeological research on similar sites and artifacts. Archaeologists make a basic assumption that people who lived in the past had needs similar to ours including food, shelter, families or

social organization, and a need to explain the world around them in religious or cosmological terms. Several students were also able to reason that the absence of certain types of objects or artifacts such as weapons may be indicative of some past behavior or belief.

Students used different cognitive operations to arrive at their understandings of the concepts. For example, when describing how they arrived at an observation on Learning Probe 5: Observation and Inference, students often said, “I just looked at it.” For an inference, they cited the fact that the statement could not be “proven” with the information at hand. On Learning Probe 2: Classification, most students relied primarily on what they remembered from the lesson on classification; research questions should guide the classification of artifacts. On Learning Probe 4: Context, students’ prior knowledge of the Ancestral Puebloans and of modern American homes figured heavily in their reasoning about the context of the pottery jar in the two drawings.

Because I could not interview the students about their responses on Learning Probe 3: Evidence, I cannot draw any conclusions about how they arrived at their understanding of the concept. From the written responses, I suspect that they drew their explanations from their instruction in archaeological inquiry, from prior school experiences, and possibly from general knowledge of the connection between evidence and proof.

Most of the students understood that there is a connection between evidence and data and cited specific examples. Most of their examples were plausible sources of data, that could become evidence, however, an operation such as classification, observation,

inference, or the use of context of a site or an artifact seems to be required for data to become evidence. When students applied any one of these four concepts they were better able to explain the nature of evidence. Without one of the operations, their explanations of evidence were limited to a list of possible sources of data.

Research Question 3: Application to Archaeological Inquiry

How do students apply these concepts to archaeological inquiry?

Application of the Inquiry Concepts (Performance Task)

The Performance Task was intended to assess students' ability to apply the five concepts to archaeological inquiry. Table 8 summarizes the data from the Performance Task.

Table 8. Summary of Results from the Performance Task.

Team	Names	Q	O	I	C	X	E	M	N
1	<i>Matthew Alex</i>	2/2 4		17	0	14/11	4/1	0	0
2	<i>Luna Billy</i>	3/1 2		6	0	1/1	3/3	1	0
3	<i>Annie Shirley</i>	2/2 1		28	1	11/11	12/12	0	1
4	<i>Fred</i>	1/1 1		4	0	2/1	4/4	0	2
5	<i>George Amelia</i>	2/1 0		2	0	0	3/2	0	3
6	<i>Walt Kate</i>	3/3 0		26	3	9/8	10/9	0	3
7	<i>Mia Sue</i>	2/1 7		29	1	12/2	4/4	0	2

Table 8. Summary of Results from the Performance Task (continued).

Team	Names	Q O	I	C	X	E	M	N
8	<i>Antwan Lane</i>	1/1 0	8	1	0	12/12	0	0
9	<i>Bella Brezy</i>	1/0 10	41	1	13/11	9/9	0	1
10	<i>John Sally</i>	1/0 5	28	0	8/4	7/1	1	0
11	<i>Mazy Roger</i>	1/0 0	9	1	1/0	5/5	1	0
12	<i>Edison Roy</i>	3/2 0	26	0	0 12/5		0	5
13	<i>Jake Reed</i>	2/2 6	17	9	0	6/5	0	2
14	<i>EJ Dan</i>	2/0 12	10	2	4/1	6/4	0	2

Table Note: Q = Question - top = # of questions, bottom = # investigable questions; O = Observation; I = Inference; C = Classification; X = Context - top = # of examples of context, bottom = # of examples of context used as evidence; E = Evidence - top = # of examples of evidence, bottom = # of examples of evidence used to support an inference; M = Misconceptions; N = Awareness of Inquiry Process

Questions. I used the questions that the students wrote on their Performance Task sheets. I differentiated between questions that could be successfully investigated with the data provided and those that could not be investigated with the data at hand. Six teams formulated one, two, or three questions that could be investigated with the data provided. Examples of questions that could be investigated are:

“What was it (the site) used for?”

“What did they eat?”

“How many people lived here?”

“What did they do outside?”

“Where did they eat?”

“How old (in relative terms) were the people who lived here?”

Four teams formulated some questions that could be investigated and some that could not be investigated. The remaining four teams did not formulate a single question that could be investigated with the earthlodge artifacts and map. Examples of questions that could not be investigated are:

“Why are there gaming pieces?”

“Why is the house round instead of square?”

“Why did they have so many post holes?”

“Why did they leave?”

“What did they dye?”

“Where is the river?”

“How long the house lasted before they had to make a new one?”

While all of these questions are interesting and an archaeologist might pursue them if he or she was actually studying the real site, none of these questions was answerable with the data that was provided. It may be that the exercise was not designed adequately and the instructions were not explicit enough to guide all the teams to propose only questions that could be addressed with the data available.

Most of the teams asked additional questions while they were conducting their investigation, especially when they arrived at number 4 on the sheet. Rather than interpreting this as additional “data” sources that they would like to have to continue their investigation, most teams simply asked more questions. Some of these questions were good and could have been investigated with the data at hand. Many of these questions were asking for specific information such as “What kind of people were they?” “What

were the metal pieces (marked as “unknown” use) for?” “What kind of symbolism the bison skull and figurine had?” “What games did they play?”

Question 4 (What other information would you like to have?) on the Performance Task sheet was intended to elicit additional data sources that they thought would be helpful for their investigation. Some of the teams did express interest in seeing photographs of the site, before and after pictures of the excavation, and more information about where the site is located in Kansas, but most of them simply wanted to have their questions answered rather than thinking of other information that might help them answer the questions themselves. These students probably do not yet consider themselves to be producers of knowledge (Davis, 2005).

Observation. As I observed each of the Performance Task teams, all of the students seemed to be actively engaged in making observations. Relatively few observations were recorded, however, simply because most of the teams observed the data silently and only occasionally vocalized a statement. Observations were recorded for only nine teams. Team 14 vocalized the most observations (12) and teams 3 and 4 each vocalized one observation. Amelia and George (Team 5) did not speak to each other during their entire performance task; they spoke only when I interviewed them about their processes and findings. They each did their own work throughout and took turns writing on the Performance Task sheet, but said that they agreed with one another’s questions and inferences.

Examples of observations include: “There’s a lot of knives.” “See these post holes.” “There is a lot of posts.” “Falling posts.” “There’s only one figurine.” “They had arrow points.” “There is a lot of artifacts.” “This looks like a tool.”

Inference. All of the teams made inferences that were recorded either on paper or audio files. Team 5 made only two inferences (one per student) while Team 9 made 41 inferences. Five teams made between 26 and 29 inferences. For some teams, the number of recorded inferences was high because they repeated the same inferences. This was especially true when I interviewed them about their processes and asked them what concepts they had used; they usually read the inferences they had written and sometimes added additional information. I decided to record all vocalizations of inferences even though they were very similar to those made earlier in their process because it was often very difficult to determine if the inference had a slightly different meaning in a different context and with different evidence. The numbers also give some information about how willing they were to vocalize their conclusions. For example, the transcript for Team 9 is clearly dominated by inferences while Team 5 spent most of their time observing silently; the comparison shows a marked contrast in approaches to the task.

All of the teams formulated some reasonable and defensible inferences that gave them the ability to further examine the data at hand. “They grew a lot of corn because there’s a lot of corncobs,” “Yeah, they probably hunted stuff,” “They killed animals with arrows and knives,” “They used whetstones to sharpen their tools,” “Symbolic, yeah it would probably be for a game,” “There’s one, two, three people,” “This must be the

door,” and “There must have been a lot more men in this hut (the earthlodge) than women.”

During Team 10’s work, John said, “It’s in Kansas, well you know, Kansas does get a lot of tornados.” Sally asked, “You’re saying that they, a tornado came and took all the artifacts?” John used the “tornado theory” to explain why all of the artifacts were strewn about and why the people left. Sally tried to steer him away from the tornado idea, but did not have much luck. John also thought the people who lived here must be very “sloppy people” and they left because “their house was falling apart and they had to leave.” In addition, he was quite sure that they had “no money or materials” to rebuild, so they had to leave. John’s statements indicate that he persisted in his assessment that people who lived at archaeological sites were “poor” and “sloppy.”

Classification. Eight teams used classification to answer their questions, but only one team (Team 13) grouped all of the artifacts by manipulating them physically. Teams 6 and 9 began sorting artifacts but did not finish the task. Teams 3, 7, 8, and 14 classified the artifacts “mentally,” but did not move them physically. For example, Team 3 classified objects to answer the question, “What did they do outside?” They determined that the men worked outside because arrow points and axes (men’s artifacts) were found outside. Similarly, they decided that they stored food inside because all of the food remains (corn cobs and a bison skull) were found inside the structure. Team 8 decided that gun parts, arrows, and knives were “men’s artifacts” and built their conclusions based on this classification. Team 11 confused classification with placing the artifacts on

the map, indicating that both students still conflated context and classification as they were completing the performance task.

Team 13 used classification to conduct an elegant and efficient investigation of the earthlodge. They placed all of the artifacts on the map in their correct locations then decided on their question for investigation: How many people lived here? Then they decided to remove all the artifacts and classify them by their uses. They concluded that the artifacts had five different uses that could be attached to the gender and/or age of the occupants, for example, the “dad” would have tools, the “mom” would have food and pottery, and the “kid” would have the figurine (like a doll) and gaming pieces. At the end of their investigation, the two students concluded that at least three people had lived at the site: a mother, a father, and at least one child.

Context. All of the teams began their investigation by placing all or most of the artifacts on the map in their correct locations. Ten teams used context to conduct their investigation. Team 1 noted the location of artifacts frequently, for example, “Most of them (artifacts) are up here so far,” “Okay, so most of this stuff is located on the edge of it (the earthlodge),” “Most of the weapons are located on the right on the outside,” and “More of the pottery and food is located on the inside.” Team 1 also used context extensively to support their inferences (64 percent), for example, “So, they would have their weapons area on the outside where they made them and then they would eat on the inside.” Similarly, Team 3 used context to support a significant percentage (39 percent) of their inferences; for example, “They probably shot things outside since there was an arrowhead, right here outside the house.”

Team 4 (Fred) said, “I think people ate the most in the northwest quadrant because there was lots of corn and a buffalo skull.” When I asked him if he had used context in his investigation, he answered, “slightly” not seeming to understand that context was involved in one of his four inferences. When asked about context, Team 11 said that “we put like the little pieces of paper on where the artifacts were found at.” They seem to understand context as simply placing the artifacts on the map, which is part of the concept, but not all of it.

Evidence. All of the teams used data from the materials they were given as evidence to support their inferences. Examples include, “Maybe they ate animals a lot because they have scrapers for scraping hides,” “They had crops since they had corn,” “They liked to eat corn because there was lots of corn,” “Men (lived here) because there is gun parts, arrows, and knives,” “They might have killed a bison because there’s a bison skull,” and “Figurines, so there would probably be a kid there.” Although the figurine at the site probably has symbolic or religious meaning, but using it as evidence for the presence of children is not unreasonable because it looks like it could be a doll or toy. Several of the students came to a similar conclusion.

Half of the teams used data from the site and prior knowledge as evidence to support their inferences. Several students knew that a whetstone was used for sharpening tools and supplied the information to help the team classify artifacts and infer uses. Amelia (Team 5) reasoned correctly that “They traded with white men because they (white men) have metal and Indians don’t make metal.” Team 1 relied on their knowledge of the environment of Kansas to conclude that the house was built with lots of

small trees because “there probably wouldn’t be that many big trees there.” In reality, the site is located next to a river that grows lots of large cottonwood trees, some of which were used to support the central part of the earthlodge. Several teams connected the gaming pieces with children, but some noted that “adults play games, too.” John’s prior knowledge about tornados in Kansas contributed to some shaky inferences about the abandonment of the earthlodge and the “sloppy” nature of the house. For some of the teams, prior knowledge and reasoning by analogy to modern times clearly led to some unsupported inferences.

Misconceptions. Team 8 seemed to have been confused about classification and context. As noted above, Mazy in Team 11 thought that context was equivalent to placing the artifacts on the map. A brief exchange between Mazy and me illustrates her thinking.

Jeanne: What skills were you using?

Mazy: We umm... We grouped them into what we wanted to know or knew.

Jeanne: Okay and how did you group them?

Mazy: Um, like what the paper said to do. Gun parts, B3, we did that, we put like the little pieces of paper on where the artifacts were found at.

Team 2 understood context primarily in terms of what was missing. While they were not incorrect, their response shows that they may not have a complete understanding of context, i.e., it is the relationship of artifacts to each other and to the location in the site. When I asked Luna, “Was context important (in your investigation)?” she answered,

“Yeah, because if like some of the knives were taken out, or three of something it would have changed some inferences because there would be less of that artifact.”

As discussed above, John’s misconception that people who lived at archaeological sites were “poor” and “sloppy” continued through the performance task. His misconception may run even deeper; it may be possible that he did not understand what an archaeological site is. The misconception certainly influenced his inferences about the people who lived at the site and why they might have abandoned it.

Application of the Inquiry Concepts (Learning Probes)

Students had an opportunity to apply the concepts while completing three of the learning probes: Observation and Inference, Context, and Evidence.

Observation and Inference. During the interviews on Learning Probe 5: Observation and Inference, I asked all of the students how they would find out if Statement E (“We can tell from the artifact that these were peace-loving people.”) were the case, if they had access to the site where the ancient coin was found and all the other artifacts at the site. Most students came up with a reasonable explanation of how they might confirm their inference with archaeological data. Many of the students thought that the absence of weapons might indicate that the makers of the coin were a peace-loving people. Luna’s statement, “If you didn’t find any weapons or protection” is a good example of the majority of the responses. Archaeologically speaking, it is certainly possible that this line of reasoning would not actually hold up in the face of more evidence, but I did not think it would be productive to pursue this possibility. Conversely,

other students thought that the presence of religious artifacts or monuments or pictures of peace signs would confirm the inference.

Context. Most of the students (N=20) successfully applied the concept of context to the study of archaeology on Learning Probe 4: Context. As discussed above, 19 of these students used their prior knowledge of the Ancestral Puebloans and Aztecs to interpret Drawing A and the context of the pottery jar. Matthew did not refer to the Ancestral Puebloans or the Aztecs, but made a reasonable application of the concept to archaeology: “The context is important because if you find a necklass (necklace) in a house you don’t know where it came from, but if it was found in an old house you could determine if people liked jewelry why they had it.” As written, his inquiry might not be possible or fruitful, but his scenario would be a reasonable investigation.

When asked on the assessment for the lesson on context (shown in Appendix C, p. 235), “if artifacts are removed from an archaeological site, could you learn as much? Explain your answer” all 27 students answered “No” and 22 provided comprehensible explanations such as “you would not have all the information,” “there’s less information,” “you won’t have all of the data without the missing pieces,” “you need all the artifacts,” “you are taking away clues,” or “one artifact can make a difference to an inference.” As discussed above, five students defined context primarily in terms of the loss of information or data at an archaeological site. An additional five students mentioned that taking an artifact from an archaeological site or even moving it from one place to another within the site would constitute a loss of context and, therefore, a loss of information. Billy’s statement illustrates this idea: “Because if you take context away,

your inference can change and if somebody else knew and took something away they would have a different inference from you probably.” Other examples can be found in Appendix G.3.1.

A few students applied context to archaeology without specific reference to Ancestral Puebloans or Aztecs (G.3.2). The best examples are as follows:

Amelia: Like if a bone is found near your house, it is probably because they ate something or killed something there.

Lane: That means they took information from an archaeology site and it’s going to be harder to find information about the tribe.

Evidence. Generally speaking most students did their best work on Learning Probe 3: Evidence when describing how evidence is used in archaeology. Three students provided particularly cogent explanations.

Amelia: It is used in archaeology when an archaeologist is trying to answer a questions (*sic*) they will use evidence. Like when we studied the artifacts near the slave cabin we used evidence.

Walt: Evidence is used in archaeology because you can infer that the slaves did sewing outside because the evidence is there are sewing needles outside.

Dan: Well grouping evidence is like grouping artifacts together (*sic*) and telling if there was a mother or a father or sons or daughters.

Amelia and Walt both included the concept of context in their example and Dan used classification. Eight additional students provided substantial explanations of evidence using archaeological examples (G.3.3).

Summary of Research Question 3: Application

All of the students, in at least one instance, did a reasonable job of applying one or more of the five concepts to archaeological remains such as hypothetical sites and artifacts or to archaeological data presented to them in the Performance Task. While their examples were not always well-informed, most made the essential connection between material remains and inferences about the past. Except for Learning Probes 3 (Evidence) and 5 (Observation and Inference), students were not specifically asked to apply their conceptual knowledge to the study of archaeology, hence there was little opportunity for application. On Learning Probe 3, most students were able to provide an acceptable example of how evidence was used in archaeology. Some examples were particularly well-constructed and showed considerable understanding of the use of evidence in archaeology. On Learning Probe 5, most students could provide a reasonable example of applying observation in archaeology when asked how they would examine the veracity of an inference. On Learning Probe 4: Context the majority of students used their knowledge of Ancestral Puebloans to explain their understanding of context. The students who did not refer to the Ancestral Puebloans successfully referred to other hypothetical archaeological sites or artifacts.

Research Question 4: Transfer of Concepts

How do students transfer and apply these concepts to other school subjects or to everyday life?

Observation and Inference

Students did not transfer their knowledge of observation and inference to any other subjects or to everyday life in this data set; however, there was really no opportunity for them to do so.

Classification

Seven students gave examples from everyday life to illustrate their understanding of classification. Examples of categories include basketballs, blankets, dolls, bolts, nails, cotton, cars, balls, shovels, and “stuff on shovels.” Billy and Dan both recognized that objects could be classified by the age or gender of the people who owned the objects. Jake used geometric shapes (circles and squares) and colors (red and blue) to illustrate the need for a question in classifying objects, otherwise there “is no point in doing it.” Brezy grouped tools and building supplies together (hammer and nail; paintbrush and paint).

Context

Only two students transferred the concept of context to another subject or to everyday life. Edison recognized the connection between archaeological context and the use of context in reading: “Like books, you can skip the words and maybe figure it out, what the word was without reading it.” Brezy used an everyday example to illustrate how context works. “Like, if you take a fork out of the kitchen then it’s different or out of context.”

During my final meeting with both groups (Black and Orange) I asked the students if they could think of another science in which the concept of context is important. A student in each group immediately answered, “Ecology.” I asked them if context would be important in paleontology and all of the students agreed that it would be important.

Evidence

Some of the students provided reasonable examples of the use of evidence in biology, earth science, or forensics. I included forensics in the Learning Probe 3: Evidence because I thought they may be able to use prior knowledge from criminal forensics programs on television to think about evidence. Amelia provides a good written example of the use of evidence in other subjects: “In earth science you use evidence of volcanoes. Like when it will erupt (*sic*). You will use evidence of when it has erupted (*sic*) before.” Other examples include:

- Luna: You can take a picture of a fish jumping and use it to prove that that species of fish can jump. (biology)
- Walt: Forensics – An example is when an officer is investigating a crime scene, he can say somebody was killed because the evidence is blood and (a) dead body on the ground.
- Dan: Biology – The color of plants. The species of frog. The fur on bears. Earth Science – When Volcano erupt (erupt). When earthquakes happen. Forensics – If bugs are eating it. If it(s) dead or not.
- Shirley: Other evidence could be rocks, animals, and crime materials. They (they’re) evidence because you can find stuff around those things.

Luna, Walt, and Dan all used observation to help explain what evidence is, Amelia used observation of historical evidence, and Shirley used context to help with her explanation.

Many of the students equated evidence and data and simply listed sources of data in their examples. For example, Kate wrote: “In biology tracks, do(?), and smells would be veterina (*sic*). In earth science dirt, air, plants, and germs would be veterina (*sic*). And in forensics blood, hair, saliva, dirt, particles and body parts would be evidence.”

Summary of Research Question 4:
Transfer of Concepts

None of the learning probes except Probe 3: Evidence explicitly asked students to transfer their learning to another subject or context. Some evidence of transfer was detected in some of the other probes. For example, two students transferred the concept of context to another subject (reading) and to everyday life (objects outside of their usual context have a different meaning). Seven students used everyday examples to explain their understanding of classification.

Learning Probe 3: Evidence asks students how evidence is used in other subjects besides archaeology. Some students provided good examples of evidence in other subjects, but several students provided only brief lists of the type of data that scientists in other fields might use (plants and animals for biology) or a description of the subject (“Biology is living history—history from today”).

Research Question 5: The Nature of Science

What do students think science is? How do students understand the relationships between science, history, and archaeology?

Learning Probe Prompts

Learning Probe 6: Nature of Science contained five prompts for consideration.

What Is Science? Fifteen students thought of science as “doing” or as a process; “experimenting” was the most frequently mentioned word. Other processes mentioned included observing, inferring, discovering, classifying, and testing. Examples of their responses illustrate the range of ideas:

- Billy: I think science is experimenting and mixing chemicals and studying plants and animals. They (scientists) use microscopes to study plant cells and they can dissect animals to look at them.
- Luna: I think science is studying, learning, discovering, and observing. Scientists look at thing(s) and study things and they also experiment with things.
- Roy: Science is when you experiment with things and try to discover things, like how the stars work and how the orbit went. That is what scientists do. They try to discover how things work.
- Reed: I think science is doing and making experiments and or making observations and inferences.
- Sally: Science is testing things, like testing rubber band planes and how many lines to send them across the room.

Six students thought of science primarily as learning or study (G.5.1). For example, Sue stated, “I think science is the study of chemicals ... the animals and basically the ecosystem.”

Mia thought of science as “a place where you learn about different things” which is similar to the students who focused on learning or study, but the addition of “place” was unique. Walt thought that science is inventing new things. EJ thought of both science and history as subjects that you learn in school. John tried to explain science in

terms of its relationships with history and archaeology and could not provide an explanation or a definition of science by itself.

How Is Science Different from History? Nearly all of the students (N=20) said that history had something to do with the past and/or with people (G.5.2). Cogent examples include:

Sally: In science you do experiments and in science you don't study the past. In history you study the past.

Antwan: History is learning about people from a long time ago. Science is learning about people today.

Antwan thought that both science and history study people only, but some thought that science never studies the past and never studies people. During the interviews and in other parts of the probe, most of these students recognized that science sometimes studies the past (e.g., earth science, archaeology) and sometimes studies people (e.g., medicine). Luna recognized that scientists "sometimes study the past, but I think they mostly study around today."

Ten students thought that history and science use different processes or different data (G.5.3). Cogent examples include:

Matthew: Science does experiments while history does a different process of observing and concluding.

Shirley: Because, sometimes science experiments with stuff and history doesn't. History just studies stuff from the past to find inferences and conclusions.

Some of these ten students recognized that history and science use different processes, but struggled with explaining what that meant. Answers to this question

demonstrate that some students misunderstood what science is. Three examples illustrate some difficulties encountered in explaining the differing processes:

- Dan: History and science, well, in science you are using a lot of math and using all these test tubes and equations and you have all of these shots that you use in dissecting stuff with knives. History has a lot of reading in it and English and you have all this reading. History mostly has to do with digging up something from the past or learning about some(thing?) from the past.
- Edison: History you study the past and you don't really do math. That's all. (Science) You do math and you sometimes study the past and sometimes the future."
- Fred: I don't really think much of how they are different because the only thing different about them is history usually just has facts and science just uses guesses, but not very accurate.

Similarly, five students thought that science and history use different data. For example, Billy noted, "You mostly study plants and animals and land forms in science and you study things from the past and people in history." Roy said, "In history, you don't try to find how plants grow."

How Are History and Science Similar? Twenty students said that history and science use some of the same processes, methods, or concepts. They especially noticed that science and history use many of the same words such as observation, inference, and classifying as these three examples show:

- Billy: They both study things. You group things and you use some of the same words.
- Mia: Um, well you can learn something from both of them and you can use observations and inferences.
- Kate: In both you can study about animals and you can use both to find answers. They both use inferring and maps and grouping. Some history words are also science words. They both use charts and you also experiment in both.

They also noticed that procedures might be similar, i.e., both scientists and historians study their data in a systematic way, they observe, they make inferences, and they sometimes classify or group like items (artifacts, animals, plants, or rocks). Both use questions to guide their study. They had some difficulty in describing the similarity in processes as Matthew's statement shows:

They are similar because you look back at peoples' past in both of them because science you test land and what kind of food they had back then. Same as archaeology, I mean history. You also group them in categories because science it is not all about just taking pictures. You have to group them (data?) into categories to find out what happened and how it happened.

Three students noticed that history and science sometimes use the same data, particularly in regards to the study of archaeology. Examples include plants in archaeological sites, animals that may have lived in the vicinity of a site, or animal bones that have become artifacts. Another three students noticed that archaeologists use both science and history (see below).

Archaeology and Science. Jake summed up the relationship between archaeology and science succinctly, "Well, the science and history thing is archaeology, it's kind of both. Because it's doing history but it's a science at the same time." Fifteen students recognized that archaeology and science had a lot in common or that they shared many common processes, methods, and concepts and they might sometimes use the same data (G.5.4 and G.5.5). Fred could not think of how science and history were similar, so he said, "archaeologists use both of them." Two other students said:

Luna: I learned that you can use science to study history.

Matthew: I always thought archaeology and science were a lot different. It turns out it has a lot in common.

Annie thought that archaeology would be really hard, while Roger thought that archaeology might not be too difficult for a science. Four students (G.5.6) thought that archaeology made science “fun” or it broadened their view of what science is as Shirley’s statement illustrates: “Yeah, because since history make(s) me think that studying all the stuff from the past and making those inferences and conclusions and looking at the artifacts made me think maybe science was like that and it would be fun.”

Walt, Brezy, George, and Antwan did not think that science and archaeology had much in common. Walt thought that science and archaeology were more different than the same, but could not explain his answer. Brezy said, “We did not do much science in this study.” Antwan could not explain why archaeology was not a science. George said that archaeology is not a science but contradicted himself during the interview. He explained that everything he had done in archaeology, he had already done in science, but continued to maintain that archaeology is not a science.

Jeanne: Can you give me an example (of some things) that were the same between science and archaeology?

George: Well, we’ve studied sand and dirt and clay in the dirt. We studied that in the archaeology and has the calcium in the dirt.

Jeanne: So, you studied that in science and then studied at in archaeology as well?

George: Yeah.

Being a Scientist. Seventeen of the students thought that they could be scientists. Most thought that being a scientist was mostly a matter of getting the proper education

and anyone could be anything they want to be when they grew up. Of these students, ten wanted to be scientists. Shirley and Bella both expressed interest in becoming archaeologists and Jake would like to be an archaeologist if he “could still be in plays”; Jake’s main interest is acting. Amelia was interested in chemistry, Mazy wanted to be a veterinarian, Sally wanted to be an animal scientist, and Sue wanted to be a zoologist like her father. Mia, Antwan, and Kate all thought that science would be fun, but did not know what type of science they would like to do.

Some of the students did not think they were smart enough to be scientists and were not good enough at performing some of the operations that scientists need to do. Matthew said, “Ah no. I would not be a scientist because I am not very good at classifying objects by how or what they were used for.” Matthew prefers sports anyway. Annie wants to be a veterinarian but does not want to be a scientist and did not think that she could be a scientist. Roger wants to be a scientist, but thought that science would be too hard; he thought that archaeology might not be too hard. Roy wanted to be an “astronaut scientist” but did not think he was good enough at science to become a scientist. EJ, Edison, and John did not think they were smart enough or responsible enough to be scientists and did not want to be scientists either. Dan did not know if he wanted to be a scientist or not.

Brezy thought that she could be a scientist, but did not want to be a scientist because she is more interested in other things. Luna also thought that she could be a scientist but did not want to be one because she “prefers to be in nature.” I suggested that she might become a naturalist.

Summary of Research Question 5:
The Nature of Science

Only three students (Matthew, Kate, and Amelia) demonstrated a well-informed understanding of the nature of science and the relationship between science, history, and archaeology. Matthew and Kate showed a particularly good understanding of the relationship between archaeology and science. Jake provided the most succinct portrayal of the relationship between science and archaeology. Most of the other students (N=13) demonstrated a naïve understanding of science and typically equated data with evidence. The remaining 10 students had varying ideas about what science and history are and their relationship to each other.

The majority of the students (N=16) thought of science as “doing” or as a process. Martha explained that students think of science as doing because history is just memorizing information and “not doing.” Experimenting was the most frequently used word, but several students also mentioned observing, inferring, discovering, classifying, testing, or inventing. The remaining students thought of science as a field of study or a subject in school or could not explain what science is.

The majority of the students (N=17) thought that they could be a scientist when they grew up. Most thought that being a scientist was a matter of getting the proper education. Some students were clearly confused about the applications of science. For example, Annie did not want to be a scientist, but she did want to be a veterinarian. Students commonly hold incorrect or incomplete beliefs about the nature and scope of science (Bell & Linn, 2002); the fifth grade students in Riverside Elementary are probably no exception as indicated by Annie’s statement. Similarly, some of the students

did not think that they had done any science during their unit on archaeology, but then contradicted themselves by using archaeological examples to illustrate science learning.

Learning Probe 6: Nature of Science may have created some confusion about the relationship between science and history. Questions 2 and 3 on the probe may have created the misconception that science and history are the same. Most of the students recognized that science and history use some of the same processes, methods, concepts, analytical tools such as graphs and charts, and sometimes they even use the same data (as in archaeology). They had noticed during the unit that “science” words were appearing in social studies class and found it somewhat perplexing. Martha used their cognitive dissonance to demonstrate that knowledge was not always neatly divided into subjects. Despite these earlier class discussions, Martha thought that the students had probably never been asked to formally consider the relationship between the two subjects before they received the probe. They may have wondered about it, but had never attempted to express their thoughts until they received the probe and completed the interview with me.

Most of the students did recognize that there were differences between science and history. They recognized that history and science do use different data and may use some different processes. For example, some students clearly explained that history does not use experimental methods while science does. While the majority of the students thought that science and history were different, they could not explain why or provided inaccurate explanations. Some differentiated science and history through the time period that each studies; history studies the past while science does not study the past. Similarly, some said that history studies people, while science does not study people.

Research Question 6: Tools for
Assessing Conceptual Understanding

What are the most effective tools for assessing understanding of science concepts?

Learning Probes and Interviews

All of the learning probes except for Learning Probe 1: Doing Archaeology worked well and elicited the desired data about student understanding of the five science inquiry concepts and the Nature of Science. The interviews provided deeper information about students' cognitive processes in their understandings of science inquiry concepts. Because Learning Probe 1 did not produce any usable results, I have placed its discussion entirely within Research Question 6.

Learning Probe 1: Being an Archaeologist. This Learning Probe produced extremely problematic results. The results were so problematic, in fact, that they could not be used in this study. I used Learning Probe 1: How an Archaeologist Works as a pretest and posttest. The learning probe was designed to find out if students can discern the difference between appropriate activities in archaeological inquiry and inappropriate activities and if students change their ideas as a result of instruction. Martha administered the probe before beginning her unit on archaeology and again after instruction was complete. I tallied the number of correct and incorrect responses on each probe; results of pretest and posttest are presented in Table 9 below.

Table 9. Summary of Results from Learning Probe 1
Used as Pretest and Posttest Showing the Number of Correct
and Incorrect Answers by Student.

Name	Pretest Correct	Pretest Incorrect	Post Correct	Post Incorrect
<i>Sue</i>	6 1		6 1	
<i>Matthew</i>	6 1		1 5	
<i>Billy</i>	6 0		4 2	
<i>Mia</i>	4 2		5 1	
<i>Alex</i>	3 3		6 0	
<i>Luna</i>	6 0		6 0	
<i>Walt</i>	6 0		5 1	
<i>Fred</i>	5 1		5 1	
<i>Shirley</i>	6 1		6 0	
<i>Kate</i>	5 1		5 1	
<i>George</i>	4 0		5 0	
<i>Amelia</i>	4 0		6 0	
<i>Annie</i>	4 3		3 0	
<i>Lane</i>	5 1		6 0	
<i>Bella</i>	4 1		6 0	
<i>Jake</i>	6 0		5 1	
<i>Mazy</i>	3 4		6 0	
<i>Roger</i>	6 1		6 0	
<i>EJ</i>	6 0		4 1	
<i>Roy</i>	5 0		6 0	
<i>Reed</i>	5 0		5 0	
<i>Antwan</i>	5 1		3 2	
<i>Dan</i>	5 0		6 0	
<i>Edison</i>	6 0		5 0	
<i>Dominique</i>	6 0		6 0	
<i>Sally</i>	6 1		6 1	
<i>John</i>	4 2		4 0	

Generally speaking the pretests were very good; much better than I had expected.

I knew that both groups had been studying about the Native Peoples of North American throughout the year, but they had not yet undertaken their study of archaeology. Slightly less than half of the students (N=13) performed better on the posttest than on the pretest as would be expected following a rigorous six-week unit on archaeology. However, gains

were very slight for six of these students. They may have improved their number of correct answers by only one or two and decreased their number of incorrect answers by only one or two. Amelia was one of the few students to improve in both the number of correct and incorrect answers, but also in the quality of her descriptions.

Amelia (pre): An archaeologist studies facts from artifacts at sites. Also form (from) observations he or she makes. They also make observations by historical photographs.

Amelia (post): An archaeologist makes observations and inferences of artifacts and sites. They also rely on things around a site. They ask certin (certain) questions about what they want to know. They preserve sites for other archaeologists to study. They also use pictures to figure out other things they might not know.

Eight of the students showed little or no change in learning between their pretest and posttest. For some (Dan and George, for example) the number of correct answers increased or incorrect answers decreased, but the quality of the descriptions deteriorated on the posttest.

George (pre): What an archaeologist does is ask question about how people lived in the past. Make observations, help preserve sites for future study. Make inferences by observing artifacts and sites.

George (post): An achologist (*sic*) studies stuff so people can learn about stuff in the past and to tell about countries and people's past.

Six students did worse on the posttest than on the pretest. Matthew is the most striking example; he was nearly correct on all of the statements on the pretest, but chose only one correct statement on the posttest and five incorrect statements. His description on the pretest was quite complete. The description on the posttest was not as complete, but does show some new content knowledge.

Matthew (pre): An archaeologist will look at a sight (site) and make observations. They would ask questions about how people lived in the past to other people. They also might make inferences by observing artifacts and sites. They might make observations on facts they found.

Matthew (post): An archaeologist does a lot of stuff like study past human culture, classify artifacts into quadrants, look back and observe then make inferences, and study archaeologist sites and take pictures.

Matthew was clearly engaged in learning about archeology throughout the unit. He had clearly given a great deal of thought and effort to all of the learning probes, was able to articulate most of his ideas during interviews, and exhibited only a few minor misconceptions or misunderstandings about content or processes.

Martha explained that students completed the posttest on one of the last days of school for the year, and probably were not very interested in doing a good job. Given the complete reversal of expected performance, this explanation seems inadequate. George and Matthew provide two solid examples of students who were engaged throughout the unit and research process and who seemed to be proficient with all or most of the science processes and archaeological content. At this time, I cannot explain the reversal in the quality between the pretest and posttest. Learning Probe 1 certainly needs to be tested in another research venue with a larger sample. Student interviews will be critical in identifying the problems with the assessment.

Learning Probe 2: Classification. All of the students chose a reasonable, defensible answer to the assessment probe. Most of them (N=17) chose River as being the most correct, either initially on the probe or through the interview process when they were asked to choose between River and Crystal. The remainder of the students (N=9)

chose Crystal as being the most correct because they thought that classifying by use was more important than classifying by a question. Several of these students thought that use was the way to classify artifacts because “that is the way archaeologists do it.” Three of the students made connections between classification and the archaeology inquiry process.

Learning Probe 3: Evidence. Before beginning research, I attempted to develop a clever learning probe to elicit student understanding of evidence, but was unsuccessful. I could not think of a way to differentiate “data” and “evidence.” In consultation with Martha and members of my committee, I decided that the best approach was to ask them some direct questions about evidence and see what happened. I developed Learning Probe 3: Evidence, which consists of three simple questions. Despite the simplicity of the probe, their written responses were very revealing. They also seemed to have difficulty in differentiating between evidence and data, just as I had had from the other end. Interviews might have provided more information about conceptual understanding.

Learning Probe 4: Context. The probe did not clearly explain that the pottery jar in the two drawings was the same jar. Twelve students thought the jars were the same, eight thought they were different, three did not know, and there was insufficient information for four students to determine if they thought the jar was the same or different. Despite this shortcoming in the instrument, all except two students recognized that different contexts produced different inferences about the jar.

Virtually all of the students used some prior knowledge about present-day life and used it to engage in reasoning by analogy. Most of the students demonstrated considerable knowledge about the Ancestral Puebloans and the Aztecs. Their prior knowledge and use of analogy clearly helped them to develop plausible and defensible interpretations of the past and archaeological context. Results may have been very different if the subjects did not have significant prior knowledge of the Puebloan peoples.

Learning Probe 5: Observation and Inference. Generally, the Observation and Inference probe worked well. Two problems were revealed in the interview process. First, three students confused the coin with the statement itself; they thought that the “answer” to the question was in the statement rather than in the coin. This problem might be remedied by adding more explicit instructions to the instrument. Second, some of the students did not think of themselves as the person doing the inquiry; instead they thought of themselves as “observing” someone else doing the inquiry, usually some unknown archaeologists. If they had taken a more active perception of their role as inquirers, the outcome may not have changed, however, the purpose of the unit is to teach students to conduct their own investigations. Again, more explicit instructions might remedy the problem.

The majority of the students understood the concepts and could explain their understanding in writing or verbally. Only one student seemed to be confused about the concepts, but examination of his class work indicates that he had some understanding of both observation and inference. He could not, however, apply the concepts on the learning probe nor could he explain them in the interview. While some of the students

did not provide “correct” answers, they all did quite well at articulating their understanding and making a case for their choices.

Learning Probe 6: Nature of Science. By necessity, the probe was tailored to the instruction and more widely available Nature of Science assessments (e.g., Abd-El-Khalick et al., 2001) could not be used for this study. The probe and interview produced a large body of data about students’ understanding of science, history, and archaeology and the relationships between the three disciplines. These students had probably never been asked to describe science and history, including their similarities and differences. While this probe elicited some basic information about student understanding of the nature of science at the end of instruction, it probably would have provided better information if it had been administered as both a pretest and a posttest.

Performance Task

The Performance Task provided a useful means for observing students while they were engaged in the archaeological inquiry process and applying their skills and understandings to unfamiliar data. These students had recently completed a similar inquiry in class and were very familiar with the procedures. Subjects without this level of expertise with archaeological inquiry may have struggled with completing the task without significantly more direction than I provided.

It was not possible to directly assess the students’ understanding and use of the concept of observation during the performance task because most of the teams ostensibly observed silently. Silent observations could not be captured on the audio transcriptions

and my notes provided little information about individual observations. Another means for eliciting and recording observations is needed for further study.

The Performance Task alone would not have provided adequate data for addressing any of the research questions except for question 3 on application to archaeological inquiry. The Performance Task, the Learning Probes, and interviews together, provided a broad picture of student understandings and misunderstandings. Specifically, very few misconceptions were detected during the Performance Task, while several major or minor misconceptions were identified through the learning probes.

Summary of Research Question 6: Effective Data Collection

The combination of the six learning assessment probes and the performance task provided a large body of usable data about student understanding of the five science inquiry concepts and the Nature of Science. Only one learning probe (Learning Probe 1: Doing Archaeology) produced no usable results.

Unexpected Outcomes

Two unexpected outcomes were identified during this study: evidence of student reflection on their own inquiry processes and the difference between questions that can be investigated with the data at hand and questions that may be interesting, but cannot be fruitfully investigated with the data at hand.

Reflection on the Inquiry Process

Some of the students expressed some awareness of their own inquiry processes. Examples include an awareness of observing, reasoning based on context (the location of artifacts), classifying artifacts to answer a question, and reasoning based on analogy to present-day life. Billy understood the connection between the basis for a classification system and the ability to use that information to learn about people. “You can’t classify tools by shape and color because they are all different shapes and that won’t help you by their shape and color to make a good inference about people.” Billy based most of his reasoning about the correctness of the statements on the ability of each way of classifying to yield good inferences about people. Alex recognized the relationship of using a question to classify artifacts to conduct an investigation. He said, “You shouldn’t have to classify stuff the same way every time. That’s why it is called investigating and not solving.” Roy said, “Artifacts don’t have to be classified in the same way because if they are then it’s harder to investigate,” however, he could not explain what he meant by this statement.

More than half of the Performance Task teams (N=9) expressed some awareness of their own inquiry processes (G.7.1). Several students reported on their processes when I asked them what concepts they were using and how they had arrived at their conclusions. Amelia stated it succinctly: “We looked at the artifacts around the earth lodge and inside of it and what they were and it helped us with that.”

Unfortunately, I did not ask all of the teams to describe their processes and the skills that they used, hence there was no data for some of the teams. Some students (e.g.,

Reed and Jake) noted elements of their process while they were working and some teams discussed their processes while they worked together.

Reed: So, we have 15 minutes to see if we can find out how many people lived there and stuff?

Jeanne: Yes, about 10 minutes now.

Jake: Do we leave this stuff (artifacts) on here (the map)?

Jeanne: No, you can do whatever you want.

Jake: Let's put them in groups.

Reed: First, we'll do what they were used for.

Jake: Probably tools.

Reed: Whetstone, scraper, arrow points, gun parts, here...let's do the pile right here.

Jake: For tools?

Reed: Yeah.

All of the teams were very engaged in the task and worked cooperatively. As noted above, George and Amelia (Team 5), did not speak to each other for the entire investigation, but did work cooperatively to arrange the artifacts on the map. Clearly, collaboration helped the students conduct the investigation and answer their questions. Jake and Reed's exchange above is one of the better examples of cooperative work. Walt and Kate also worked cooperatively:

Jeanne: Kate, could Walt help you with that?

Walt: What are you looking for? How many people lived there?

Kate: Yeah.

Walt: Probably the dad would use that or the boy. Well you might have a dad and two boys.

Kate: A girl.

Walt: An older girl and a mom.

Kate: Six people.

Walt: Yeah, six people might have lived there because of all the tools and stuff and what the dad might have used and because of how many people there were.

Questions and Inquiry

In the Performance Task, 10 of the 14 teams asked at least one question that could be investigated and could conceivably be answered with the archaeological data they had at hand. Four of the teams did not generate a single question that could be productively addressed with the information at their disposal. For example, it would be impossible to know how far the river is from this site with only a map of the house and some artifacts. All of the teams generated some very interesting questions based on their observations of the site map and the artifacts. An archaeologist might be able to investigate some of these questions if he or she could examine the actual site and/or artifacts.

All of the teams made lots of inferences about the site, but most did not systematically manipulate the data by classifying the artifacts or separating the artifacts according to their location or context within the site. Two teams generated an investigable question and completed an investigation based on that question. Both of these teams systematically classified the artifacts by their use and drew reasonable conclusions about what types of people had lived at the site.

Summary of Unexpected Outcomes

Most of the data on the students' understanding of their own inquiry processes was collected during the Performance Task. More than half of the performance task teams verbalized some awareness of the processes they were using to investigate the archaeological site. All of the teams worked cooperatively to complete their investigation; two of the teams seemed to be aware of the cooperative nature of their work and used it to their advantage to finish the task quickly and effectively.

Three students described portions of the inquiry process during their interviews on classification. Two of these students recognized that using a question to guide inquiry made the difference between investigating and solving or simply made it easier to investigate. The third student recognized the relationship between classification of artifacts and making inferences.

During the Performance Task, most of the students produced questions that could be investigated with the data at hand, while four teams did not. The difference between the two is vital to successful investigations.

Trustworthiness and Dependability of the Data

Trustworthiness

Data came from multiple sources including written responses on probes, interviews designed to provide additional information about student understanding and cognitive processes, analysis of student work, observation of student performance, a research journal, and consultation with the cooperating teacher. With only a few

exceptions, the data set for all study subjects was nearly complete. I compared findings and confirmed conclusions by examining and comparing all relevant sources of data.

Martha Jones, the cooperating teacher, reviewed the results in January 2011. She confirmed that the results presented here match her impression of student understanding of science inquiry and the Nature of Science.

Given my background as a professional archaeologist and curriculum designer and my training in educational research, I was well-prepared to conduct this study. I was able to devote 14 field sessions and adequate time to analyze the data.

Dependability

The dense description of the cases (above and in Appendix G) provides other researchers with the opportunity to review the findings of this study. All study subjects were quoted at least once in the presentation of results, hence all subjects are represented in the findings. Project records are available to other researchers for review or further study.

Chapter Summary

The data allowed me to address each research question thoroughly. Analytical processes allowed me to develop a well-founded idea of student understanding of science inquiry concepts and the Nature of Science.

Student understanding of the five science inquiry concepts was highly individual; no student was “typical” and students could not be categorized into levels of understanding. Misunderstandings, misconceptions, and incomplete understandings

provided valuable insight into student learning and can therefore, provide teachers and curriculum designers with points of entry into the learning process. Most of the students were able to apply the five science inquiry concepts to archaeological contexts and many were able to transfer the concepts to other subjects or to everyday life. Most of the students demonstrated some understanding of the Nature of Science and the relationships between science, history, and archaeology. The data collection strategies, while adequate for these research purposes, could be improved and further tested. In addition to the six research questions, data on students' reflection on their own inquiry processes was gathered and analyzed. During the performance task, the majority of students generated questions that could be investigated with the available data.

CHAPTER FIVE

CONCLUSIONS

This case study examined how 27 fifth grade students understood and used five concepts of science inquiry (observation, inference, evidence, classification, and context) through an archaeological investigation of a historic slave cabin in Virginia. Additionally, the study examined the students' views of the nature of science; the relationships between science, history, and archaeology; and their own interest in becoming scientists. The study developed and tested six learning assessment probes and one performance task.

Conclusions are organized by research question and include a discussion of unexpected outcomes of the study. A discussion of how the results inform our understanding of learning follows a summary of results for each research question. The implications of the results for curriculum and teaching are included as are recommendations for improvement in both areas. The chapter concludes with a discussion of broader implications for curriculum design and professional development for teachers. Methodological considerations and potential questions for future research complete the chapter.

Conclusions

Research Question 1. Understanding, Misunderstanding, and Misconceptions

How do students understand the concepts of observation, inference, classification, context, and evidence as a result of instruction in archaeological inquiry? Do they misunderstand these concepts? If so, how?

All of the students except one were conversant in all five science inquiry concepts; they recognized the concept and could discuss it on some level either in writing or verbally. One student did not seem to recognize the concept of “evidence,” but he was at least minimally conversant on the other four concepts. While some students did seem to be conceptually confused on the written learning probes and in their interviews, their class work indicated some understanding of the concept. Without exception, all students performed well on the performance task. In summary, all students, with the exception noted above, had some level of understanding of each concept. Even students who struggled with the concepts and with expressing their understanding, either verbally or in writing, demonstrated moments of clear understanding.

Students clearly constructed their own understanding of the five inquiry concepts. No one student provided a representative picture of understanding. I found it unproductive to categorize students by “levels” of understanding and could not identify individual students who might represent a certain level of understanding. The more deeply I dug into student understanding, the more complex the picture of individual understanding became.

Misconceptions, misunderstandings, and incomplete understandings were of seminal importance in this study because they provided a picture of student understanding at that particular point in their learning process (Ausebel, 1965; Novak, 1977; Wiggins & McTighe, 2005). All students except three showed at least one instance of misunderstanding a concept. While the misconceptions detected in this study were mostly of a fairly minor nature, they indicated when students did not quite understand the concept. One of the clearest examples was Statement F on the observation and inference learning probe, “The face on the ancient coin is the nation’s king.” While almost all of the students handled the other five statements with ease, this statement tripped almost half of them. These students successfully used the skill of “observing,” but because they did not have a complete understanding of the concepts of “observation” and “inference,” they chose “observation” when “inference” was clearly the better choice. Moreover, when most of these students explained their reasoning, they described the skill of observing quite well, but still did not select the best possible choice.

Even practicing scientists may have difficulty in determining when an observation becomes an inference. In archaeology, for example, stones arranged in circles are ubiquitous on the Northern Plains of the western United States. Based on considerable research they have long been thought to represent the presence of a tipi (a conical shelter) at some time in the past (e.g., MT State Historic Preservation Office, 2002). Stone circles are so common that they are often referred to as “tipi rings” and the presence of tipi rings is often an observation rather than an inference when recording archaeological sites in the Northern Plains. If archaeologists did not think that stone circles commonly represent the

presence of a tipi or other human-made structure, then researchers would not record them while in the field. Once a tipi ring is identified in the field, archaeologists begin making other observations such as size, number of stones, or the presence of other artifacts, and begin drawing further inferences from these observations. In other sciences, scientists sometimes blur the distinction between observation and inference. Immunologist Rob Bargatze (Personal Communication, 2011), notices that the germ theory of disease frequently causes medical scientists to jump directly to conclusions about the cause of a certain set of symptoms. For example, pain and swelling of the skin accompanied by white material could be diagnosed as an infection caused by a microorganism. Depending on circumstances, the medical scientist might not determine exactly which microorganism (e.g., bacteria, fungus, or parasite) is causing the infection before beginning treatment.

In archaeological inquiry, classification and context are both useful and distinct conceptual tools. If archaeologists do not know exactly what these concepts are they will not be able to use them effectively. In archaeological inquiry, the number of artifacts in a certain category sometimes needs to be separated from their location or their physical relationship to other artifacts. While locations of artifacts are routinely recorded in the field, archaeologists may want to group them by attributes such as material type, form, or function to answer research questions in the laboratory. In this study, a few students did not separate the two concepts, which led to confusing interpretations of the archaeological data in the Performance Task.

Similarly, some students did not differentiate between evidence as it is used in science and as it is used in legal contexts. These students used the terms “proof” or “prove” to describe the meaning of evidence in a scientific context while these terms more adequately describe the use of evidence in legal contexts.

Learning. Student conceptual understanding of science inquiry was clearly constructed by the students themselves, and sometimes it was constructed incorrectly especially when pre-existing knowledge was faulty or incomplete (Novak, 1977; von-Glaserfeld, 1989; Bransford et al., 2000). Conceptual knowledge is always under construction and concepts, like words, can change and grow in meaning as learners encounter them in different contexts (Brown et al., 1989). In the future, as these learners encounter each of the concepts in a new context or at a deeper level, their understanding may change again.

In the course of this study, it was not possible to discern how students subsumed or integrated their new knowledge into existing superordinate knowledge structures (Novak, 1977). Most of the students were able to differentiate between the five concepts most of the time, but a few students conflated context and classification. Similarly, some students did not demonstrate a complete understanding of the difference between observation and inference or the difference between evidence in science as opposed to evidence in legal contexts. As discussed above, these inadequacies in differentiation actually provide an excellent opportunity to expose flaws in reasoning and help students understand the differences between the concepts.

Misconceptions are persistent (Bransford et.al, 2000), therefore, both researchers and teachers would be wise to check again for conceptual understanding following these remedial measures. The methods for dispelling these misconceptions described here may work in the short term, but ideally, understanding should be checked again because misconceptions can often reappear at a later date or within a different context.

Curriculum. From a curriculum design standpoint, the misunderstandings and misconceptions detected in this study were of seminal importance (Mintzes & Wandersee, 2005a; Wiggins & McTighe, 2005). *Project Archaeology: Investigating Shelter* was designed to minimize misconceptions about archaeological inquiry and the nature of archaeological knowledge and includes a series of Misconception Alerts to help teachers identify and dispel common misconceptions and preconceptions. This study shows that this curriculum may need some additional work in this area (see Implications below).

Teaching. While a large number of misconceptions, misunderstandings, and incomplete understandings were detected on the learning probes, in most cases these misconceptions could probably be dispelled and shifted to a more complete and accurate understanding of the concept. These misconceptions should be thought of as “teachable moments,” but the teacher needs to know when misconceptions exist. Research shows that misconceptions need to be addressed directly, based on existing understanding (Bransford et al., 2000). Because these students already had a basic understanding of the concept, the shift might have been relatively easy to make.

Thirteen students thought that the statement, “The face on the ancient coin is the nation’s king,” was an observation when the statement is clearly an inference. A structured classroom discussion based on this statement would probably clarify the difference between observation and inference. A teacher could ask for a show of hands for “observation” and “inference” respectively, ask students to explain their reasoning, and then guide discussion to expose potential flaws in reasoning. During the interview process, two students exposed their own flaws in reasoning and, consequently, changed their answers to “inference.” In this case, the difference between observation and inference is contextual—kings and queens are often represented on currency. Because context enters into explanation, observation and inference may also provide a good opportunity to examine the role of context in differentiating between the two conceptual tools.

Similarly, the difference between context and classification could be established through a simple differentiation exercise. A card-sorting activity in which students decide if each card is an example of classification or context might be sufficient for most students to differentiate the two concepts. Following the activity each student could write a brief description of each concept to make his or her understanding visible to the teacher for checking (Driver et al., 1994).

Because eleven students used the words “proof” or “prove” in their explanations of evidence, I classified them as having a misconception about the concept. A brief class discussion of the uses of evidence in science as support for inferences or a way to answer research questions may have been sufficient to shift students to a better understanding of

the concept. Students could also write a paragraph describing how evidence is used in science inquiry as opposed to how it is used in legal contexts to check for understanding. Again, context (legal or scientific) is highly relevant in differentiating between the two applications of the concept of evidence.

Research Question 2: Cognition

How do students construct (logical progression of thought) their understandings or misunderstandings of these concepts?

The learning probes, interviews, and the performance task were designed to elicit as much information as possible about the underlying cognitive processes that students used to arrive at their understanding of the five inquiry concepts (Pellegrino et al., 2001). Results show that students constructed much of their knowledge by reasoning through analogy to existing knowledge, especially to their knowledge of present-day life. Reasoning through analogy to present-day life is a perfectly reasonable approach in archaeological inquiry especially in the absence of historical data, ethnographic data, or the results of previous archaeological research on similar sites and artifacts. Several students were also able to reason that the absence of certain types of objects or artifacts such as weapons may be indicative of some past behavior or belief.

Students used different cognitive operations to arrive at their understandings of the concepts. For example, when describing how they arrived at an observation, students often said, “I just looked at it.” For an inference, they cited the fact that a statement could not be “proven” with the information at hand. For classification, most students relied primarily on what they remembered from the lesson on classification; research

questions should guide the classification of artifacts. Students used their prior knowledge of the Ancestral Puebloans and modern American homes to reason through the archaeological context problem.

Students used their instruction in archaeological inquiry, prior school experiences, and possibly general knowledge of the connection between evidence and proof to explain evidence. Most of the students understood that there is a connection between evidence and data and cited specific examples. Most of their examples were plausible sources of data that could become evidence. The application of an operation such as classification, observation, inference, or the use of context of a site or an artifact helped students turn data into evidence. When students applied any one of these four concepts they were better able to explain the nature of evidence. Without use of one of these operations, their explanations of evidence were limited to a list of possible sources of data.

Learning. Students in this study clearly constructed their own understanding of the five inquiry concepts. In many cases, they acquired some misunderstandings or misconceptions along the way. Starting misconceptions seems to be relatively easy to do, while detecting and dispelling them is more difficult. Without detection and explicit efforts to dispel them, misconceptions can easily continue throughout an entire unit or even an entire course of study.

Curriculum. The curriculum intervention used in this study, *Project Archaeology: Investigating Shelter*, was designed to minimize misconceptions and also provides ways for teachers to identify misconceptions and dispel them through instruction. Most of the

students in this study acquired some misconceptions about the five inquiry concepts indicating that the curriculum may need additional work in this area. After determining exactly why students acquired these misconceptions, the lessons in *Project Archaeology: Investigating Shelter* that teach science inquiry concepts should be adjusted to circumvent misunderstanding in the first place or to better detect misunderstandings and dispel them as part of the lesson.

Teaching. More knowledge of cognitive operations may help teachers find where students' reasoning goes off track and where misunderstandings and misconceptions are introduced into learning (Pellegrino et al., 2001). For example, the learning probes allowed me to identify previously unsuspected misconceptions about classification and context and the relationship between the two concepts. The interviews and the performance task allowed me to probe more deeply into the cognitive processes students used to arrive at these misconceptions.

Research Question 3: Application

How do students apply these concepts to archaeological inquiry?

The ability to apply new knowledge or new concepts in a different context indicates understanding of the concept or content (Bransford et al., 2000). All of the students, in at least one instance, applied one or more of the five concepts to archaeological remains such as hypothetical sites and artifacts or to archaeological data presented to them in the Performance Task. While their examples were not always well-informed, most made the essential connection between material remains and inferences

about the past. Students were not specifically asked to apply their conceptual knowledge to the study of archaeology, hence there was little opportunity for application. Most students were able to provide an acceptable example of how evidence was used in archaeology. Some examples were particularly well-constructed and showed considerable understanding of the use of evidence in archaeology. Similarly, most students could provide an example of applying observation in archaeology when asked how they would examine the veracity of an inference. The majority of students used their previous knowledge of Ancestral Puebloans and archaeological inquiry to explain their understanding of context.

Learning, Curriculum, and Teaching. Understanding of an inquiry concept is probably not solid until the student can apply it to specific content and to provide a relevant example of application within a specific discipline. In this study, all of the students successfully applied at least one of the five inquiry concepts in at least one instance, indicating some level of conceptual understanding of archaeological inquiry.

Science curricula of all kinds should include prompts for students to apply inquiry concepts within the specific scientific discipline under study, to other sciences, to everyday life, and to non-science subjects. These prompts would help solidify understanding and provide teachers with a built-in check for understanding. Asking students to apply concepts in other subjects and to everyday life solidifies learning and provides an opportunity to check for understanding of a particular concept or new knowledge.

Research Question 4: Transfer of Concepts

How do students transfer and apply these concepts to other school subjects or to everyday life?

Similarly to application, transfer of knowledge to other subjects and to everyday life is an important indication of understanding (Bransford et al., 2000). Students had little opportunity to transfer their knowledge of the five inquiry concepts to other subjects in the course of this study. Two students did, however, transfer the concept of context to another subject (reading) and to everyday life (objects outside of their usual context have a different meaning). Seven students used everyday examples to explain their understanding of classification. Some students provided good examples of evidence in other subjects.

Learning, Curriculum, and Teaching. Because none of the learning probes were specifically designed to examine transfer of knowledge, this study provides only a few examples of transfer of knowledge of science inquiry concepts to other subjects and to everyday life. It does provide evidence that the study of archaeological inquiry can help students understand basic inquiry concepts sufficiently to transfer them to other subjects as a few of the subjects of this study did.

Because transfer of knowledge often involves application of a concept, curricular materials should include prompts to apply concepts in other subjects or to everyday life. Concomitantly, transfer prompts could provide teachers with opportunities to check for deep conceptual understanding.

Research Question 5: Nature of Science

What do students think science is? How do students understand the relationships between science, history, and archaeology?

Most of the students in this study retained a fairly naïve or incomplete view of the Nature of Science (Abd-El-Khalick et al. 2001; Bell & Linn, 2002; Lederman, 2007).

Most of the students thought of science as processes or “doing,” rather than as building knowledge. About a third of the students explained scientific evidence in terms of proof or facts, despite curricular focus on evidence as support for inferences and as a way to answer research questions. While most students did not show a strong view of themselves as producers of knowledge, most thought that anyone could be a scientist if he or she went to school and studied. Many students wanted to be scientists and thought that it would be fun to be a scientist.

An insufficient understanding of the nature of evidence and how to use it to support inferences, to answer questions, and to build explanations may indicate an insufficient understanding of the Nature of Science itself. In science, all knowledge is tentative and it is never possible to prove anything. Instead, students should know that “Knowledge claims in science are supported or refuted in the light of available evidence” (Driver et al., 1996, p. 144). If students think that evidence is synonymous with “proof” in science, they will probably have difficulty in building evidence-based explanations as required in the *National Science Education Standards* (NRC, 2000). In other words, they cannot apply the skill without understanding the basic concept behind it. As discussed in Chapter One, evidence is often associated with proof in legal matters, hence the

misconception is understandable. An understanding and appreciation of the nature of data and how it is collected are the most important components of understanding how data can become evidence. The next step is evaluating the accuracy, validity, reliability, and replicability of evidence (Driver et al., 1996). Not all evidence is equal; some evidence is much better than other evidence because of how it was collected.

This study was probably the first time that most of these students had ever been asked to consider the relationship between science and history. Archaeological inquiry gave them a perspective from which to consider the question and some clearly grasped the role of archaeology at the confluence of the two disciplines. Other students did not make this connection and a few of the students did not think that archaeology had anything to do with science.

Learning. Most students in this study retained a naïve view of science as “doing” rather than seeing science as a discipline which builds knowledge through systematic inquiry. Archaeological inquiry clearly provided an opportunity to practice with inquiry in a new context. Interestingly the new context was in social studies and particularly in United States history, which probably created some cognitive dissonance as students tried to reconcile the use of scientific processes and scientific concepts in the study of history.

This study demonstrates that students probably need disciplinary knowledge of science and history to successfully integrate scientific and historical knowledge (Jacobs, 1989; Cornbleth & Champagne, 1991). Many educators call for curricular integration to help students make meaning of real world knowledge (Beane, 1995). Research on conceptual understanding of the relationships between science and history is scant.

While, this study barely touched the surface of an important part of education, archaeology clearly offers a way for educators to seamlessly integrate science inquiry, history, and even mathematics.

Curriculum. Curricula in archaeological inquiry should include opportunities for students to reflect on how science inquiry works and how it helps archaeologists build knowledge about the human past. Any curricula that integrate science with other subjects should include instruction in disciplinary knowledge and a schema for integrating disciplines to help students understand the relationships between them.

Teaching. Teachers still need better preparation for teaching about the Nature of Science (Lederman, 2007) and archaeological inquiry can provide another venue for exploring how science works and how it can help build knowledge of the human past. Professional development in archaeological inquiry would help prepare teachers for teaching about the Nature of Science; how to integrate science, social studies, and history through archaeology; and how to guide students through integration of traditional school subjects to conceptual understanding of the disciplines themselves and the relationships between them.

Research Question 6: Data Collection Techniques

What are the most effective data collection methods for examining conceptual understanding of science inquiry through archaeological investigations?

The Curriculum Topic Study unit approach (Keeley, 2005) provided a solid basis for designing new assessments for conceptual understanding of science inquiry in

archaeology. Because the prototypes have been extensively tested, adaptations to new content areas or to specific curricula have a reasonable chance of success. I found no other assessment tools for archaeological learning. The assessments produced for this study and tested with these students provided adequate data for uncovering student understanding of archaeological inquiry concepts.

The Learning Probes and Interviews allowed me to “get a picture” of student understanding of the five science inquiry concepts. These assessments also allowed me to identify numerous misconceptions that were not identified during instruction. For example, Martha detected no conceptual confusion during instruction and she was surprised to learn that several students conflated or confused classification and context. When misconceptions were detected, examination of student work provided an opportunity to check for general understanding. These documents did not, however, identify the precise point in the learning process where misconceptions occurred.

The Performance Task showed students’ ability to apply the concepts in a largely self-guided inquiry of archaeological data. The cooperative work by the teams while completing the task provided rich data on comprehension of the concepts and some information on the role of interaction in inquiry. Additionally, I detected a few persistent misconceptions through this performance task, particularly the confusion of classification and context and the assumption that people who lived at an archaeological site were “poor or sloppy.” Performance tasks alone, however, would not have provided the in-depth data on student conceptual understanding that the learning assessment probes provided.

While all of the data collection techniques worked well for the most part, all of them could be improved. This study identified specific problems with each assessment and provided concrete ways to improve them. More explicit instructions would probably improve results on Learning Probe 4: Context, Learning Probe 5: Observation and Inference, and on the Performance Task and, thereby, produce a better picture of conceptual understanding. One of the statements on Learning Probe 2: Classification may have misled some of the students and could be changed. Results from this study point to better ways to assess conceptual understanding of evidence. For example, a learning probe that elicits thinking on questions such as “How does data become evidence?” may necessitate deeper reflection. Similarly, students might be able to choose between two short scenarios that differentiate between evidence as it is used in legal contexts as opposed to scientific contexts. Learning Probe 6: Nature of Science produced some valuable data about student understanding of science within the confines of this study, but results cannot be broadly compared to other studies. Development of a new learning probe more closely aligned with widely used protocols would make results more broadly applicable. Learning Probe 1: Doing Archaeology closely followed some of the CTS prototypes and should have worked better than it did. It could be tested in other case studies or with a larger sample to see if the problem lies in the probe itself or is specific to this case.

Unexpected Outcomes

I identified two unexpected outcomes in this study: (1) evidence of student reflection on their own inquiry processes and (2) the importance of differentiating questions that are appropriate for investigation from those that are not appropriate.

Reflection on Inquiry Process. Metacognition or reflection on one's own practice or learning, is essential for developing independent inquirers (Metz, 2004). This study certainly could have been expanded to include direct research on students' reflection of their own inquiry processes. Even without direct exploration, some students clearly showed some awareness of their own inquiry processes and some recognized when to use a particular tool for a particular purpose such as classifying artifacts to find out how many people lived within an archaeological structure.

Both curriculum and instruction in archaeological inquiry should be designed to include more opportunities for students to reflect on their own inquiry processes. For example, students could describe their inquiry processes at the completion of a self-guided investigation of archaeological data as part of their report, just as scientists would do.

Questions for Investigation. While *Project Archaeology: Investigating Shelter* devotes considerable instructional time to helping students understand the role of questions in the research process and how to develop good research question, this study did not directly address questioning. During the performance task, students generated two kinds of questions: those that could be investigated with the data at hand and those

that could not be investigated. Most of the questions that were not investigable, were interesting questions; questions that an archaeologist might pursue if he or she had access to the site and all the artifacts. The *NSES* (NRC, 2000) requires learners to hone the skill of asking investigable questions. Archaeological inquiry, in general, and the Performance Task used in this study, could provide an engaging opportunity to develop investigable questions.

By simply instructing students to generate questions that could be successfully investigated, both verbally and in writing, with the data available might have prompted students to provide more investigable questions. Students may, however, need more prior instruction in differentiating the two and additional scaffolding of questioning skills before completing the performance task (Metz, 2004).

Discussion of the Study

Science inquiry concepts can be effectively taught through archaeological inquiry in fifth grade. Archaeological inquiry can be an effective tool for increasing science literacy and meeting the goals of Project 2061. The students in this study were engaged in learning through archaeological inquiry and archaeological content and processes provided them with new ways to deepen and broaden their understanding of science. Several students, by their own admission, changed their attitudes about the nature of science, their own abilities to become scientists, and their interest in science as a potential career because science could be “fun.” The unit provided an opportunity to apply their conceptual understanding and to practice their inquiry skills. Through the performance

task, the study itself provided a rare opportunity for students to conduct their own largely self-guided investigation.

A similar case study may not work as well in another classroom. This situation was optimal in terms of teacher effectiveness with instruction. Both cooperating teachers were able to provide sufficient time for Martha to teach the entire unit and for me to interview all of the students on multiple occasions. Originally, I thought that I would not be able to interview all students and would have had to rely primarily on written responses to the learning probes for data. Additionally, all students completed the performance task, rather than only a small sample as originally planned, and I observed 13 teams and one individual student engaged in self-guided inquiry.

Students clearly need help with open or self-guided inquiry (Metz, 2004). *Project Archaeology: Investigating Shelter* provided students with a structure for investigating archaeological data and instruction provided scaffolding for initial student inquiry efforts. All of the students did a reasonably competent job of conducting their own investigation of unfamiliar archaeological data. Additional scaffolding on choosing appropriate and investigable questions for a self-guided inquiry would be a useful addition to the curriculum.

It is easy to introduce misconceptions during instruction. In this study, several students confused classification and context, apparently thinking of them as the same concept. At least one student was confused about the nature of the archaeological record itself (sites and artifacts); it is possible that he did not understand exactly what an archaeological site was at the end of the unit. He persisted in thinking that people who

lived at archaeological sites were “poor” and “sloppy.” He used the deterioration of the material remains visible in maps and in broken artifacts as evidence that the people who lived at sites were unable to have new things and did not take care of things they did have.

When asked how science and history are similar, most students recognized many similarities in inquiry processes, but also recognized that the two disciplines used different data and some different processes. They thought that science and history were different, but could not clearly explain why except that the two disciplines usually study different time periods. While archaeology integrates curricula naturally because of its interdisciplinary nature, students need help with conceptually differentiating and integrating the two disciplines. Solid understanding of the disciplines would provide a basis for integrating knowledge from each and successfully placing archaeology at the nexus between history and science.

While the results of this study are unique to this case and cannot be broadly generalized, the assessment process that I used could be transferred to other cases or to other disciplines with science content. For example, the process might be used to assess conceptual understanding of science inquiry and the Nature of Science acquired through curricular interventions about invasive weeds, pond ecology, or the geomorphology of glaciated landscapes.

This study provided me with an opportunity to step back from developing curriculum, preparing teachers to use archaeology education curricula, and evaluating a program and assessing what students actually understand about science inquiry. Even

more importantly, I was able to trace at least to some degree how students acquire both conceptual understanding and misconceptions. From a curriculum development standpoint, it was the best project I have ever done and it will profoundly influence all future curriculum development and teacher preparation work that I do. The implications of this study for *Project Archaeology: Investigating Shelter*, the curriculum intervention used for this study, are significant and many improvements in the curriculum itself and in preparing teachers to use it can be implemented immediately.

Implications

This study has direct implications for the curriculum used in this study, *Project Archaeology: Investigating Shelter*, for development of future inquiry-based curricula in archaeology, and for the larger issue of teacher preparation for science inquiry education. The study may also have implications for the design of other science inquiry curricula.

Curriculum Design. From a curriculum design standpoint, this study has significant implications. Immediately, findings can be used to improve *Project Archaeology: Investigating Shelter* in seven ways:

1. Develop new lesson plans or an appendix for conducting open or self-guided inquiries using a second shelter investigation from the selection of regional shelter investigations (similar to “Investigating a Slave Cabin”) in the Project Archaeology database. With some guidance, the students in this study conducted a brief investigation with unfamiliar archaeological data. Improved guidance and additional scaffolding should enable students to conduct self-

guided investigations of a second investigation. Students could conceivably choose their own investigation based on their interests, develop their own questions, and report their findings to other classmates for comparison and evaluation.

2. Provide additional opportunities for students to reflect on their own inquiry processes including a report on the inquiry methods used in conducting a self-guided investigation of a shelter.
3. Develop more Misconception Alerts specific to the findings of this study, e.g., the difference between classification and context, the nature of the archaeological record, and the nature of archaeological knowledge. Additionally, procedures exposing flaws in reasoning and for differentiating between concepts could be included. Concomitantly, additional instructions to help teachers identify and address misconceptions could be included.
4. Revise the Learning Probes used in this study and make them available to teachers of *Project Archaeology: Investigating Shelter*. Teachers could use them to continually check for conceptual understanding and to detect misconceptions throughout the unit on archaeological inquiry.
5. Develop a schema and instruction for integrating science and history through archaeology and make both available to teachers of *Project Archaeology: Investigating Shelter*. A graphic, a concept map, a table, or other schematic organizer may help students better understand the relationships between history, science, and archaeology.

6. Include opportunities for students to reflect on the nature of science inquiry and how science inquiry helps archaeologists build knowledge about the human past.
7. Include clear distinctions between the concepts of observation, inference, classification, context, and evidence and the skills of observing, inferring, classifying, identifying context, and using evidence. For example, the definition of “observation” in *Investigating Shelter* (Letts & Moe, 2009) could be changed to better express the concept behind “observing.” It currently reads “recognizing or noting a fact or occurrence,” which could be interpreted as a skill.

Results could be used to design and assess the efficacy of new inquiry-based curricula in archaeology. The findings could also be used to design other science curricula. All of the improvements suggested above could be included in inquiry-based curricula at the outset of the development process. The innovations should be further tested as part of formative evaluation.

Teaching and Professional Development for Educators

The interviews with the students clearly demonstrated the value of one-on-one time in assessing student conceptual understanding or misunderstanding. For example, Martha was surprised that some of the students conflated two concepts, classification and context. For this reason, Martha intends to use the learning probes developed for this study when she instructs *Investigating Shelter* in the future and she intends to interview

her students as frequently as possible about their conceptual understanding. She also thought that the probes and interviews solidified students' learning of the science concepts. Simply verbalizing their thoughts seemed to provide a significant step towards deeper understanding. Good teaching involves constant assessment and the probes developed for this study will provide a relatively easy way to assess for conceptual understanding throughout the unit of study.

Most teachers receive *Project Archaeology: Investigating Shelter* through an in-service or pre-service professional development workshop or through an online course. Professional development would be a perfect opportunity to employ the findings of this study and better prepare teachers to teach science inquiry, the nature of science, and archaeological content knowledge. Specifically, professional development could be designed to help teachers detect misconceptions early in the learning process and give them ways to dispel them quickly and effectively. These teaching skills should be applied to archaeological inquiry as well as to science inquiry in general, or even to historical inquiry.

Many teachers may need explicit information about the disciplines of science and history before attempting to integrate them in the classroom. Disciplinary knowledge may help with understanding of the Nature of Science and with interdisciplinary learning (Lederman, 2007). Additionally, a schema for integrating historical and scientific knowledge through archaeology would be helpful for both teachers and their students.

Future Research

This study provides a baseline case study of conceptual understanding in science inquiry from which to build future research. Discussion of future research possibilities is divided into methodological considerations and potential research questions.

Methodological Considerations. This baseline case study could be replicated to see if results are similar in a different context. Do students arrive at similar conceptual understandings in other classrooms? Do the same misconceptions and misunderstandings appear? Are other students capable of conducting largely self-guided investigations of archaeological data? Do students transfer their conceptual understanding to other sciences or to other non-science subjects? Do they understand the relationships between history, science, and archaeology? The learning probes and the performance task should be refined based on the findings of this study, then further tested in another case study. The learning probes could be adapted to other curricula, both archaeology and non-archaeology and could be tested through a similar case study approach.

The data from this study could be used to follow each student or a sample of students through the entire unit of instruction with the questions: How does conceptual understanding develop? Where and how do misconceptions develop? What preconceptions do students bring to their learning? Does instruction successfully dispel erroneous preconceptions? Data may shed light on how students differentiate new knowledge and subsume it into existing knowledge structures.

A larger study could be designed to examine differences in implementation of the curriculum intervention in diverse settings with different populations. Researchers could

select a smaller sample of students from many classrooms. Both randomly selected samples and purposeful samples based on prior knowledge of science inquiry or archaeological inquiry; interest in science, history, or archaeology; and student ability could provide useful data. Such a study would allow comparisons across a much broader demographic base and at different levels of implementation.

Potential Research Questions about Learning and Conceptual Understanding.

Research on the misconceptions detected in this study, especially the conflation of classification and context, may elucidate deeper cognitive processes. Where does this misconception come from? From a curriculum design standpoint, important questions include: How could this misconception be dispelled in instruction or avoided entirely? Do minor misconceptions disappear with new knowledge or do they need to be addressed and dispelled before further instruction can continue?

This study shows that research focused on how students understand the relationship between history and science through archaeology is clearly needed. Potential research questions include: Does archaeological study produce misconceptions about the nature of science? Does it produce misconceptions about the relationship between science and history? How could archaeology be used to demonstrate the broadness of science and its relationship to other disciplines?

This study raised many new questions about students' understanding and misunderstanding of science inquiry concepts and processes. Future research should focus on digging deeper into student conceptual understanding of science through archaeological inquiry.

APPENDICES

APPENDIX A

LESSONS FOUR THROUGH SIX AND ASSESSMENT FROM

PROJECT ARCHAEOLOGY: INVESTIGATING SHELTER

(Used with permission from Montana State University)



4 Lesson Four

Observation, Inference, and Evidence

(Adapted from *Intrigue of the Past*, Smith et al. 1996)

Enduring Understanding

Using the tools of scientific and historical inquiry, archaeologists study shelters and learn how people lived in them.

Essential Question

How do archaeologists study the past?

What Students Will Learn

- Archaeologists use observation and inference to form meaningful questions.
- Archaeologists use data and evidence to answer their questions.

What Students Will Do

- Differentiate between observation, inference, and evidence.

Assessment

Students will conduct an investigation of a room from a modern home to show their understanding of observation, inference, and evidence.

Materials

For Each Student

- Illustration of “The Old Homestead” (page 43)
- “The Old Homestead” data collection sheet (page 44)

For the Teacher

- Transparency of “The Old Homestead” illustration (page 43)
- Transparency of “The Old Homestead” data collection sheet (page 44)
- Chart paper and markers for recording students’ ideas

SUBJECTS: social studies, language arts, science

SKILLS:

- **Bloom’s Taxonomy:** remember, understand, apply, analyze, evaluate
- **Facets of Understanding:** explanation, interpretation, application, self-knowledge

DURATION: 45 to 60 minutes

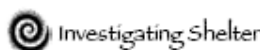
CLASS SIZE: any, groups of two

NATIONAL STANDARDS: social studies, history, language arts, science (see Appendix 3, page 154)

Background Information

Scientists may not use exactly the same procedures in exactly the same order, but most scientists rely on a methodical application of observation, inference, and data collection to answer their questions. Any phenomenon being studied must first be observed, whether from a satellite or through a microscope or directly with the naked eye. An inference is a reason proposed to explain an observation and it often raises questions for further inquiry. A single observation can produce many plausible inferences; the scientist’s job is to determine which of the inferences best explains the observation. When scientists have completed the process of observing, inferring, asking questions, and gathering data, they use evidence to answer their questions.

Archaeologists use observation and inference to learn how people lived in the past. By making observations about objects (artifacts and sites), they infer the behavior of the people who used the objects. For example, when archaeologists find the remains of a large village (observation), they could infer that the people were farmers because a large village needs a large food supply. To find out if that is the case, they would look for evidence of farming



such as farming implements (like hoes), and food remains from crops (corn cobs and squash seeds). Archaeologists might also infer that the village was a trade center and would look for imported items to find out. A single observation might generate multiple inferences each of which could be plausible. A scientist's job is to examine all the data carefully to find out which inference is the best.

Misconception Alert! Archaeology and Excavation

When people think about archaeology, they usually imagine archaeologists busily excavating sites in exotic places. While excavation is an important part of archaeology, it is not the only way archaeologists learn about the past. Many sites are visible on the surface and a lot can be learned just from mapping and basic recording procedures. Archaeologists also study existing collections and records in museums to learn more about sites that have already been excavated. After field work is complete, archaeologists spend much of their time in the laboratory analyzing the information and reporting their findings to archaeologists, other scientists, and the public. For every day spent in the field, archaeologists spend two to three days in the laboratory analyzing the data and interpreting the results.

Preparing to Teach

1. Make a copy of the "The Old Homestead" data collection sheet and illustration for each student.
2. Make transparencies of "Old Homestead" data collection sheet and illustration.
3. Prepare to share background information.
4. Set up chart paper and markers to share students' ideas.
5. Post the Word Bank words.
6. Post the essential question: "How do archaeologists study the past?"

Word Bank

archaeological site: a place where people lived and left objects behind

evidence: data which are used to answer questions

inference: a conclusion derived from observations

inquiry: an organized investigation to learn new information or solve a problem

observation: recognizing or noting a fact or occurrence

question: something that is asked to guide the inquiry process

Uncover Prior Knowledge

1. Ask students: Imagine you think your brother or sister was in your bedroom while you were gone. How would you find out? What steps would you take to investigate? How would you determine that he or she had in fact been in the room?
2. List the students' ideas on chart paper to return to in Reflect on New Knowledge.

Discover New Knowledge

How do archaeologists study the past?

Inform students that this question will guide their learning. Indicate the Word bank words (archaeological site, evidence, inference, inquiry, observation, and question) and inform students that they will use these words as tools and define them during the lesson.

1. Distribute "The Old Homestead" illustration and data collection sheet.
2. Explain that the illustration shows an old house used and later abandoned by people. It is an imaginary example of a place archaeologists might study. Students will use the illustration as they learn to do scientific inquiry.
3. Indicate the words **observation**, **inference**, **evidence**, and **inquiry** and tell students they will learn the meaning of



these words through an activity.

4. **Observation:** Ask students: What do you notice about The Old Homestead? Have them list six or more objects and observations on their data collection sheet. As the students are working, they may have questions about how the people lived. Encourage them to list their questions under number 2.
5. **Inference:** Ask students: What inferences (conclusions) can we make about this place and the people who lived here based on our observations? Have them write at least two inferences for each of their observations.
6. Tell students: Asking good questions can help us find out more about how the homestead was used and what happened there. Write these two questions on the board: Is this an old house? How long ago did people live in this house? Ask students: Which question is the better question? Why? Guide students to recognize that questions answered with yes or no are too narrow. Meaningful questions usually begin with *Where, What, Why, Who, or How*.
7. **Questions:** If students have not written any questions under number 3, encourage them to do so. They may add more questions at this time.
8. Students share their questions in small groups. Assist students with improving their questions, if necessary.
9. Tell the students: We are going to use evidence to answer our questions. For example, if we asked the question, "How long ago did people live in this house?" the Model-T truck could be evidence that people lived here a long time ago.
10. **Evidence:** Students complete step 4 on the data collection sheet using their observations and list of objects (data).
11. Assist students with defining **observation**, **inference**, **evidence**, and **question** and adding them to their Word Banks.
12. Explain to students that the illustration of the homestead is an example of an archaeo-

logical site, a place where people lived and left objects behind, and they have just conducted an inquiry much as archaeologists do. Assist students with defining **archaeological site** and **inquiry** and adding them to their Word Banks.

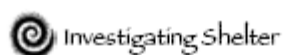
13. Use the background information and the "Misconception Alert: Archaeology and Excavation" to show students that archaeologists can learn a great deal by observing sites and artifacts on the surface.

Reflect on New Knowledge

1. Return to the Uncover Prior Knowledge chart, and as a class, review their ideas.
2. Ask students: Based on the inquiry process you just completed, would you change the investigation of who was in your bedroom? Explain.
3. On chart paper or the board, write some examples of students' observations and inferences to show that students had different inferences for the same observation. Ask students: How do you account for the differences in inferences? Use the background information to lead a discussion on the possibility of obtaining multiple plausible inferences from a single observation.
4. Ask students: How have we used inquiry to learn about people?
5. Give students a few minutes to write what "Observation, Inference, and Evidence" means to them on their "Investigating Shelter: Understandings" sheet. You may want to collect sheets to check for understanding, and then return them to the students.

Assessment

The assessment for Lesson Four is located on page 59. This activity will assess students' knowledge of Lesson Four: Observation, Inference, and Evidence; Lesson Five: Classification, and Lesson Six: Context. You will need to set



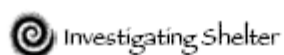
up ahead of time. While the assessment takes some preparation, it is very engaging for the students and provides an active means for them

to solidify their understanding of the concepts they will need to complete the archaeological investigation of a shelter in Lesson Eight.

ANSWER KEY		
THE OLD HOMESTEAD		
Object (examples)	Observation (examples)	Inferences (examples)
Horse shoes	There are four horse shoes near the fence.	There were horses here. People were playing horseshoes.
House	The house has broken windows and is falling apart.	The house is old. A tornado struck.
Outhouse	The house has an outhouse.	The house was built before indoor plumbing was the standard. The people who lived here were poor.
Model -T truck	There is a Model-T truck.	The people who once lived at this house owned a Model-T truck, which must have been in the early 1900s when Model-Ts were still in use.
Cow Skull	There is a cow skull.	There were cows here. Someone brought a cow skull to the homestead.
Tall grass	The grass is very tall.	No one has been around to cut the grass for a long time. Grass grows quickly in this climate.

The Old Homestead





Name _____

The Old Homestead

1. In the chart below, list some of the objects that you see and make an observation and an inference for each one.

Object	Observation	Inferences (two or more)
Example Horse shoes	Example There are four horse shoes near the fence.	Example There were horses here. Someone was playing horseshoes.

2. What do you wonder about as you observe the homestead? Write three or more questions.

3. Think about what makes a good question. Choose your best question and write it below.

4. Answer the question in step 3. What is your evidence?



5 Lesson Five

Classification

(Adapted from *Intrigue of the Past*, Smith et al. 1996)

Enduring Understanding

Using the tools of scientific and historical inquiry, archaeologists study shelters and learn how people lived in them.

Essential Question

How do archaeologists study the past?

What Students Will Learn

- Archaeologists use classification to study artifacts and answer questions about past lifeways.

What Students Will Do

- Classify objects based on their attributes to help answer questions.
- Explain that scientists and specifically archaeologists use classification to help answer research questions.

Assessment

Students will continue to conduct an investigation of a room from a modern home to understand how classification helps answer questions.

Materials

For Each Group

- A Doohickey Kit, each containing about two dozen familiar objects such as bolts, string, rocks, paper clips, etc. (each kit must be identical)
- "Artifacts from a Historic Home" (page 49)
- Scissors

SUBJECTS: social studies, science, language arts

SKILLS:

- Bloom's Taxonomy: remember, understand, apply, analyze, evaluate
- Facets of Understanding: explanation, interpretation, application, self-knowledge

DURATION: 30 to 45 minutes

CLASS SIZE: any, groups of three or four

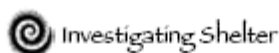
NATIONAL STANDARDS: social studies, science, history, language arts. (see Appendix 3, page 155)

Background Information

Classification is a basic tool for organizing different objects, situations, and thoughts. We group items into categories so that we don't have to respond to each new object or situation as a completely new experience. Classification also helps us to sort a multitude of sensory impressions quickly and enables us to simplify complex data.

We classify objects almost instinctively by choosing certain attributes or characteristics to pay attention to while ignoring others. We cannot take all attributes into account at once; therefore, we select only a few as being relevant to the task at hand. For example, if we have a group of blocks alike in every way except color, then color is going to be the attribute we use to group or classify the blocks. If size is variable, then it, too, could become important for categorizing the blocks.

Classification of data is an important part of any scientific study, including archaeology. Scientists must categorize data based on various attributes to reduce their complexity and to examine the relationships between types of data. For example, it is not possible to compare each individual house cat with every other member of the cat family. Instead, the category *house cat*



includes creatures with certain shared attributes. All house cats are not identical, but all are alike in some way within a range of variation. The category house cat can then be compared with the category tiger, or lion, or lynx.

Objects (artifacts) left by past people form the archaeological database. Like all other scientists, archaeologists classify data (in this case artifacts and sites) into categories based on their attributes. A site might contain hundreds of pottery sherds that vary in appearance. An archaeologist cannot compare every pottery sherd to every other pottery sherd. Instead, he or she classifies the pottery into categories and compares the categories, thereby greatly reducing the number of comparisons that have to be made.

Misconception Alert! Classification

Classification systems are prevalent in many branches of science including archaeology. Biologists classify plants and animals, geologists classify rocks, and archaeologists classify artifacts. To non-scientists, it may appear that the categories or classes are inherent in the objects themselves. But in fact, classification is a very human endeavor of creating order among discrete objects or concepts. Archaeologists classify artifacts to help answer research questions or learn more about how people lived in the past.

Preparing to Teach

1. Make a copy of the "Artifacts from a Historic Home" for each group.
2. Prepare identical Doohickey Kits for each group.
3. Post the Word Bank words.
4. Post the essential question: "How do archaeologists study the past?"

Word Bank

artifact: any object made or used by people
attribute: characteristics or properties of an object such as size, color, or shape
category: a group within a classification
classification: systematic arrangement in groups or categories
classify: the process of arranging objects in groups or categories

Uncover Prior Knowledge

1. Ask students: Have you ever placed objects such as bottle caps, T-shirts, trading cards, beads, marbles, etc., in groups? If so, what were the objects? How did you group them? What was your purpose for grouping them?
2. Have as many students as possible share their responses.

Discover New Knowledge

How do archaeologists study the past?

Inform the students that this question will guide their learning. Indicate the Word Bank words (artifact, attribute, category, classification, and classify) and inform students that they will use these words as tools and define them during the lesson.

Doohickey Kits

1. Divide the class into teams according to the number of Doohickey Kits and distribute the kits.
2. Have each group sort the objects into categories chosen by their team and record how they sorted the objects on a piece of paper.
3. Take the class on a tour to each group's classification. Have the classifiers explain their classification by describing which attributes they used to place an object in a certain category (shape, color, function, type of material, other).



4. Compare and contrast how each group chose to classify the objects.
5. Students return to their original group.
6. Explore with students the idea that one classification system is not better than another. The classification system depends on what the classifier wants to know. When archaeologists bring artifacts back to the laboratory, they decide what they want to know, and using classification, organize the data accordingly.
7. Devise some simple questions that might be answered by classifying the objects in the Doochickey Kits. For example: What colors are present? How many different shapes are there (name them)? The students will need to reclassify the objects to answer each question. Briefly share some examples of how their classification systems changed.
8. Have the groups devise a more open-ended question such as: How might these objects be used? From what kinds of materials are common household objects made? Have groups state their question and describe how they reclassified their objects. Remind students that not all questions may be answered with the objects at hand; questions must be appropriate for what is available.
9. Assist students with defining **classification**, **classify**, **category**, and **attribute** and adding them to their Word Banks.
6. Have students choose a question they would like to answer.
7. Have students cut out the artifacts and classify them to answer their question.
8. Ask students:
 - What question did you ask?
 - How well did your classification work to answer your question? Explain.
 - Do you need more evidence to answer your question? If so, what kind of evidence might you try to collect?
 - Why is classification a useful tool for studying the past?
 - If some of the artifacts (for example, all of the children's toys) had been removed from this historic home site, how would your classification change? How would your interpretation change?

Reflect on New Knowledge

1. Ask students: (Use Misconception Alert: Classification to guide the discussion.)
 - How does classification help archaeologists analyze and interpret artifacts? How does it help archaeologists learn about people who lived in the past?
 - How does classification help other scientists?
 - How might classification be useful in everyday life?
2. Give students a few minutes to write what "Classification" means to them on their "Investigating Shelter: Understandings" sheet. You may want to collect the sheets to check for understanding, and then return them to the students.

Artifacts from a Historic Home

1. Remind students that archaeologists study how people lived in the past.
2. Distribute a copy of the "Artifacts from a Historic Home" to each team of students.
3. Assist students with defining **artifact** and adding it to their Word Banks.
4. Have students imagine they are archaeologists who have found these artifacts in and around an old historic home.
5. As they observe the artifacts, what questions might they ask about how people lived at this home? List their questions on the board.

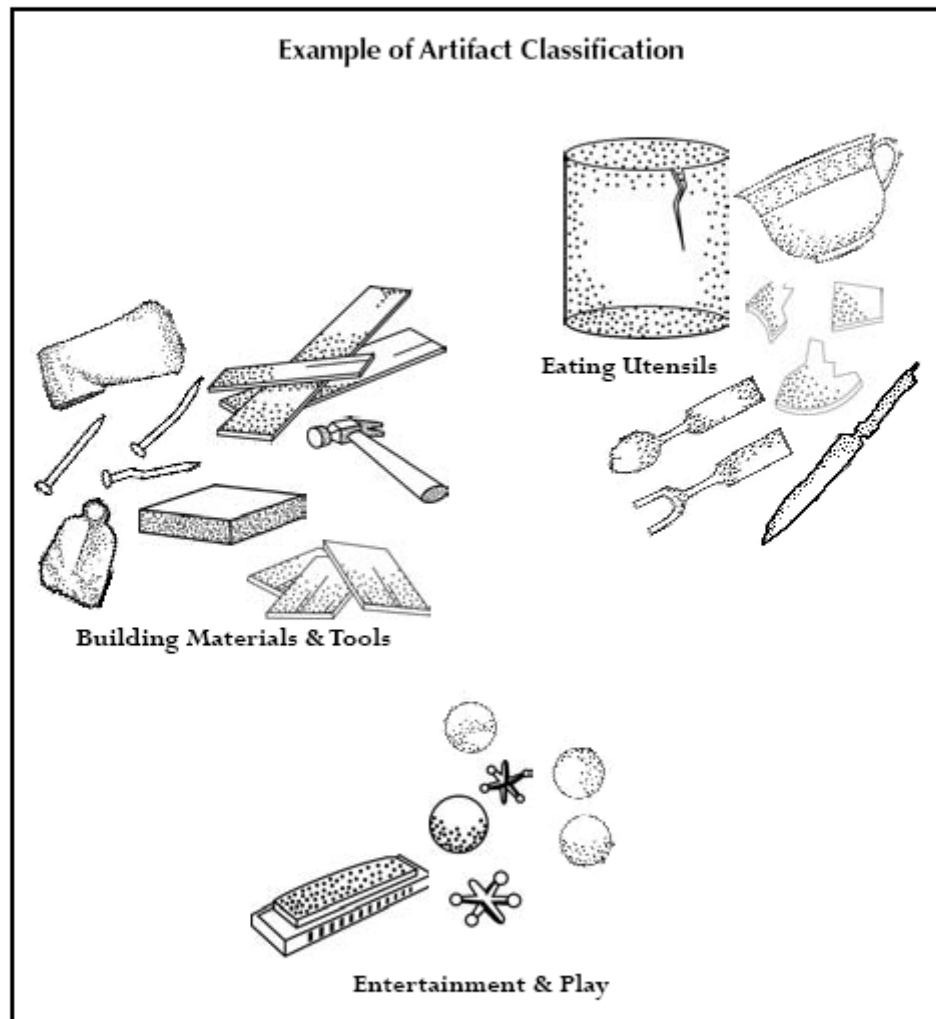
Whole Class Assessment

The assessment for Lesson Five is located on page 60. This assessment will assess students' knowledge of Lesson Four: Observation, Inference, and Evidence; Lesson Five: Classification, and Lesson Six: Context. You will need to set up

 Investigating Shelter

ahead of time. While the assessment takes some preparation, it is very engaging for the students and provides an active means for them to solidify

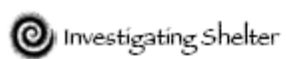
their understanding of the concepts they will need to complete the archaeological investigation of a shelter in Lesson Eight.





Artifacts from a Historic Home





Notes



Context

(Adapted from *Intrigue of the Past*, Smith et al. 1996)

Enduring Understanding

Using the tools of scientific and historical inquiry, archaeologists study shelters and learn how people lived in them.

Essential Question

How do archaeologists study the past?

What Students Will Learn

- Archaeologists study artifacts in context to learn about past people.

What Students Will Do

- Students will demonstrate the importance of artifacts in context.

Assessment

Students will continue to conduct an investigation of a room from a modern home to understand the importance of context in archaeological inquiry.

Materials

For Each Student

- An index card
- The “Instructions and Checklist for the Context Game” (pages 55–56)
- “Old Ghost Town Dilemma” (page 57)

For the Whole Class

- A sheet of paper to record guesses in context game
- A bell or other signal

6 Lesson Six

SUBJECTS: social studies, language arts, science

SKILLS:

- **Bloom’s Taxonomy:** remember, understand, apply, create, evaluate
- **Facets of Understanding:** explanation, interpretation, application, self-knowledge

DURATION: 30 to 60 minutes

CLASS SIZE: any, groups of four

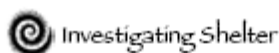
NATIONAL STANDARDS: social studies, history, language arts, science (see Appendix 3, page 155)

Background Information

The things that people own can tell something about the owners. The objects a person possesses can indicate a person’s age, gender, and interests. For example, a baseball bat and a football helmet in someone’s bedroom suggest that the owner likes sports. Posters of pets and a collection of stuffed animals could mean that the person is an animal lover. The objects (artifacts) can tell a complete story only if they are found together, where their owners left them (in context). Archaeologists rely on the objects that people made (artifacts) and where they left them (context) to learn the story of past people.

Imagine a beautifully painted pottery bowl. It has a very different meaning if it is found at a prehistoric site in a grave than if it is found full of corn in an ancient storage room. Its meaning changes further if it is found in someone’s modern living room—the bowl has now lost its original context and all connection with its prehistoric owners. It has become only a thing, and cannot tell us very much about the people who made or used it.

Archaeologists preserve the context of artifacts they recover from sites by recording the location of everything they find. The artifact and its context provide more information to the



archaeologist than could the artifact by itself. When context is lost, information is lost. “The Context Game” in this lesson will demonstrate that removing artifacts from a site removes them from their context and makes it very difficult to get a complete understanding of past people.

Misconception Alert! Artifacts and Context

Lewis Binford (2002), a famous archaeologist, was once asked what he did for a living. He told the man he was an archaeologist, and the man replied, “That must be wonderful, for the only thing you have to be to succeed is lucky.” It took Dr. Binford some time to explain to the man that archaeologists don’t depend on luck and they don’t simply “dig up the past.”

Archaeology really isn’t about discovery, but rather about piecing together a picture of the past by decoding the information in objects and their relationship to one another (context). Archaeologists are not interested in finding one fabulous artifact by itself, because it can’t tell them much about the past. Instead, they reconstruct past lifeways through the painstaking work of recording and studying all the artifacts in a site and their relationship to each other.

Preparing to Teach

1. Make a copy of the “Instructions and Checklist for the Context Game,” the “Context Assessment,” and the “Old Ghost Town Dilemma” for each student.
2. Gather additional supplies needed for the Context Game (index cards, a bell or signal, and a recording sheet).
3. Post the Word Bank words.
4. Post the essential question “How do archaeologists study the past?”

Word Bank

context: the relationship artifacts have to each other and the situation in which they are found
dilemma: a problem that is hard to solve

Uncover Prior Knowledge

1. Ask students:
 - If I had never met you and walked into your bedroom, what could I infer about you from the things you have there?
 - Could I infer if you were a boy or a girl?
 - Could I infer what your interests are?
 - Could I infer if you share your room?
2. Tell students: Think of something in your bedroom that is very special to you. How does that object tell something about you, along with everything else in your room? Everything together tells about you because it is in context. You have selected certain things to have, and these things tell about you when they are all found together.
3. Have students imagine that their special object has been removed and is found in the city park or other familiar public place. How does this change what could be known about you? When it is removed from your room, the object alone may tell little, if anything, about you, and your room is now missing an important piece of information about you. Context has been disturbed, and information about you is now lost.
4. Assist students with defining **context** and adding it to their Word Banks.

Discover New Knowledge

How do archaeologists study the past?

Inform the students that this question will guide their learning. Indicate the Word Bank words (context and dilemma) and inform students that they will use these words as tools and define them during the lesson.



Context Game

1. Distribute the "Instructions and Checklist for the Context Game" to each student.
2. Divide class into groups of four. Assign each group a number from 1–6. Note: If you have fewer or more than 24 students, reduce or increase the number of groups and adjust the group size accordingly. Give each group 5–6 cards (use fewer cards if there are fewer than six groups). As a group, the students choose a room in a house such as a bathroom, a kitchen, or an attic. They decide what objects (artifacts) in the room make it distinctive; then they draw and/or write the objects on the cards. The stack of cards from each group is passed to the next group, until every group has seen every stack and inferred the function of each place. Be sure that students do not hear the identity of other groups' rooms. After the first pass, the card handler will remove one card from the stack before passing it on. When every group has seen all the stacks, the presenters share their inferences and learn the identity of the room from the other groups.
3. Review the procedure for the game by reading "Instructions and Checklist for the Context Game" with the students.
4. Play the game. Refer to the instructions to assist students at appropriate times.
5. Use the background information and Misconception Alert: Artifacts and Context to illustrate the importance of context to the study of archaeology.

Reflect on New Knowledge

1. Distribute the "Old Ghost Town Dilemma" to each student.
2. In their groups, have students read the dilemma and the possible responses.
3. Have them discuss how they would solve the dilemma. They don't have to come to a group agreement.

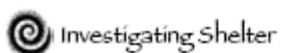
4. Have each group share the results of their discussion.
5. Tell students that it may not be safe to approach unknown people. Tell them that their own safety is the most important consideration in any decision.
6. Assist students with defining dilemma and adding it to their Word Banks.
7. Give students a few minutes to write what "Context" means to them on their "Investigating Shelter: Understandings" sheet. You may want to collect the sheets to check for understanding, and then return them to the students.

Assessment

The assessment for Lesson Six is located on page 60. This assessment will assess students' knowledge of Lesson Four: Observation, Inference, and Evidence; Lesson Five: Classification, and Lesson Six: Context. You will need to set up ahead of time. While the assessment takes some preparation, it is very engaging for the students and provides an active means for them to solidify their understanding of the concepts they will need to complete the archaeological investigation of a shelter in Lesson Eight.



Archaeology is hard work.



ANSWER KEY

CONTEXT GAME

The more artifacts you have, the easier it is to infer what the room is because there are more relationships (context) to give you clues. The type of artifacts present may also provide important clues to the use of the room.

ANSWER KEY

OLD GHOST TOWN DILEMMA

There is no right answer, but the following information will help you guide discussion and assist students with deciding on the best course of action.

- *Ask the family politely if they have read the sign.* – This could be a good first step, but it may not solve the problem. It is also possible that the family cannot read English.
- *Ignore them; it is really none of your business.* – While it may not be wrong to simply watch the artifacts be taken, inaction will not help protect the archaeological record.
- *Tell them they are damaging an archaeological site.* – This might be a good way to educate the family about archaeology and the importance of context.
- *Tell them they are breaking the law.* – The family might not like being accused of breaking the law.
- *Say nothing and try to hike out first to find a ranger and report them.* – This solution will avoid a confrontation, but the site will probably be damaged before the ranger can return.
- *Other.* – This could be a combination of the above or a new option.



Archaeologists work slowly and carefully to preserve the context of artifacts.



Instructions and Checklist for the Context Game

You are going to play a game to help you understand the meaning of and the importance of context in the science of archaeology. Put a check on the line after you complete each step.

Get Ready!

1. _____ Select one person in your group to be the:

Name

Recorder _____ Records inferences.

Card Handler _____ Passes and receives cards.

Checker _____ Checks off each task on this sheet as it is completed.

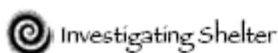
Presenter _____ Presents inferences to the whole class.

2. _____ **Card Handler:** Write your group number on one side of each card, then turn cards over to the blank side.
3. _____ **Card Handler:** Give a card to each person in your group.
4. _____ **Recorder:** Create a place to record your answers. Down the side of a sheet of paper, write 1–6 (or the number of the groups in the classroom).

Choosing a Room and Making Your Drawing

Listen to your teacher describe the next three steps before completing them.

1. _____ As a group, decide on a room in a home whose artifacts tell something about how the room is used. A bedroom or a playroom could be used.
2. _____ Brainstorm artifacts that would be found in the room.
3. _____ Each person chooses one artifact and makes a drawing of that object on the blank side of her/his card. For example, if your group chose an entertainment room, one student might draw a TV, another student a CD, another student a couch, another student a bowl of popcorn, etc.



Get Set!

____ **Card Handler:** The Card Handler collects your group's cards into one stack.
Listen to your teacher as he/she explains the directions!

Directions

- a. At the sound of a bell, the Card Handler in Group 1 will pass their stack of cards to the Card Handler in Group 2; Group 2 to Group 3 and so on.
- b. Upon receiving the cards, the Card Handler lays the cards out so everyone in the group can see them.
- c. Your group looks at the cards and guesses (or infers) what the room is. Discuss quietly so that other groups cannot hear.
- d. The **Recorder** looks at the number found on the card's backside and writes the guess next to that number on the recording sheet.
- e. **Card Handler Important!:** On the second pass of cards between groups, remove one object (artifact) from the stack of cards and place it off to one side so it does not get mixed up with the other sets of cards. Repeat this for every pass until you are done.
- f. Continue until everyone has studied each group's cards, and the Recorder has recorded inferences. By the last rotation each group will receive only one card. Each time you hear the bell, you will pass the set of cards to the next group.

Go!

____ Play the game.

Conclusion

1. ____ **Presenter:** The Presenter from each group tells the whole class what room they guessed for Group 1, and Group 1 shares the identity of their room. If your group made an incorrect inference, the Presenter records the correct identity.
2. ____ Repeat for each group.

Final Question

What did you notice about your ability to make inferences as objects (artifacts) were removed? Was it easier or more difficult to make inferences? Explain your answer.



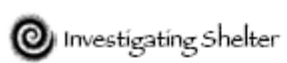
The Old Ghost Town Dilemma

Imagine you are visiting an old ghost town in a state park with your family. Several rock buildings are still partially standing. There is a large sign by the ruins saying, "These walls are very fragile! Do not take anything, and do not walk on or go into the ruins." You are eating your lunch when a family arrives and ignores the sign. Kids are walking on top of the ruins and are picking up glass fragments and old nails and putting them in their pockets.

What do you do? Would you respond in any of the following ways? You might choose more than one answer. Think about what you have learned about context as you choose your answer.

- Ask the family politely if they have read the sign.
- Ignore them; it is really none of your business.
- Tell them they are damaging an archaeological site.
- Tell them they are breaking the law.
- Say nothing and go to the Park Headquarters to find a ranger and report them.
- Other.





Notes:



4-5-6 Lessons Four-Five-Six

Assessment

Materials

For Constructing the Family Room Site

- Map and objects for setting up the “Family Room Site” Assessment
- Bags for collecting artifacts from the “Family Room Site” investigation
- Butcher paper to form an 8-foot by 10-foot rectangle when taped together or a sheet of lightweight plastic
- Black markers for drawing on butcher paper
- Carpenter’s square and 10-foot tape measure
- Post-it notes or masking tape for labeling artifacts

To Construct the Family Room Site

1. Prepare the “Family Room Site” ahead of time. A map of a family room has been provided on page 62. Reproduce this map on a piece of butcher paper 8-foot by 10-foot using the directions on page 63. This process takes approximately 1–2 hours depending on accuracy and level of detail. Alternatively you can create the “Family Room Site” on the floor of your classroom or the gymnasium or other large space using masking tape. It may be possible to make the site closer to life size using this alternative, but you will have to recreate the site every time you teach this unit.
2. Bring objects from your home that represent day-to-day activities that would occur in a family room, such as books, CDs, objects that indicate various hobbies, toys, family photos, and decorative objects. Additionally, bring the remains of a special event such as a birthday celebration. Distribute these objects on the map in each of the four quadrants where they would most likely be found in a family room. Provide

enough objects to tell a story about the people who use the room, but not so many that students can’t handle the complexity. (Note: The artifacts will be used without the map in the assessment for Lesson Five. The map and the artifacts will be used in the assessment for Lesson Six.)

3. Find four sturdy bags to hold all of the artifacts from each quadrant of the room. Label each bag with the quadrant number.

Word Bank

quadrant: any one of the four quarters into which a thing has been divided

■ Lesson Four Assessment

Investigation of a “Family Room Site”

Materials

For Each Student

- Lesson Four Assessment: “Family Room Site” data collection sheet (pages 64–65)

Procedure

1. Lay out the “Family Room Site” that you have recreated on butcher paper or plastic on the classroom floor or in a larger space such as the library or gymnasium.
2. Divide students into teams of two.
3. Distribute a “Family Room Site” data collection sheet to each student.
4. Assist students with defining **quadrant** and adding it to their Word Banks.
5. Have students rotate around the site and record observations and inferences for each quadrant and complete their data collection sheet. Instruct them to treat the objects with care and respect. They may pick them up to examine them, but must replace them in their exact location.

 Investigating Shelter

6. Explain to students that after archaeologists study an archaeological site, they gather the data (objects and records) in an orderly way and take everything to a laboratory, university, or museum for further study.
7. To simulate this gathering of data, use the four bags labeled to correspond with the four quadrants. Assign two students per quadrant to label each object with the quadrant number (use sticky notes or masking tape), collect the objects within each quadrant, and place them in the corresponding bag.

■ Lesson Five Assessment

Classification of the “Family Room Site”

Materials

For Each Student

- Lesson Five Assessment: “Family Room Site” data collection sheet (page 66)

For the Whole Class

- Bags of “Family Room Site” artifacts from each quadrant

Procedure

1. Place the bags of objects that were collected from each of the quadrants in the Lesson Four Assessment: “The Family Room Site” on the floor where the class can gather in a circle.
2. Have students bring their “Family Room Site” Assessment data collection sheet from Lesson Four and gather in a circle around the bags of artifacts from the four quadrants.
3. Ask students: What is the archaeological word for objects? (*artifacts*)
4. Have students share the question they choose in Step 4 of the “Family Room Site” Assessment data collection sheet. Write these on the board.
5. Have all of the students classify the artifacts.
6. Have students select one question they

would like to work with further, and have them write this question on their data collection sheet.

7. Have students complete the remainder of the data collection sheet.
8. How did classification help you learn about the people in your investigation?

■ Lesson Six Assessment

Context of the “Family Room Site”

Materials

For Each Student

- “Context Assessment” (page 67)

For the Whole Class

- The display of the “Family Room Site” with the celebration artifacts removed

Procedure

1. Return all of the artifacts except the celebration artifacts to their place (or as close as possible) in the “Family Room Site” and have students gather around it.
2. Have students refer to their Lesson Four Assessment data collection sheets (page 44).
3. Ask students:
 - How has the site changed?
 - How does this change affect what could be learned about people who used this site?
 - Why is it important to study artifacts in context?
4. Distribute the “Context Assessment” and have students complete it.



ANSWER KEY

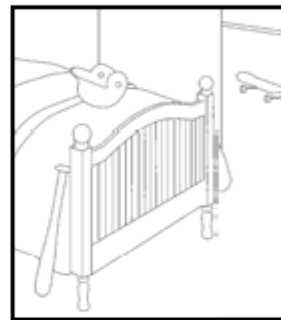
CONTEXT ASSESSMENT



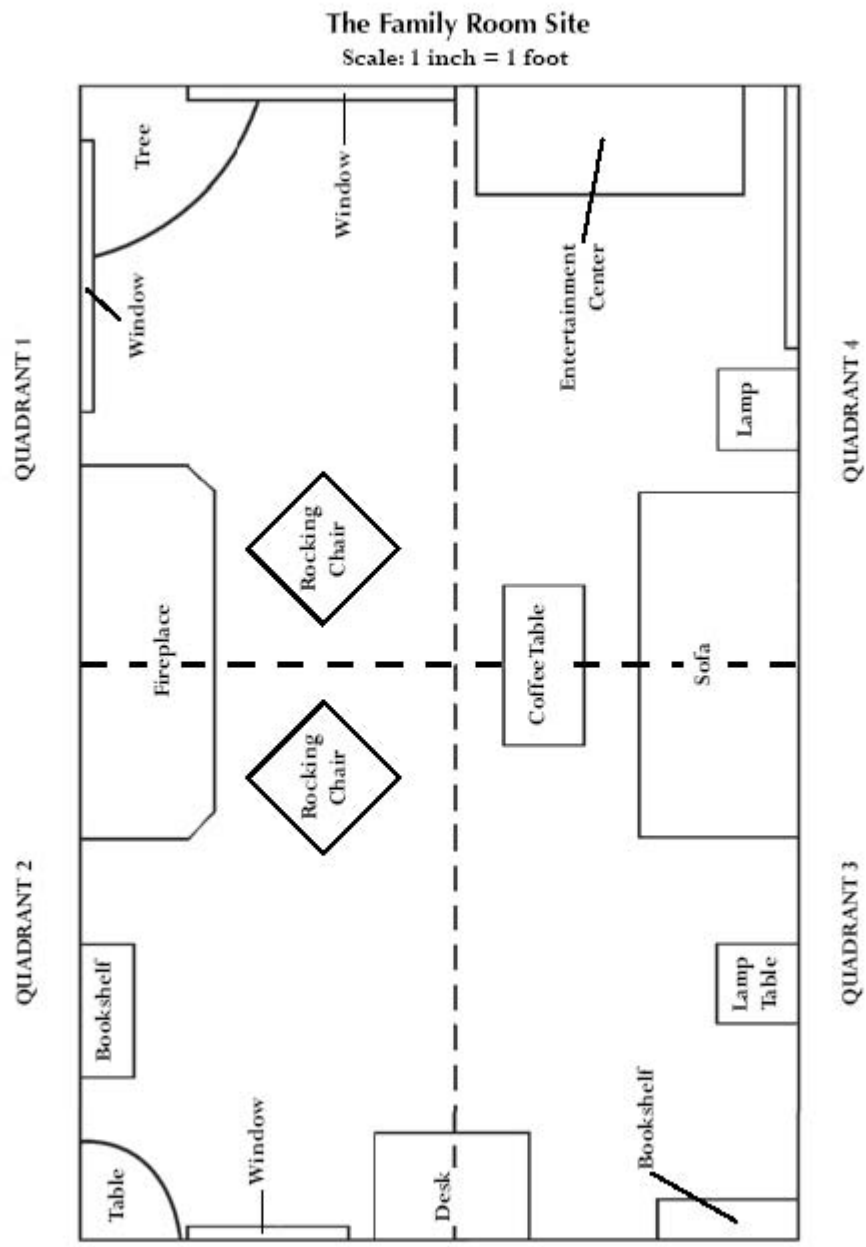
X



*

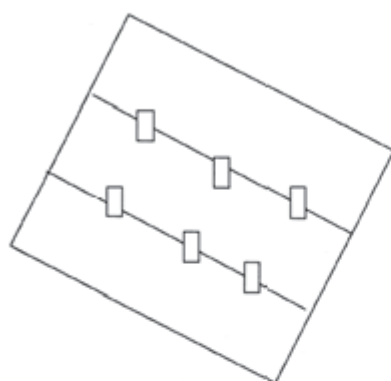
☐

4. It is easier to learn more about X than ☐ because there are more objects and relationships (context) to observe
5. When artifacts are removed from archaeological sites there are fewer objects and relationships (context) to observe and interpretations will probably change.

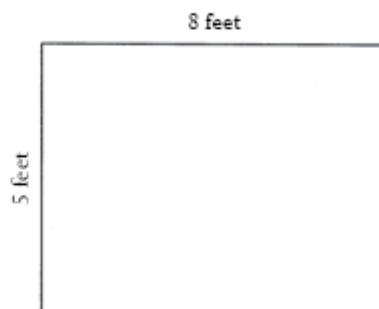




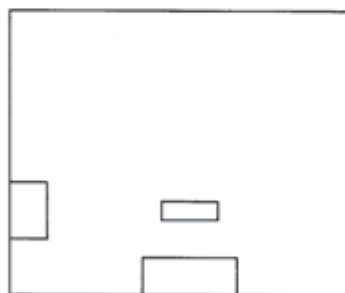
Instructions for Creating the Family Room Site



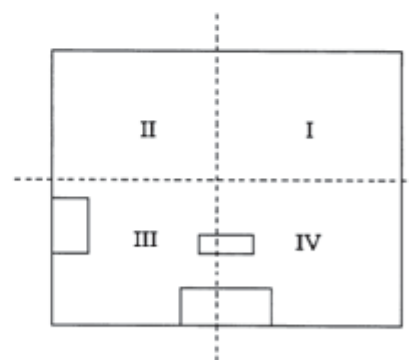
Step 1: Cut butcher paper into three, 10-foot long pieces and join them with tape on the back side. Or, cut a piece of clear plastic to measure about 8-feet by 10-feet.



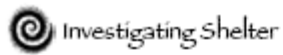
Step 2: Draw a rectangle 8-feet by 5-feet. Use a carpenter's square for right angles.



Step 3: Use the carpenter's square to draw placement of furniture (using the "Family Room Site" map on page 62). Use the outside line for measuring. Sketch in plants. Perfection is not necessary; the relationship between objects is more important.



Step 4: Draw two dotted lines through the map to create four quadrants. Label the quadrants I–IV in a counter clockwise direction.



Name _____

Lesson Four Assessment: "Family Room Site"

1. Make observations of the site and its objects. List your observations. Next to each observation, make an inference about the people who used this room.

Quadrant 1.

Object	Observations	Inferences

Quadrant 2.

Object	Observations	Inferences

Quadrant 3.

Object	Observations	Inferences

Quadrant 4.

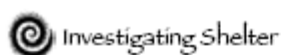
Object	Observations	Inferences



2. What do you wonder about as you observe the room? Write three or more questions.

3. Choose your best question and write it below.

4. Answer the question in step 3 using data and evidence from the room.



Name _____

Lesson Five Assessment: "Family Room Site"

1. Write the class's chosen investigation question.
2. Classify the room's artifacts to answer your question. Sort the artifacts on the floor or a table. Record the titles of each group in the circles below. You may need more circles.

_____ Group 1 _____ Number of Artifacts	_____ Group 2 _____ Number of Artifacts
_____ Group 3 _____ Number of Artifacts	_____ Group 4 _____ Number of Artifacts

3. Count the artifacts in each group and record the number in each circle. Create a bar graph or pie chart to show your data.
4. Based on your classification, answer the class's question as best you can.
5. Did classifying the artifacts give you more information, or change what you thought about how people used the room? Explain.



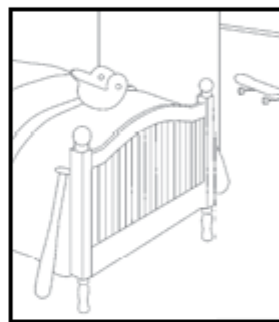
Name _____

Context Assessment

Directions:

Here are three drawings of the same room.

1. Put a ☐ under the picture that would tell you the least about the person who used this room.
2. Put a * under the picture that would tell you something about the person who used this room.
3. Put an X under the picture that would tell you the most about the person who uses this room.



- _____
- _____
- _____
4. Why can you learn more about X than ☐ ?

5. Remembering the Context Game, if artifacts are removed from an archaeological site, could you learn as much? Explain your answer.

APPENDIX B

RELEVANT MONTANA EDUCATION STANDARDS

(OPI, 2000 & 2006)

Science Content Standard 1

A proficient student will:

End of Grade 4	End of Grade 8	Upon Graduation
1.3 use data to describe and communicate the results of scientific investigations	1.3 review, communicate and defend results of investigations, including considering alternative explanations	1.3 review evidence, communicate and defend results, and recognize that the results of a scientific investigation are always open to revision by further investigations. (e.g., through graphical representation or charts)
1.4 use models that illustrate simple concepts and compare those models to the actual phenomenon	1.4 create models to illustrate scientific concepts and use the model to predict change (e.g., computer simulation, stream table, graphic representation)	1.4 analyze observations and explain with scientific understanding to develop a plausible model (e.g., atom, expanding universe)
1.5 identify a valid test in an investigation	1.5 identify strengths and weakness in an investigation design	1.5 identify strengths, weaknesses, and assess the validity of the experimental design of an investigation through analysis and evaluation
1.6 identify how observations of nature form an essential base of knowledge among the Montana American Indians	1.6 compare how observations of nature form an essential base of knowledge among the Montana American Indians	1.6 explain how observations of nature form an essential base of knowledge among the Montana American Indians

Social Studies Content Standard 1

Students access, synthesize, and evaluate information to communicate and apply social studies knowledge to real world situations.

Rationale

Every discipline has a process by which knowledge is gained or inquiry is made. In the social studies, the information inquiry process is applied to locate and evaluate a variety of primary and secondary sources of information. Information gathered in this manner is then used to draw conclusions in order to make decisions, solve problems and negotiate conflicts. Finally, as individuals who participate in self-governance, the decision making process needs to be understood and practiced by students as they prepare to take on civic and economic responsibilities.

Benchmarks

Students will:

End of Grade 4	End of Grade 8	Upon Graduation—End of Grade 12
1. identify and practice the steps of an inquiry process (i.e., identify question or problem, locate and evaluate potential resources, gather and synthesize information, create a new product, and evaluate product and process). 2. evaluate information quality (e.g., accuracy, relevance, fact or fiction). 3. use information to support statements and practice basic group decision making strategies in real world situations (e.g., class elections, playground and classroom rules, recycling projects, school stores).	1. apply the steps of an inquiry process (i.e., identify question or problem, locate and evaluate potential resources, gather and synthesize information, create a new product, and evaluate product and process). 2. assess the quality of information (e.g., primary or secondary sources, point of view and embedded values of the author). 3. interpret and apply information to support conclusions and use group decision making strategies to solve problems in real world situations (e.g., school elections, community projects, conflict resolution, role playing scenarios).	1. analyze and adapt an inquiry process (i.e., identify question or problem, locate and evaluate potential resources, gather and synthesize information, create a new product, and evaluate product and process). 2. apply criteria to evaluate information (e.g., origin, authority, accuracy, bias, and distortion of information and ideas). 3. synthesize and apply information to formulate and support reasoned personal convictions within groups and participate in negotiations to arrive at solutions to differences (e.g., elections, judicial proceedings, economic choices, community service projects).

Social Studies Content Standard 3

Students apply geographic knowledge and skills (e.g., location, place, human/environment interactions, movement, and regions).

Rationale

Students gain geographical perspectives on Montana and the world by studying the Earth and how people interact with places. Knowledge of geography helps students address cultural, economic, social, and civic implications of living in various environments.

Benchmarks

Students will:

End of Grade 4	End of Grade 8	Upon Graduation—End of Grade 12
1. identify and use various representations of the Earth (e.g., maps, globes, photographs, latitude and longitude, scale).	1. analyze and use various representations of the Earth (e.g., physical, topographical, political maps, globes; geographic information systems; aerial photographs; satellite images) to gather and compare information about a place.	1. interpret, use, and synthesize information from various representations of the Earth (e.g., maps, globes, satellite images, geographic information systems, three-dimensional models).
2. locate on a map or globe physical features (e.g., continents, oceans, mountain ranges, land forms) natural features (e.g., flora, fauna) and human features (e.g., cities, states, national borders).	2. locate on a map or globe physical features (e.g., continents, oceans, mountain ranges, land forms) natural features (e.g., flora, fauna) and human features (e.g., cities, states, national borders) and explain their relationships within the ecosystem.	2. differentiate and analyze the relationships among various regional and global patterns of geographic phenomena (e.g., land forms, soils, climate, vegetation, natural resources, population).
3. describe and illustrate ways in which people interact with their physical environment (e.g., land use, location of communities, methods of construction, design of shelters).	3. analyze diverse land use and explain the historical and contemporary effects of this use on the environment, with an emphasis on Montana.	3. assess the major impacts of human modifications on the environment (e.g., global warming, deforestation, erosion, pollution).
4. describe how human movement and settlement patterns reflect the wants and needs of diverse cultures.	4. explain how movement patterns throughout the world (e.g., people, ideas, diseases, products, food) lead to interdependence and/or conflict.	4. analyze how human settlement patterns create cooperation and conflict which influence the division and control of the Earth (e.g., treaties, economics, exploration, borders, religion, exploitation, water rights).
5. use appropriate geographic resources (e.g., atlases, databases, charts, grid systems, technology, graphs, maps) to gather information about local communities, reservations, Montana, the United States, and the world.	5. use appropriate geographic resources to interpret and generate information explaining the interaction of physical and human systems (e.g., estimate distance, calculate scale, identify dominant patterns of climate and land use, compute population density).	5. select and apply appropriate geographic resources to analyze the interaction of physical and human systems (e.g., cultural patterns, demographics, unequal global distribution of resources) and their impact on environmental and societal changes.
6. identify and distinguish between physical system changes (e.g., seasons, climate, weather, water cycle, natural disasters) and describe the social and economic effects of these changes.	6. describe and distinguish between the environmental effects on the earth of short-term physical changes (e.g., floods, droughts, snowstorms) and long-term physical changes (e.g., plate tectonics, erosion, glaciation).	6. Analyze the short-term and long-term effects that major physical changes in various parts of the world have had or might have on the environments (e.g., land use, population, resources).
7. describe and compare the ways in which people in different regions of the world interact with their physical environments.	7. describe major changes in a local area that have been caused by human beings (e.g., a new highway, a fire, construction of a new dam, logging, mining) and analyze the probable effects on the community and environment.	7. describe and compare how people create places that reflect culture, human needs, government policy, and current values and ideas as they design and build (e.g., buildings, neighborhoods, parks, industrial and agricultural centers, farms/ranches).

Social Studies Content Standard 4

Students demonstrate an understanding of the effects of time, continuity, and change on historical and future perspectives and relationships.

Rationale

Students need to understand their historical roots and how events shape the past, present, and future of the world. In developing these insights, students must know what life was like in the past and how things change and develop over time. Students gain historical understanding through inquiry of history by researching and interpreting historical events affecting personal, local, tribal, Montana, United States, and world history.

Benchmarks

Students will:

End of Grade 4	End of Grade 8	Upon Graduation—End of Grade 12
1. identify and use various sources of information (e.g., artifacts, diaries, photographs, charts, biographies, paintings, architecture, songs) to develop an understanding of the past. 2. use a timeline to select, organize, and sequence information describing eras in history. 3. examine biographies, stories, narratives, and folk tales to understand the lives of ordinary people and extraordinary people, place them in time and context, and explain their relationship to important historical events. 4. identify and describe famous people, important democratic values (e.g., democracy, freedom, justice) symbols (e.g., Montana and U.S. flags, state flower) and holidays in the history of Montana, American Indian tribes, and the United States. 5. identify and illustrate how technologies have impacted the course of history (e.g., energy, transportation, communications). 6. recognize that people view and report historical events differently. 7. explain the history, culture, and current status of the American Indian tribes in Montana and the United States.	1. interpret the past using a variety of sources (e.g., biographies, documents, diaries, eye-witnesses, interviews, internet, primary source material) and evaluate the credibility of sources used. 2. describe how history can be organized and analyzed using various criteria to group people and events (e.g., chronology, geography, cause and effect, change, conflict, issues). 3. use historical facts and concepts and apply methods of inquiry (e.g., primary documents, interviews, comparative accounts, research) to make informed decisions as responsible citizens. 4. identify significant events and people and important democratic values (e.g., freedom, equality, privacy) in the major eras/civilizations of Montana, American Indian, United States, and world history. 5. identify major scientific discoveries and technological innovations and describe their social and economic effects on society. 6. explain how and why events (e.g., American Revolution, Battle of the Little Big Horn, immigration, Women's Suffrage) may be interpreted differently according to the points of view of participants, witnesses, reporters, and historians. 7. Summarize major issues affecting the history, culture, tribal sovereignty, and current status of the American Indian tribes in Montana and the United States.	1. select and analyze various documents and primary and secondary sources that have influenced the legal, political, and constitutional heritage of Montana and the United States. 2. interpret how selected cultures, historical events, periods, and patterns of change influence each other. 3. apply ideas, theories, and methods of inquiry to analyze historical and contemporary developments, and to formulate and defend reasoned decisions on public policy issues. 4a analyze the significance of important people, events, and ideas (e.g., political and intellectual leadership, inventions, discoveries, the arts) in the major eras/civilizations in the history of Montana, American Indian tribes, the United States, and the world. 4b analyze issues (e.g., freedom and equality, liberty and order, region and nation, diversity and civic duty) using historical evidence to form and support a reasoned position. 5. analyze both the historical impact of technology (e.g., industrialization, communication, medicine) on human values and behaviors and how technology shapes problem solving now and in the future. 6. investigate, interpret, and analyze the impact of multiple historical and contemporary viewpoints concerning events within and across cultures, major world religions, and political systems (e.g., assimilation, values, beliefs, conflicts). 7. Analyze and illustrate the major issues concerning history, culture, tribal sovereignty, and current status of the American Indian tribes and bands in Montana and the United States (e.g., gambling, artifacts, repatriation, natural resources, language, jurisdiction).

Social Studies Content Standard 6

Students demonstrate an understanding of the impact of human interaction and cultural diversity on societies.

Rationale

Culture helps us to understand ourselves as both individuals and members of various groups. In a multicultural society, students need to understand multiple perspectives that derive from different cultural vantage points. As citizens, students need to know how institutions are maintained or changed and how they influence individuals, cultures and societies. This understanding allows students to relate to people in Montana, tribes, the United States and throughout the world.

Benchmarks

Students will:

End of Grade 4	End of Grade 8	Upon Graduation—End of Grade 12
1. identify the ways groups (e.g., families, faith communities, schools, social organizations, sports) meet human needs and concerns (e.g., belonging, self worth, personal safety) and contribute to personal identity.	1. compare and illustrate the ways various groups (e.g., cliques, clubs, ethnic communities, American Indian tribes) meet human needs and concerns (e.g., self esteem, friendship, heritage) and contribute to personal identity.	1. analyze and evaluate the ways various groups (e.g., social, political, cultural) meet human needs and concerns (e.g., individual needs, common good) and contribute to personal identity.
2. describe ways in which expressions of culture influence people (e.g., language, spirituality, stories, folktales, music, art, dance).	2. explain and give examples of how human expression (e.g., language, literature, arts, architecture, traditions, beliefs, spirituality) contributes to the development and transmission of culture.	2. analyze human experience and cultural expression (e.g., language, literature, arts, traditions, beliefs, spirituality, values, behavior) and create a product which illustrates an integrated view of a specific culture.
3. identify and describe ways families, groups, tribes and communities influence the individual's daily life and personal choices.	3. identify and differentiate ways regional, ethnic and national cultures influence individual's daily lives and personal choices.	3. analyze the impact of ethnic, national and global influences on specific situations or events.
4. identify characteristics of American Indian tribes and other cultural groups in Montana.	4. compare and illustrate the unique characteristics of American Indian tribes and other cultural groups in Montana.	4. evaluate how the unique characteristics of American Indian tribes and other cultural groups have contributed to Montana's history and contemporary life (e.g., legal and political relationships between and among tribal, state, and federal governments).
5. identify examples of individual struggles and their influence and contributions (e.g., Sitting Bull, Louis Riel, Chief Plenty Coups, Evelyn Cameron, Helen Keller, Mohandas Gandhi, Rosa Parks).	5. explain the cultural contributions of, and tensions between, racial and ethnic groups in Montana, the United States, and the world.	5. analyze the conflicts resulting from cultural assimilation and cultural preservation among various ethnic and racial groups in Montana, the United States and the world.
6. identify roles in group situations (e.g., student, family member, peer member).	6. identify and describe the stratification of individuals within social groups (e.g., status, social class, haves and have nots).	6. analyze the interactions of individuals, groups and institutions in society (e.g., social mobility, class conflict, globalization).

Science Content Standard 1

Students, through the inquiry process, demonstrate the ability to design, conduct, evaluate, and communicate the results and form reasonable conclusions of scientific investigations.

Rationale

Students must understand the process of science—how information is gathered, evaluated and communicated to others. Learning by inquiry mirrors the process of science itself. The knowledge and skills related to scientific inquiry enable students to understand how science works. Inquiry allows students to construct an understanding of scientific facts, principles, concepts and applications. In addition, scientific inquiry stimulates student interest, motivation and creativity.

Safety is a fundamental concern in all experimental science. Appropriate safety procedures must be applied when storing, using, and caring for materials.

Benchmarks

A proficient student will:

End of Grade 4	End of Grade 8	Upon Graduation
1.1 develop the abilities necessary to safely conduct scientific inquiry, including (a step-by-step sequence is not implied): (a) asking questions about objects, events, and organisms in the environment, (b) planning and conducting simple investigations	1.1 identify a question, determine relevant variables and a control, formulate a testable hypothesis, plan and predict the outcome of an investigation, safely conduct scientific investigation, and compare and analyze data	1.1 generate a question, identify dependent and independent variables, formulate testable, multiple hypotheses, plan an investigation, predict its outcome, safely conduct the scientific investigations, and collect and analyze data
1.2 select and use appropriate tools including technology to make measurements (including metric units) and represent results of basic scientific investigations	1.2 select and use appropriate tools including technology to make measurements (in metric units), gather, process and analyze data from scientific investigations	1.2 select and use appropriate tools including technology to make measurements (in metric units), gather, process and analyze data from scientific investigations using appropriate mathematical analysis, error analysis, and graphical representation

APPENDIX C

LEARNING PROBES AND PERFORMANCE TASK

(Adapted from Keeley, 2005; Keeley et al., 2007; and Keeley et al., 2008)

Learning Probe 1: Doing Archaeology

Explanation and Notes

Purpose

The purpose of this assessment probe is to elicit students' ideas about the nature of archaeological inquiry. The probe is designed to find out if students can discern the difference between appropriate activities in archaeological inquiry and inappropriate activities and if change their ideas as a result of instruction.

Related Concepts

observation, inference, evidence

Explanation

The statements that best describe archaeological inquiry are A, B, E, F, G, and H. Archaeologists regularly make observations and inferences, rely on the context of artifacts to interpret and explain what they find, and sometimes use historical photographs if they are available to interpret artifacts and sites. Most archaeologists actively help preserve archaeological sites for further study.

Archaeologists do not dig up dinosaurs (C); that is the job of paleontologists. Archaeologists sometimes use experimental methods, but not always (I). They never take artifacts home with them (D); artifacts to the laboratory for further study or to a museum for curation. Archaeologists do not always agree on interpretations of archaeological materials (J).

National Science Education Standards

5-8 The History and Nature of Science

- Scientists formulate and test their explanations of nature using observations, experiments, and theoretical and mathematical models (NSES 1996, p. 171).
- It is part of scientific inquiry to evaluate the results of scientific investigations, experiments, observations, theoretical models, and the explanations proposed by other scientists.

Related Research

Students' perceptions of scientists and how they do their work are usually stereotypical (Driver et al., 1996; AAAS 1993, p. 333). While people of all ages typically admire scientists, they tend to think of their work as uninteresting, not creative, and always performed through "the scientific method." They do not understand that scientists explore all aspects of the world in a variety of ways and their investigations are driven by a variety of questions.

Procedure

The probe was administered at the beginning of the unit and again at the end of the unit to see if students gain new knowledge and to discern how they might organize new knowledge. Students were not interviewed about their responses to the probe.

Learning Probe 1: Doing Archaeology

Put an X next to the statements you think describe what archaeologists do.

- _____ A Make observations.
- _____ B Ask questions about how people lived in the past.
- _____ C Dig up dinosaurs.
- _____ D Keep artifacts in their personal collections.
- _____ E Make inferences by observing artifacts and sites .
- _____ F Rely on context to make explanations.
- _____ G Help preserve sites for future study.
- _____ H Sometimes use historical photographs to interpret what they find.
- _____ I. Always use experimental methods.
- _____ J Always agree with each other on interpretations of archaeological artifacts and sites.
- _____ K Are usually men.

Examine the statements you checked. Use these to describe what an archaeologist does.

Learning Probe 2. Classifying Objects

Explanation and Notes

Purpose

The purpose of this assessment probe is to elicit students' ideas about classifying artifacts and classifying objects in general. The probe is designed to find out if students understand that classification systems should be based on a question or something that the scientist wants to know, if students can and do generate appropriate questions to guide their classifications, and if they can transfer their knowledge of classification to unfamiliar assemblages of artifacts. (See Performance Task on page ____.)

Related Concepts

inquiry, questions

Explanation

The best answer is River's: "You should classify artifacts based on a question or something you want to know." Crystal is correct in saying that artifacts can be classified based on how they are used and Erika is also correct in saying that both Crystal and River are right. However, River's is the best answer because he clearly articulates the relationship between classification and the role of research (inquiry) questions.

National Science Education Standards

Content Standard A (Grades 5-8): Science as Inquiry

- Identify questions that can be answered through scientific investigations. Students should develop the ability to identify their questions with scientific ideas, concepts, and quantitative relationships that guide investigations (NRC 1996, p. 145).

Related Research

No research specifically on children's understanding of the role of questions in scientific inquiry in general, or in the skill of classification in particular was found for this study. According to the Standards in reference to biology, "younger students generally use mutually exclusive rather than hierarchical categories. Young children, for example, will typically use two groups, but older children will use several groups at the same time" (NRC 1996, p. 128). According to the *Benchmarks for Scientific Literacy* (AAAS 1993, p. 103), "The aim is to move students to the realization that there are many ways to classify things but how good any classification (in biology) is depends on its usefulness."

Procedure

The probe was administered after students received instruction on classification in Lesson Five: Classification. Students were interviewed regarding their responses to the probe (see interview form below).

Learning Probe 2: Classifying Objects

Six students were talking about how archaeologists classify artifacts. This is what they said:

Abe: "Artifacts should always be classified in exactly the same way."

River: "You should classify artifacts based on a question or something you want to know."

Ivy: "It doesn't matter how you classify artifacts. They will still tell you the same thing."

Crystal: "Artifacts can be grouped according to how they were used."

Dallas: "No, you always group artifacts based on their shape and color."

Erika: "I think that both River and Crystal are right."

Which student do you think is the most correct? _____

Explain why you think that student is the most correct? Include why you think the other students are not correct.

Learning Probe 2: Classifying Objects
Interview

Tell me what you think about each of the statements.

Abe:

River:

Ivy:

Crystal:

Dallas:

Erika:

If Erika, had not been part of the conversation, which state would you choose as being the most correct? Explain your thinking.

Learning Probe 3: What is archaeological evidence?**Explanation and Notes**Purpose

The purpose of this assessment probe is to elicit students' ideas about what constitutes evidence in archaeology and in other sciences such as biology, earth sciences, and forensics.

Related Concepts

inquiry, context, classification, observation, inference, data

Explanation

The probe is open-ended and asks for a basic definition of the concept of evidence. It also asks for examples of evidence in archaeology and in other science subjects (biology, earth sciences, and forensics).

National Science Education Standards

Content Standard A (Grades 5-8): Science as Inquiry

- Think critically and logically to make the relationships between evidence and explanations. Thinking critically about evidence includes deciding what evidence should be used and accounting for anomalous data.

Related Research

“Students of all ages find it difficult to distinguish between theory and the evidence for it, or between a description of evidence and interpretation of evidence” (AAAS, 1993, p. 332). Students tend to think of evidence as something that is already known to them or something in second hand sources (like an encyclopedia or other publication), rather than something produced from an experiment or an investigation (AAAS, 1993, p. 361).

Procedure

The probe was administered near the end of the unit after students had an opportunity to learn about evidence in Lesson Four: Observation, Inference, and Evidence and to use evidence to interpret and explain the archaeological data they encounter in Lesson Eight. Students were not interviewed about their responses on this probe due to time constraints.

Learning Probe 3: What is evidence?

What is evidence?

How is evidence used in archaeology? Provide an example.

What are some examples of evidence in another science? Biology or earth science or forensics?

Learning Probe 4: Context in Archaeology.**Explanation and Notes**Purpose

The purpose of this assessment probe is to elicit students' ideas about what context is and why it is important in archaeological inquiry. Students should realize that the ability to observe and infer and to build evidence is reduced when context is destroyed.

Related Concepts

inquiry, observation, inference, evidence

Explanation

Drawing A shows the artifact in the context of the archaeological site where it is found. Students could make several inferences about the artifact, e.g., it is in a room of a shelter, it is with an arrow point, it is close to a fire pit, etc.. In Drawing B, the artifact has been removed from its original context at the archaeological site. In this case, observations can be made only about the artifact itself (size, shape, color, decoration, etc.), but not about the circumstances of its deposition.

National Science Education Standards

Content Standard A (Grades 5-8): Science as Inquiry

- Think critically and logically to make the relationships between evidence and explanations.

Related Research

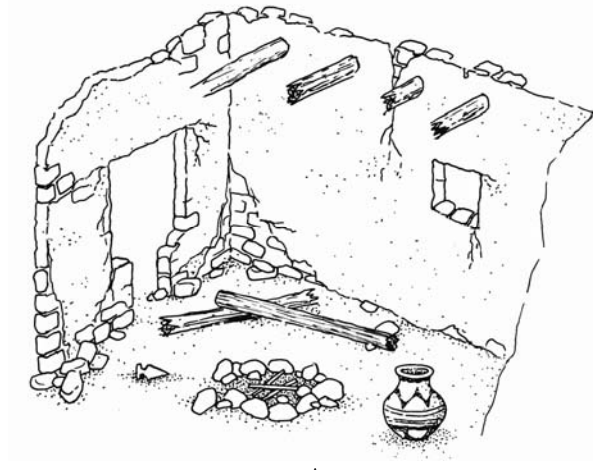
No research on students' understanding of context within scientific inquiry was found for this study. The concept of context is essential to archaeological inquiry. Archaeology is often referred to as "The Science of Context" because archaeologists rely so heavily on the relationships of sites and artifacts to each other and to the environment in which they are found.

Procedure

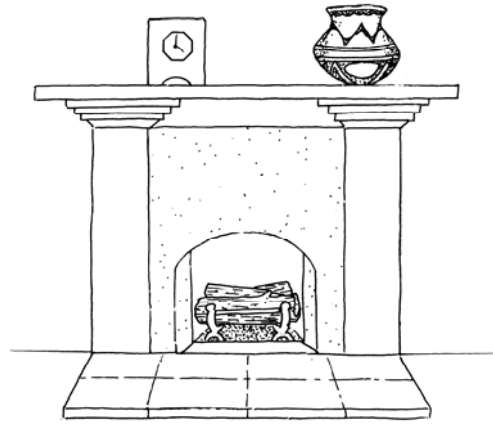
The probe was administered after students had completed Lesson Six: Context. Students were interviewed regarding their responses to the probe (see interview form below).

Learning Probe 4: Context

Context is very important in the study of archaeology. Look at the two drawings below and notice the pottery jar in both drawings.



A



B

What might you infer (conclude) about the pottery jar from Drawing A?

What might you infer (conclude) about the pottery jar from Drawing B?

Are your inferences the same or different for the two drawings? _____ If they are different, why are they different?

Explain what context is and why it is important in the study of archaeology (use the back).

**Learning Probe 4: Context
Interview**

How did you arrive at different inferences (conclusions) about the pottery jar in the two drawings? Explain your thinking.

How did you arrive at the same inferences (conclusions) about the pottery jar in the two drawings? Explain your thinking.

Learning Probe 5: Observation and Inference

Explanation and Notes

Purpose

The purpose of this assessment probe is to determine if students can differentiate between observation and inference in archaeological inquiry. The assessment probe is adapted from Smith et al., 1996).

Related Concepts

inquiry, observation, inference

Explanation

Statements A, C, and D are observations while Statements B, E, and F are inferences. The observation statements refer specifically to attributes of the coin that are readily visible and can be verified by any observer. The inferences statements are conclusions drawn from observing and may or may not be the case. In every inference statement, further observations and/or investigations would be necessary for verify the accuracy of the statement.

National Science Education Standards

Content Standard A (Grades 5-8): Science as Inquiry

- Develop descriptions, explanations, predictions, and models using evidence. Students should base their explanation on what they observed, and as they develop cognitive skills, they should be able to differentiate explanation from description—providing causes for effects and establishing relationships based on evidence and logical argument.

Related Research

Students often do not distinguish between observations and the inferences (or conclusions) that they draw from their observations (Kuhn et al. 1988; Driver et al., 1996). People of all ages seem to jump to conclusions (inferences) immediately upon making an observation. Scientists (including archaeologists) carefully distinguish between the two and present their observations as description and their inferences about the observations as conclusions. Some inferences are chosen for testing and become hypotheses.

Procedure

The probe was administered following instruction in Lesson Four: Observation, Inference, and Evidence as the two skills are used by archaeologists when investigating shelters of the past. The students were interviewed regarding their responses to the probe to better understand their choices and how they arrived at their choices (see interview form below).

Learning Probe 5: Observation and Inference

(Adapted from *Intrigue of the Past: A Teacher's Activity Guide Fourth through Seventh Grades*, Smith et al., 1996).

An Ancient Coin: This coin was found in an archaeological site. The drawings below show both sides of the coin. Look at the coin carefully and decide if each of the statements below is an observation or an inference.



Place an "O" before statements that are observations and an "I" before statements that are inferences.

_____ A. There is a picture of a face on one side of the coin. Explain your answer.

_____ B. The coin tells us that these were deeply religious people. Explain your answer.

_____ C. The words "We Trust the Gods" are printed on the coin. Explain your answer.

_____ D. On one side of the artifact is a drawing of leaves. Explain your answer.

_____ E. We can tell from the artifact that these were peace-loving people. Explain your answer.

_____ F. The face on the coin is picture of the nation's king. Explain your answer.

**Learning Probe 5: Observation and Inference
Interview**

How did you arrive at your answer?

A.

B.

C.

D.

E.

F.

How would you test the inference in E?

Learning Probe 6: The Nature of Science

Explanation and Notes

Purpose

The purpose of this assessment probe is to identify students' ideas about what science is. The students studied archaeology in social studies and used it to further their understanding of history, therefore the probe includes questions about the differences between science and history and their similarities. They are also asked how the study of archaeology has changed their understanding of science. The probe asks them if they think they could be a scientist and in the interview I also asked them if they would like to be scientists. Generally, the probe may help to see if students can distinguish between the processes of science and the nature of scientific knowledge (Abd-El-Khalick et al., 2001, p. 5).

Related Concepts

inquiry, history

Explanation

This assessment probe is based on the work of Abd-El-Khalick et al. (2001) on the Views of Nature of Science Questionnaire (VNOS) research. Some of the questions were used verbatim while others were tailored to reflect student learning in this unit and the needs of this study. The probe is completely open-ended and the follow-up interview is designed to allow students to elaborate on the thoughts they outlined on paper. The probe examines how students view themselves in relationship to science; whether or not they think they are capable of being scientists and whether or not they are interested in being scientists.

National Science Education Standards

Content Standard G (Grades 5-8): Nature of Science

- Scientists formulate and test their explanations of nature using observation, experiments, and theoretical and mathematical models.

Related Research

“Scientific inquiry is more complex than popular conceptions would have it. It is, for instance, a more subtle and demanding process than the naïve idea of ‘making a great many careful observations and then organizing them.’ It is far more flexible than the rigid sequence of steps commonly depicted in textbooks as ‘the scientific method.’ It is much more than just ‘doing experiments,’ and it is not confined to laboratories. More imagination and inventiveness are involved in scientific inquiry than many people realize, yet sooner or later strict logic and empirical evidence must have their day” (AAAS 1993, p. 9). “There are few studies that investigate what elementary-school learning experiences are effective for developing an understanding of the nature of science” (AAAS, 1993, pp. 331-332). Driver and her colleagues in the United Kingdom (1996) developed a framework to describe students’ epistemological reasoning in science

consisting of three levels based on sophistication: Phenomenon-based Reasoning, Relation-based Reasoning, and Model-based Reasoning. Most students they studied were characterized as phenomenon-based reasoners and very few were model-based reasoners with a few students falling in between the two at the relation-based level. Lederman (2007, p. 869) distills five generalizations from 50 years of research on the understanding of the nature of science:

- K-12 students do not typically possess “adequate” conceptions of NOS.
- K-12 teachers do not typically possess “adequate” conceptions of NOS.
- Conceptions of NOS are best learned through explicit, reflective instruction as opposed to implicitly through experiences with simply “doing” science.
- Teachers’ conceptions of NOS are not automatically and necessarily translated into classroom practice.
- Teachers do not regard NOS as an instructional outcome of equal status with that of “traditional” subject matter outcomes.

Procedure

The probe was administered at the end of the unit. The teacher instructed the students that the probe should serve as a way to get them thinking about the questions and not to be overly concerned about the written responses; they would have an opportunity to explain their thinking during the interview. Students were interviewed on all of their responses to the questions; no separate interview was developed.

Learning Probe 6: The Nature of Science

(Outline your thoughts about the following questions.)

What, in your opinion, is science?

How is science different from history?

How is science similar to history?

Could you be a scientist? Why or why not?

Has the study of archaeology changed how you think about science? If so, how? If not, why not?

Probe 6: The Nature of Science

Interview Protocol (No interview sheet was developed to accompany the interview)

Instructions to subjects: "Please explain your answers to each of these questions in your own words. Refer to your written responses, if you need to."

1. What, in your opinion, is science?
2. How is science different from history?
3. How is science similar to history?
4. Could you be a scientist? Why or why not?
5. Would you like to be a scientist? Why or why not?
6. Has the study of archaeology changed how you think about science? If so, how? If not, why not?

Performance Task: Investigating an Archaeological Site

Explanation and Notes

Purpose

The purpose of the performance task is to provide an opportunity for students to apply the five inquiry concepts (observation, inference, classification, context, and evidence) and to use their related skills (observing, inferring, classifying, identifying context, and using evidence) to conduct a self-guided investigation of unfamiliar archaeological data.

Observation was designed to determine how students approached the investigation and what their findings would be.

Related Concepts

questions to guide investigation

Explanation

The performance task was structured by four questions (see below) and brief instructions from the researcher. The task was open; no specific outcomes or conclusions were expected. Application of the five science inquiry concepts were recorded and analyzed.

National Science Education Standards

Content Standard A (Grades 5-8): Science as Inquiry

- Identify questions that can be answered through scientific investigations. Students should develop the ability to identify their questions with scientific ideas, concepts, and quantitative relationships that guide investigations (NRC 1996, p. 145).
- Think critically and logically to make the relationships between evidence and explanations. Thinking critically about evidence includes deciding what evidence should be used and accounting for anomalous data.
- Develop descriptions, explanations, predictions, and models using evidence. Students should base their explanation on what they observed, and as they develop cognitive skills, they should be able to differentiate explanation from description—providing causes for effects and establishing relationships based on evidence and logical argument.

Related Research

While the *National Science Education Standards* (NRC, 1996; NRC 2000) emphasize inquiry in science instruction, students rarely have in-school opportunities to do open inquiry (Gabel, 2006). Students of upper elementary age are capable of conducting self-guided or open inquiries and learning science content at the same time (Metz, 2004).

Procedure

The performance task was completed by all students in dyads after they had completed their classroom investigation of a slave cabin in Virginia. Instructions to the students included showing the students the map, the artifacts, the four guiding questions, and the

context of the site per the information on the Performance Task sheet. The researcher answered some procedural questions while the students were working. When the students finished working, the researcher asked some of the teams a few specific questions regarding their procedures or the concepts that they employed to investigate the data. Application of the five concepts to the archaeological investigation was recorded via audio recorder, written responses to the Performance Task questions, and the researcher's notes.

Performance Task: Investigating an Archaeological Site

Context of the Site

- Located on the Plains of Kansas near a river
- Excavated Earthlodge floor about 40 feet in diameter
- Probably occupied by the ancestors of today's Pawnee Indians

1. What questions do you have about the site?
2. Use the data provided to answer your question(s). You have about 15 minutes.
3. What inferences can you make about this archaeological site? What is your evidence?
4. What other information would you like to have?

APPENDIX D

INSIDE THE CLASSROOM:
OBSERVATION AND ANALYTICAL PROTOCOL

Inside the Classroom Observation and Analytic Protocol

Observation Date: _____ Time: Start: _____ End: _____

School: _____ District: _____

Teacher: _____

PART ONE: THE LESSON

Section A. Basic Descriptive Information

1. Teacher Gender: ☐ Male ☐ Female

Teacher Ethnicity: ☐ American Indian or Alaskan Native
☐ Asian
☐ Hispanic or Latino
☐ Black or African-American
☐ Native Hawaiian or Other Pacific Islander
☐ White

2. Subject Observed: ☐ Mathematics ☐ Science

3. Grade Level(s): _____

4. Course Title (if applicable) _____

Class Period (if applicable) _____

5. Students: _____ Number of Males _____ Number of Females

6. Did you collect copies of instructional materials to be sent to HRI?

☐ Yes ☐ No, explain: _____

APPENDIX E

2000 NATIONAL SURVEY OF SCIENCE QUESTIONNAIRE

2000 National Survey of Science and Mathematics Education

Science Questionnaire

You have been selected to answer questions about your science instruction. If you do not currently teach science, please call us toll-free at 1-800-937-8288.

How to Complete the Questionnaire

Most of the questions instruct you to "darken one" answer or "darken all that apply." For a few questions, you are asked to write in your answer on the line provided. Please use a #2 pencil or blue or black pen to complete this questionnaire. Darken ovals completely, but do not stray into adjacent ovals. Be sure to erase or white out completely any stray marks.

Class Selection

Part of the questionnaire (sections C and D) asks you to provide information about instruction in a particular class. If you teach science to more than one class, use the label at the right to determine the science class that has been randomly selected for you to answer about. (If your teaching schedule varies by day, use today's schedule, or if today is not a school day, use the most recent school day.)

If You Have Questions

If you have questions about the study or any items in the questionnaire, call us toll-free at 1-800-937-8288.

Each participating school will receive a voucher for \$50 worth of science and mathematics materials. The voucher will be augmented by \$15 for each responding teacher. In addition, each participating school will receive a copy of the study's results in the spring of 2001.

Thank you very much. Your participation is greatly appreciated. Please return the completed questionnaire to us in the postage-paid envelope:

2000 National Survey of Science and Mathematics Education
Westat
1650 Research Blvd.
TB120F
Rockville, MD 20850

Design Expert™ by NCS Printed in U.S.A. Mark Reflex® EW-250954-1/854321 HR06

PLEASE DO NOT WRITE IN THIS AREA



[SERIAL]

APPENDIX F

INFORMED CONSENT FORM

SUBJECT CONSENT FORM
FOR
PARTICIPATION IN HUMAN RESEARCH AT
MONTANA STATE UNIVERSITY

Project Title: Science and Archaeological Inquiry

Your child is being asked to participate in a study of how students learn and understand science inquiry skills (observing, inferring, classifying, and using evidence) through the investigation of archaeological data. This study may help me improve curricular materials in both science and social studies.

Your child was identified as a possible subject because he/she is a member of the Ms. Martha Jones' fifth grade class at Riverside Elementary School, Riverside, Montana where the study is being conducted. Archaeology learning activities will be conducted in class as part of the social studies and science curriculum.

If you agree to allow your child to participate, he or she will be asked to complete 4-5 written learning assessments designed to better understand the mental processes children use to perform science inquiry tasks. Your child may be asked to explain his or her thinking in a brief follow-up interview. Your child was chosen to participate in addition assessment activities. He or she will complete a series of 3 performance tasks (classifying objects, using evidence to make inferences, and describing how he/she might conduct an investigation of an archaeological site). The researcher will observe the performance task and ask your child why he/she did what she did (what was the thinking behind his or her choices). Students will perform these tasks in teams of two.

Participation in the study will not involve any physical or emotional risks. The researcher will work closely with Ms. Jones at all times and if any unanticipated difficulties arise, research will cease immediately and the problem will be addressed. The assessment process will provide an added opportunity for your child to reflect on and perhaps solidify his or her learning.

Participation in the study is completely optional and will not affect your child's grade. If you or your child decline, he or she will not be asked to complete the assessment instruments or to be interviewed. There will be no cost to the subject.

All research will be conducted by Jeanne M. Moe. Please feel free to contact her with your questions at 406-994-7582 or jmoe@montana.edu. Attached is an example of assessment instrument that will be used in the classroom. She will be happy to provide you with copies of all assessment instruments if you are interested.

All project records will be kept at Montana State University and will not be released to the public at any time. Student identities will be coded.

Additional questions about the rights of human subjects can be answered by the Chairman of the Institutional Review Board, Mark Quinn at 406-994-5721.

AUTHORIZATION: I have read the above and understand the scope of this study. I,

_____ (*name of parent or guardian*) related to the
subject as

_____ (*relationship*), agree to the participation of _____

_____ (*name of subject*) in this research. I understand that the
subject or I

may later refuse participation in this research and that the subject, through his/her own
action or mine,

may withdraw from the research at any time. I have received a copy of this consent form
for my own

records.

Signed: _____

Witnessed: _____

Investigation: _____

Date: _____

APPENDIX G

ADDITIONAL EVIDENCE FOR RESEARCH QUESTIONS 1-6

Research Question 1: Understanding

Code	Statement or Interview Transcript
G.1.1	Evidence of understanding of observation. Amelia: I know it because I can see a face on the coin. Mazy: It's an observation because you can see the face on the coin.
G.1.2	Evidence of understanding of inference. Mazy: It's an inference because you don't know if it's God or there (<i>sic</i>) king. Amelia: I think that because a peace-loving saying (is) on on(e) side of the coin.
G.1.3	Evidence for understanding the connection between questions and classification. Amelia: She's (River) right because you have to have a question before you classify them or else you wouldn't know how to classify them. Mazy: I think River and Crystal are right because you can group artifacts according on how they are used and you should classify artifacts based on a question or something you want to know. Sally: I think he (River) is right because he said you should always classify artifacts based on the question or something you want to know. John: I thought River was right because she said you could classify artifacts based on a question or something you want to know. You do that and that helps you by asking questions and helps you get more information by asking.
G.1.4	Evidence for not needing a question to guide classification. Mia: ...you could get questions answered if you classify them on a question." ... sometimes you don't have questions based on what you want to know and you could guess on what the artifacts are used for. Annie: ... it doesn't need to be in a question. Some of the artifacts can be in a question but most don't need to and usually it's not.
G.1.5	Evidence for understanding of context. Billy: Context is the stuff around stuff. Luna: Context is where artifacts or anything can be found and it show(s) about it, like shows what it might be used for. Fred: Context is the looks and appearances of the area. George: Context is telling what something is by looking at its surroundings. Jake: Context is an object in its correct place.

Code	Statement or Interview Transcript
	Mazy: Context is the space around an artifact. Edison: It's (context) things around something that could probably help you figure out what it is. Brezy: Context is like an artifact's surroundings. Sally: Context is the stuff around artifacts.
G.1.6	Evidence of understanding context as a loss of information. Bella: Context is very important because if you have important artifacts and they are taken out of the context you loose (sic) a lot of information. EJ: Context is if an object gets moved, and archaeologist will not know who was the people who lived there. Roy: Umm, I put down where you take something out of where it belongs, it ruins the puzzle. Reed: Context is a problem, for example, taking artifacts.
G.1.7	Evidence of inability to explain context. Annie: The context is you have to find about archaeologists or archaeologists' sites. Jeanne: Okay, so context is finding out about archaeologists? Annie: Yeah. Jeanne: Okay, meaning the people who do archaeology? Annie: Yeah. Jeanne: And how does that help with context? Annie: You can ask the people what they found out so you can have more information. Jeanne: Okay, so it's a question of asking archaeologists to find out what the context is? Is that correct? Annie: Yeah. Jeanne: What do you think context is and why is it important? Antwan: It probably means how old it is and all that stuff. Jeanne: Why is it important in archaeology? Antwan: It's important because they could tell how long they lived and all that stuff. Jeanne: How could you know that? Antwan: By the scratches and paint got rubbed away or something. Jeanne: What do you think it means when there are scratches and paint rubbed away? Antwan: It probably means they were rough with it.

Code	Statement or Interview Transcript
G.1.8	John's response shows the correlation between the broken-down condition of the house and the owner's carelessness: For A I did the pottery is old and ancient and it comes from a careless owner because he has it on the ground. He has wood in his house and he could try and use that to build a shelf to support it and then it wouldn't be valuable if it dropped on the ground.
G.1.9	Example of context as a process that archaeologists use. John: Context is kind of like what's there and kind of like what you can prove what's there. It's not a guess, it's more of an observation. It's not an inference. Jeanne: Okay, and why is context important to archaeology? John: It's important to archaeology because they (archaeologists) can find out more about the archaeological site and they can get more information to know a lot more about a site before they visit it. Jeanne: How does that work? John: Well, they have gather their stuff first and maybe search all of the picture and after they search those pictures they can decide if they're going to go or not. If they do they would search around they had the pictures. They couldn't really find the people because they are dead.
G.1.10	Exam ple of context with evidence. Jeanne: You said we could know more about the person (referring to first picture of Dan's Room). Antwan: Because it's like a bigger view of it, of the picture. Jeanne: What does the bigger view give you? Antwan: More evidence. Jeanne: What would be an example of evidence? Antwan: A skateboard, a bat, a helmet, and a soccer ball.
G.1.11	Examples of student definitions of evidence. Sally: Evidence is things you can prove something with. Fred: I think evidence is data that helps prove things. George: Evidence supports (sic) something. Billy: Evidence is what you use to help make something true. Mia: Evidence is something you use to find something out. An example is: finding a shirt that an African wore. Jake: Evidence is something that help(s) in science and history to find things out (proof, <i>parentheses in original</i>). Mazy: Evidence is date (data) that is used to answer (a) question. An example would be if (you) found evidence of people living in a house 50 years ago. Roy: Evidence are *clues *artifacts are evidence *people *houses *bones

Code	Statement or Interview Transcript
Matthew:	Evidence is proof to prove the past, how they lived, or what they did that you want to show people about or teach them about. Evidence is also sometimes objects.
Brezy:	Evidence (sic) is proof. So finding a finger print on a hammer is proof that someone used it. in a crime it can be hair, DNA, fingerprints, sometimes even tire tracs (<i>sic</i>) can be evidence (<i>sic</i>).
Reed:	Evidence is like knowing something happened and having proof to show it. For example, River said to Abe I saw you kick my dad and River knew that because he saw abe (Abe) do it.

Research Question 2: Cognition

Code	Statement or Interview Transcript
G.2.1	Evidence of cognitive processes regarding observation.
George:	I wrote that is because there is a picture only on one side of the coin and that is an observation because I looked for it.
Amelia:	Um, it's an, the first one is an observation because you can see there's a man's face on the coin.
EJ:	Observation because the front of the quarter has a face on one side and the other side it doesn't.
G.2.2	Evidence of cognitive processes regarding inference.
Lane:	Because you don't know if they are really peaceful because it doesn't say that they are peaceful or there isn't any information that they are peaceful.
Jake:	Yes, that's because it may have a crown but that might not be the king, it might be a former king or it might not be a king at all. It might just be a face.
George:	I called that an inference because it doesn't say on the coin exactly 'we are a peace-loving people.' The guy who makes the coin could be peaceful, but the king could be a very mean man who likes to fight and stuff, but prints that on this coin, like 'brotherhood' and think they're peaceful.
John:	I chose inference because they (archaeologists) don't know if they are peace-loving because they probably have to visit where the coin came from and ... they couldn't really know that unless they visited the site.
G.2.3	Student changes her mind about observation and inference during the interview.
Jeanne:	Alright. F you said observation.

Code	Statement or Interview Transcript
	Annie: They (archaeologists) don't know which king it is and they don't know where he is or if he is still alive. That could be another person if it didn't... Jeanne: It could be another person besides the king? Annie: Yeah. Jeanne: If that was the case it could be witnesses that say it is the nation's king, but if it could be another person would that change your answer? Annie: Yeah. Jeanne: Would you pick inference rather than observation based on what you just said? Annie: Yeah.
G.2.4	Luna's interview on classification. Jeanne: Luna, tell me about each of these statements. What do you think of Abe's statement? Luna: He said that artifacts should be classified in exactly the same way but you should at least classify them in a couple different ways because when you classify them it means different things. Jeanne: And River? Luna: He thinks you should classify the artifacts based on a question or something you want to know. That could help you classify them like if you wanted to know what was the most popular color or the most used by the person. Jeanne: And Ivy? Luna: They don't tell you the same thing because, if you classify them by different things one can tell you about the colors and one can tell you about the people who used them. Jeanne: Crystal? Luna: She said artifacts can be grouped according to how they were used. That is a good way to classify them but there are many different ways also. Jeanne: What determines those different ways or how do you get those different ways? Why would you do that? Luna: She said you classify them how they are used and...you could classify them by what they were used for and what people used them. Jeanne: Would questions enter into this? What you're thinking here, like you said about River, did that influence what you thought of Crystal's statement. The idea of questions? Luna: Yeah, because you could come up with more questions if you figure it out in different ways or different ways you could group them.

Code	Statement or Interview Transcript
	Jeanne: And Dallas? Luna: He said you should group them by their shape and color. You could shape them in different ways and get different questions by grouping them in different ways because you can't answer all questions by just grouping them in shape and color. Jeanne: That's very interesting. You said you can get different questions by classifying them in different ways, did I understand you correctly? Luna: I mean you could answer different questions. Jeanne: You don't get the questions by the classification. Luna: You answer by classification. Jeanne: Okay, good. You could have chosen Erika because you also said Crystal was a good way to do it and you like River's idea of questions. Is there a particular reason you chose River over Crystal? Luna: Crystal was kind of specific and only used one category and River was saying you should classify them on a question you want to answer or something you want to know.
G.2.5	Examples of the importance of questions in classification. Sue: ... if you ask a question of what you want to know about it, you can put it into a group and categories. Amelia: Erika is the most correct. River says you should and Crystal says you can. All the other people except for Ivy say you have to do classifying some certain way. Ivy says that you get the same answer no matter what, but different questions you get different answers. Sally: They (artifacts) can be grouped by how they were used. That's one of the questions you can use.
G.2.6	Example of reasoning for not basing classification on a question. Edison: You shouldn't do it on a question or and you shouldn't do it on something you want to know. Jeanne: Why is that? Edison: Because it would be easier to do it on a question than if that person, if you just do it on your own...if you did it on your own the other person wouldn't know what it was grouped by. Jeanne: So, if you did not have a question, someone else would not know what you were doing? Is that correct? Edison: Yeah. Jeanne: How does that work?

Code	Statement or Interview Transcript
	Edison: If someone asked you a question and you did it, it would make (more) sense to them than if they didn't ask you a question and you did it on what you want to know. They might not understand.
G.2.7	Examples of analogical reasoning in context.
	Walt: I had different inferences because in (Drawing) A maybe there is an Indian tribe because it looks like they had an adobe (pottery) jar. The jar, they might have made pottery to store things." (In reference to Drawing B) Because it has a fireplace in it and not a lot of adobe houses, or none have fireplaces.)
	Shirley: That it (the pot) was used when the Indians were there. Because it's in a pueblo.
	George: You can tell it was made in an Indian camp because of the fire pit with all the stones around it. The arrowhead, the adobe walls.

Research Question 3: Application

Code	Statement or Interview Transcript
G.3.1	Examples of application of context.
	Jeanne: So, how did it (the pot) get from here (Drawing A) to here (Drawing B)?
	Luna: Maybe someone just came and took it out of that place.
	Jeanne: So, if it is gone from that place, does that change context?
	Luna: Yes, it does change context because if you found a fireplace (I think she means artifact) you would never know where it came from and around what time it came from.
	Jeanne: Because?
	Luna: Because it's in a different place than its original place where the people need it.
	Jeanne: What would you call the context of B?
	Fred: Just a normal casual fireplace and the pot was taken from the site to use as decoration.
	Jeanne: If this pot was taken from this site to use as decoration, how does that change the context of A?
	Fred: It doesn't tell the archaeologists studying the site very much. It doesn't tell who the people were because they might have been people who build pots.
	Jeanne: So, if this (the pot) was taken to here (Drawing B), what does that mean to this (Drawing A) situation?
	Brezy: You are missing part of the history of it.

Code	Statement or Interview Transcript
	Jeanne: How so? Brezy: Because it doesn't have everything that was there for people to look at. Jake: Context is having something in its correct place, its group. That's important because if you have something out of context that you don't know that could really change a complete part of history.
G.3.2	Examples of application of context to archaeological sites in general. Roy: Like if there was an old house archaeologists were about to study and I took an important piece out, that would ruin it. Reed: It is important because if you take one (artifact) it could make the whole meaning different. Like, if you took away their house archaeologists might think they didn't have a house. But, they might see the frame around it.
G.3.3	Examples of application of evidence to archaeological sites. Jake: It is used in archaeology in some ways including using evidence to prove that slaves lived at poplar forest. ... and finding a teepee ring to show life. Shirley: It is used in archaeology because if you find something somewhere you can go to that place to get evidence like if you were in a forest and found a bone somewhere and nobody believed you. You would show them where you found it and that would be evidence. Luna: Evidence is used in archaeology by finding artifacts, pictures, or notes that something exist or happened. Matthew: Evidence is used in archaeology when they find a slave cabin for example they look for evidence to prove what they want to learn about. So then they take pictures and make observations or inferences about the site they found. (He does not provide specific examples.) George: Evidence is used in archaeology by suporting (<i>sic</i>) their idea like nails, pins, peach pits to suport (<i>sic</i>) that someone lived there. (George's answer comes directly from the curriculum unit in which they studied a slave cabin and nails, pins, and peach pits were used to understand how people lived at this site. Most of the other students provided partial explanations of how evidence is used in archaeology but no specific examples.) John: Evidence is used in archaeology by the archaeologists trying to find out where the artifacts are. They use evidence whenever their proving something. Ex. It is used in archaeology by the archaeologists being able to prove something right.

Code	Statement or Interview Transcript
Lane:	Evidence is used in archaeology for information (<i>sic</i>) about their culture or to answer an unknown question (<i>sic</i>) like why did they live.
Mia:	Evidence in archaeology is used this way; finding valuables, clothing, food. that is evidence in archaeology.
Alex:	Evidence is used in archaeology by helping the people to understand more about the thing there studying (<i>sic</i>). for example the archaeologist studied the evidence.

Research Question 4: Transfer of Concepts

Code	Statement or Interview Transcript
G.4.1	Examples of evidence in other subjects.
EJ :	Biology would be people, animals, and plants. Earth science would be rocks, dirt, and grass. Forensics would be solving crimes.”
George:	Evidence in biology is bears, cows, and manatees. Evidence in earth science is volcanic ash, rocks, and dirt. Evidence for forensics is hair, finger prints, and saliva (saliva).
Matthew:	Biology – samples of animals like bones or waste (waste). Earth science – volcanic rocks after a(n) explosion to see what type of volcano was there.” Forensics – dna (DNA) because it is to test sometimes if you are guilty of a crime.
G.4.2	General explanations of evidence in other subjects with few or no examples.
John:	Ex. If you’re in court you can prove someone guilty and send them to jail.
Annie:	Biology is living history – history from today. Earth science – studying about the earth. Forensics – is used to find criminals or to solve crimes.
Lane:	Some examples of evidence are from Biology like living (<i>sic</i>) things or earth science like rocks, dirt, and volcanoes or forensics like crime.

Research Question 5: Nature of Science

Code	Statement or Interview Transcript
G.5.1	Examples of science as study.
Annie:	I think science is studying about organisms, ecosystems; about earth and stuff.
Roger:	Science is when you study land formations or plants.
Brezy:	You study planets, global warming, animals.

Code	Statement of Interview Transcript
G.5.2	Examples of history as the study of the past and/or people.
EJ:	History talks about culture and different peoples' past and it's from the past. You learn about the past. Science is about you make new things, you learn about the weather and animals sometimes, but not usually.
Mazy:	Science is learning about things just discovered and then history is learning about things, like people from the past.
Bella:	History is kind of learning about things in the past and how people did things in the past and science is when you do experiments and get answers to questions and see if you could do things in different ways each time.
Annie:	Science is different from history because history you learn about people but science you learn about earth.
Amelia:	History is studying about the past and science is more experimenting with things and figuring things out.
George:	History is learning about people in the past and what they did, their family and stuff. Science is learning about the stuff on the earth and space.
Luna:	Science is the study of today, trying to help the future and history is the study of the past.
Sue:	Science doesn't study the past unless you're talking about extinct species like dodos.
G.5.3	Examples of history and science using different data and/processes.
Kate:	In science you mix and add thing(s) and in history you sort and move things around.
Amelia:	History is studying about the past and science is more experimenting with things and figuring things out.
G.5.4	Examples of how science and history are similar.
Mia:	you can use science and history at the same time to study one thing and... Um, like, uh the archaeological site we used science in it and history. ... But it's hard to explain.
Kate:	Yes, because you can get different answers with the same thing just by doing something different with it. It also shows you that you can get the same answer twice ... with different things using different ways.
G.5.6	Examples of science and archaeology being fun and easy.
Kate:	It (archaeology) also shows me that if you are happy you can have fun while you (are) an archaeologists and in sites.
Amelia:	Yeah, because when I thought about science I just thought they were just using chemicals in a lab, not at an archaeological site.

Code	Statement of Interview Transcript
Reed:	I kind of didn't know what archaeology was but I kind of did and after doing all of the studies and stuff I really know what it is now. It's really fun and easy sometimes.

Unexpected Outcomes

Code	Statement of Interview Transcript
G.UC.1	Examples of student reflection on their own inquiry processes.
Fred:	Basically, I looked at where pieces were and used logic to put pieces together so I could make an estimate on how they did things.
Walt:	Like, it worked because you would have to think they probably wouldn't eat outside because maybe it was nicer inside or because it might have been cooler outside because of all the food in there.
Sue:	Because we said if there is something outside then they probably worked outside, like the knives. When there's, if there's a figurine that means there could be a kid. But where the organic material is supposed to there is no organic material there.
Roy:	We would look like at this (figurine) and when we looked at this we could tell there was a kid because there was a play toy right there.

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