IMPROVING MUSEUM EDUCATIONAL MATERIALS FOR ELEMENTARY TEACHERS THROUGH AN EXAMINATION OF COMMON CONCEPTIONS IN DINOSAUR PALEONTOLOGY

by

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ABSTRACT

Misconceptions about basic dinosaur paleontology concepts are common among the public and educational professionals. As a museum educator, I wanted to learn more about teacher conceptions in dinosaur paleontology to design educational materials and professional development opportunities specifically addressing the most common and important misconceptions. This study collected data based on interviews with elementary school teachers. The evidence showed a range of understanding among elementary teachers, the need for updated and clearer educational materials and products, and a need for curriculum revision at the local school district level. This research resulted in changes in the way I design educational materials and conduct teacher professional development workshops.

INTRODUCTION

Dinosaurs. What do you think of when you hear that word? Many of the images of dinosaurs in our, and especially children's minds have been created by the popular media—movies, books, television, video games and toys—not by what science has taught us. Even those who refuse to be taken in by blockbusters like *Jurassic Park* may be dredging up childhood memories of tail-dragging reptiles without even realizing that new research presents a very different picture of dinosaurs. New discoveries about dinosaurs are continually being made, and even though the scientific view of these prehistoric animals is changing, in my job as a museum educator at the Museum of the Rockies (MOR) in Bozeman, Montana, which specializes in dinosaur paleontology, I have noticed that many visitors still discuss old concepts or do not fully understand advances in the science of dinosaur paleontology. This study is the story of one museum educator's personal educational change in an effort to become a better dinosaur educator. In this study, I use systematic inquiry to pinpoint the conceptions and misconceptions about what I deem to be important fundamental ideas in dinosaur paleontology for a very specific sector of the general MOR visitor population—Bozeman School District elementary teachers

As a museum educator I am concerned with disseminating accurate information to the public through exhibits and educational outreach. During two and a half years in my job I have observed that 1) many visitors, especially children are very interested in and enthusiastic about dinosaurs, and 2) many of the same visitors seem to find our exhibits about dinosaurs fascinating and react very positively to them, but 3) many visitors,

children in particular, do not seem to have a strong or current enough background knowledge about dinosaurs, paleontology and earth history to be able to truly understand the context of our exhibits which focus on certain Montana dinosaurs living during different geologic time periods. I strongly believe that to begin to understand complicated scientific topics such as this, a person has to start at a basic level and build knowledge. In past efforts to build the basic knowledge foundation for our visitors, I have been accused by scientists of "dumbing things down." I believe that meeting people where their knowledge base ends and helping them move forward in their thinking should not be considered "dumbing down," but, on the contrary, be considered opening the door for further critical thinking about the subject.

Although many MOR visitors are tourists during the summer months whom I almost never have contact with prior to, or following their visit, a large number of our visitors during the school year are school groups (especially elementary level) from Bozeman and other towns around the state of Montana who visit the dinosaur exhibits at the museum as a field trip. If teachers are still presenting incorrect dinosaur information in their classrooms prior to the field trip, then these school students potentially arrive at the museum already full of dinosaur misconceptions. Their museum visit might be fun, and even informative--but not nearly the educationally sound experience a museum educator like me would want it to be.

I started this project to learn more about elementary school teacher's conceptions about fundamental dinosaur paleontology concepts. Since it is my job to develop educational outreach materials about dinosaurs for use in classrooms around the state (and potentially nationally and even internationally), I am in a position to educate

teachers and students about fundamental concepts that can help change the public view of dinosaurs, and more importantly, their understanding of science, through educational outreach. This project allowed me to define what I believe to be the most important current scientifically accurate fundamental content about dinosaurs and then interview a small number of local elementary teachers in great depth to identify their conceptions about that information. Through my research I have found that while the teachers I interviewed have some knowledge about dinosaurs, major misconception and confusion does exist, especially in the areas where new scientific research has recently emerged. The data collected in this study has changed the way I design dinosaur educational outreach materials that address appropriate content at the appropriate level for elementary teachers and their students, demonstrated the need for updated dinosaur educational materials from MOR and indicated the need for me to gain a better understanding of the integration of dinosaur education in the Bozeman School District.

Why is it so important for teachers and students to understand dinosaur paleontology? I personally believe, and have found much additional evidence through my experience and this project, that children's love of dinosaurs sparks an interest in science at a very young age. Children learning about dinosaurs through well designed educational materials can also be exposed to the scientific process, the idea that science is not static and gain a better understanding of the natural world in which we live. As a museum educator I have found that young children (approximately 3-10 years of age) are often extremely enthusiastic about dinosaurs. Some kids can pronounce tongue-twisting names like *Saurornitholestes* and *Deinonychus* before they can tie their shoes. But most parents are not dinosaur experts, and while they may want to foster their child's interest in

science by encouraging further investigation, they often turn to the above mentioned list of popular dinosaur media (toys, books, movies, etc.). Not all of this propaganda is wrong, but science does change quickly and libraries and bookstores often carry out of date or just plain incorrect materials and toy stores sell plastic dinosaurs and cavemen in the same packages. Young dinosaur enthusiasts may enter school full of misconceptions, or, just full of dinosaur statistics. In other words, they could tell you everything you ever wanted to know about a *Tyrannosaurus rex*, but may not have a clue *how* scientists learned that information. By the time kids are introduced to dinosaurs through school curriculum, they may have many preconceived notions about dinosaurs, and possibly science as a whole. Teachers, who are also not necessarily dinosaur experts, are faced with having to correct these misconceptions, ignore them, or condone them. Teachers need solid educational materials to aid them when teaching about dinosaurs so that they can use the opportunity of having a subject that kids *want* to learn about to introduce science process. It is up to institutions such as museums, especially one with an active and world renowned paleontology program to lead the way in clearing up both teacher and student misconceptions. Providing quality, regularly updated dinosaur educational materials to elementary educators gives them the best opportunity to encourage their students to think critically. These students may develop a love of the process of science based on their study of dinosaurs.

FOCUS QUESTION

How will a better understanding of elementary teachers' conceptions of dinosaur paleontology change the way I develop dinosaur paleontology museum educational outreach materials?

Sub-question

How will I be able to gain a better understanding of teachers' conceptions of dinosaur paleontology?

CONTEXT

Museum of the Rockies

The Museum of the Rockies is a regional museum of natural and cultural history located in Bozeman (a mid-size but quickly growing community in southwest Montana), Montana on the Montana State University (MSU-Bozeman) campus. The museum was founded in 1957 by Dr. Caroline McGill. The museum is associated with MSU-Bozeman and is partially funded by the State of Montana. It is also recognized as a 501(c)(3) non-profit organization and the remainder of it's funding comes from grants and private donors.

> MOR Mission Statement
> The Museum of the Rockies inspires visitors to explore the rich natural and cultural history of America's Northern Rocky Mountains. In partnership with Montana State University, the museum reaches diverse communities with

> engaging exhibits, educational programs and original research that advances public understanding of the collections. (www.museumoftherockies.org, retrieved May 12, 2006)

The museum showcases both the geological history of Montana (focusing on early Earth evolution and specifically the time of the dinosaurs), as well as the more recent cultural history of the past 200 years (focusing on Native American culture and homesteading). MOR also has three galleries that house temporary exhibits either created in-house or rented from outside sources. The subject matter in these galleries varies. Recent exhibit topics housed in these halls include reptiles, African American art, art history in Yellowstone National Park, the Lewis and Clark expedition, story quilts and deep space.

The majority of the museum's visitors are tourists who visit between June and August each year, but we also encourage school students to come for a free docent-guided group tour of the exhibit of their teacher's choice during the school year. In fact, beginning during the spring of 2005, MOR was able, through private donation funding, to invite all Montana accredited school groups to come to the museum free of charge. We even pay for up to half the cost of their bus travel expenses—a major obstacle for under funded schools in the fourth largest state of the nation.

Museum of the Rockies Paleontology

Although the museum has active history, textiles, photograph archive and archaeology programs, it is the world-class paleontology program for which the museum is famous. Under the leadership of MOR Curator of Paleontology and internationally

renowned paleontologist, Dr. Jack (John) Horner, the paleontology department (housed in the basement of the museum, but jointly affiliated with MSU-Bozeman) continually produces cutting-edge research published in such major scientific journals as *Science*, *Nature*, the *Journal of Vertebrate Paleontology* and more.

This research is presented to the public through new and unique exhibits at the museum. Over the past few decades, cutting-edge research in the field of paleontology has been ongoing at our institution. Only recently, however, have we put a priority on creating exhibits about dinosaurs that can change at the speed of the research. Between 1989 and 2005 the same exhibit called *One Day 80 Million Years Ago* about the Egg Mountain excavation site near Choteau, Montana which focused on displays about the hadrosaur (duckbill) dinosaur called *Maiasaura* and her parenting behavior was on display. Between 1989 and 2005 MOR Paleontology did produce two traveling exhibits which were showcased temporarily at MOR, but the permanent dinosaur display remained mostly static for over 15 years (retrieved June 11, 2006 from www.museumoftherockies.org). In 2003 the museum received a generous two million dollar donation from the Thomas and Stacey Siebel Foundation to fund renovations and construction of a series of at least three new exhibits showcasing emerging and changing paleontology research at MOR (retrieved June 6, 2006, www.museumoftherockies.org).

The Hall of Horns and Teeth opened in June 2005 and at the time of this study is MOR's only dinosaur exhibit open to the public. The hall showcases dinosaur and other animal and plant fossils from the Hell Creek formation representing the latest Cretaceous period (approximately 68-65 million years ago) in what is now eastern Montana. The major dinosaur specimens in this hall include *Tyrannosaurus rex*, *Triceratops*,

Torosaurus (another ceratopsian or horned dinosaur) and *Edmontosaurus* (a hadrosaur or duckbilled dinosaur). The hall also contains fossils from animals such as crocodilians, tortoises, mollusks and leaves from various kinds of vegetation. The idea behind *The Hall of Horns and Teeth* is for visitors to formulate an understanding of the environment and its inhabitants based on the physical evidence that has been found in the Hell Creek formation. Other major themes in the hall include growth series for *Tyrannosaurus rex*, *Triceratops* and *Edmontosaurus* to show changes to the animal throughout its lifespan, different types of teeth, how different kinds of dinosaurs chewed and what they ate and skeletal evidence that dinosaurs and birds are related.

The Mesozoic Media Center is scheduled to open during the summer of 2006, possibly before this data is presented and will house state-of-the-art audio visual technology that will be used to show video clips from paleontological dig sites (possibly some live) and provide live satellite links between MOR and other major science institutions such as the Smithsonian. Live Internet web casts will also be possible. *The Mesozoic Media Center* will also have interactive computer stations for visitors to learn more about the process of paleontology.

The last of the new dinosaur exhibit halls, *The Hall of Giants,* is scheduled to open in June 2007 which coincides with the museum's 50th Anniversary year. The *Hall of Giants* will focus on dinosaurs, other animals and environment from Jurassic period fossils found in certain locations in Montana. All of these new exhibits are dynamic and allow for updates in displays as new scientific discoveries are made, and removal of display specimens for scientific study. These exhibits provide in-depth current highly scientific information at a level that even professional paleontologists can appreciate at

our university museum. These exhibits together will compose the Siebel Dinosaur Complex and will help to make MOR one of the preeminent dinosaur museums in the country, possibly the world.

With the addition of these new and updated paleontological exhibits, the museum staff must also revise tours, educational outreach materials, online resources and programming that reflect the quality of the presentation and new content of the displays. As a museum educator, it is part of my job to address these issues.

MOR/Elementary School Educational Connections

National and State Educational Standards and School District Curriculum

As mentioned above, elementary school groups frequent MOR during the school year (September-May). MOR educational outreach materials, which take the form of publications, online resources and kits or trunks full of materials, activities and resources and more are also often used by school teachers. To provide the most useful resources to these educators, I consider National and State educational standards during resource development.

National educational standards implemented by the United States government dictate to teachers nationwide what topics should be understood by students as they progress through the school system. State educational standards for each state reiterate this, and possibly narrow the scope further. Local school district curricula (addressed below) clearly spell out the subject matter that should be addressed at each grade level.

Examples of national educational kindergarten through fourth grade (grade division inherent in national and state standards) science standards that align closely with our dinosaur exhibits and educational outreach materials include:

As a result of activities in grades K-4, all students should develop

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

As a result of activities in grades K-4, all students should develop understanding of

- The characteristics of organisms
- Life cycles of organisms
- Organisms and environments (National Research Council, 1996)

Examples of Montana state educational K-4 science standards that MOR exhibits and educational materials address include:

> Science Content Standard 3
> Students demonstrate knowledge of characteristics, structures and function of living things, the process and diversity of life, and how living organisms interact with each other and their environment.
>
> Science Content Standard 4
> Students demonstrate knowledge of the composition, structures, processes and interactions of Earth's systems and other objects in space.
> (retrieved June 6, 2006, http://www.opi.mt.gov/pdf/Standards/ContStds-Science.pdf)

Because I interviewed Bozeman School District elementary school teachers for this project, I was also interested in where dinosaur paleontology fits into the Bozeman School District Curriculum. After reviewing the science curricula for grades K-5 (grades which constitute an elementary school in Bozeman) I found the following to best address museum exhibits and educational materials:

> Bozeman Public Schools Science Curriculum Third Grade Earth Science
> Students demonstrate knowledge of the composition, structures, processes and interactions of Earth's systems and other objects in space.

1. examine, describe, compare, and classify rocks and minerals in terms of common physical properties.

2. investigate fossils and make inferences about life and the environment long ago and relate to any similar organisms that are alive today.

3. etc. (Bozeman Public Schools, 2002)

Many of the educational outreach materials and programming that the museum has and continues to create are designed at the elementary school level. Although educational materials will eventually be created that address other age groups (for example, earth science is addressed in high school therefore dinosaurs could be, also), the priority is to create materials and programming that can be implemented at the elementary school level when the majority of children are arguably most interested in learning about dinosaurs and when they are first introduced to paleontological concepts at school.

Personal Background

Education and Employment Experience

My educational background includes a bachelor's of science degree in Geology from MSU-Bozeman (December 2000) and all of my course work in the Master's of Science in Science Education (MSSE) program at MSU-Bozeman. I also gained practical experience in science education from working for Montana Outdoor Science School (MOSS) in Bozeman, Montana as a Summer Camp Instructor, the National Park Service in Yellowstone National Park as an Education Specialist, and working for the past two and a half years as the Education Coordinator at MOR. Because of the diversity of my

employment during the pursuit of my MSSE degree, I have taken a wide range of science content classes that were and are applicable to the position I held at the time I was enrolled. My undergraduate work focused much more on geomorphology (the study of landforms and the processes that create them) than paleontology and I have gained expertise in the field of paleontology mainly through my MSSE coursework and through my job experience at MOR.

My personal revolution from an interest in science to an interest in science education came about after I started leading summer camp for MOSS back in 1998. I realized how much I valued helping others truly understand the world in which we live. I specifically enjoy teaching young children who still have a sense of wonder and awe about nature. After only one summer of teaching I began to plan the camps myself and I immediately recognized my new found interest in pursuing a career in informal education.

Research Experience

I am less experienced in research than I am in education, especially in qualitative research, such as this project. Since my background is in science, I did have limited experience with quantitative research during my years as an undergraduate. I also grew up with a quantitative researcher as a father. Making the mental leap to accepting the data that I collected during this project was difficult for me. I really didn't believe in it myself until I was applying the qualitative data analysis method (described in the Methods section below). It was during that process that I became a believer in the power of in-depth research on a small number of subjects.

Personal and Professional Values

As a teacher, I am inspired by honest curiosity in students and feel that for students to develop a sincere interest in a topic, they must also develop a clear fundamental understanding of the subject matter to be able to proceed in thinking critically and inquiring deeper. I also think it is crucial for students to understand that science is fluid and what we know at present about any given topic is only as far as science has taken us to date—as we continue to learn our understanding becomes further detailed. I understand the value of educational materials that are academically sound, age appropriate and enjoyable to the learner and the teacher. As a primarily visual and tactile learner I tend to seek out educational materials that convey their objective through multi-sensory activities. I have carried these overlapping personal and professional values with me throughout my several years of science education job experience.

Role of MOR Education Coordinator

In my job at MOR I have many responsibilities. In theory, my main project is running, maintaining, updating and developing new educational outreach materials such as publications, online resources and especially our educational outreach trunk program. In reality, in the two and one half years I have been in this position, I have found very little time to do much more with the outreach trunk program than schedule and ship the existing materials. The nature of the MOR Education Department is such that I have

taken on many additional responsibilities. There are only two full time and one part time employees in the MOR Education Department, and with MOR's growth and changes and the renewed influx of school groups there are more than enough responsibilities to keep us all very busy. I have been occupied creating teaching materials and training docents for new and temporary exhibitions about topics including dinosaurs but also sharks, space, Lewis and Clark and African American Art. I have also been running the museum's summer camp and birthday party programs, developing and leading museum programming for children, and more. Although I have gathered much knowledge both about dinosaurs and the science of paleontology and the visitors' knowledge of these subjects, I have just started to use this background to put together desperately needed new dinosaur educational outreach materials.

Professional Issues that led to MSSE Research Project

Level of Scientific Content in *The Hall of Horns and Teeth*

As stated earlier, the MOR Paleontology Department is an institution of high quality, state-of-the-art paleontological research and discoveries. It is home to many top workers in the field of paleontology. Recent research at MOR and from other paleontogists worldwide has changed the way we think about dinosaurs. Our understanding of topics such as dinosaur evolution, biomechanics, behavior, environment and more has changed drastically based on relatively recent fossil observation and interpretation. Some new theories are widely agreed upon by the scientific community, but most are still debated.

The new dinosaur exhibits at MOR are unprecedented in that they incorporate cutting-edge paleontology research in a way that should allow the exhibits to change along with the pace of science, hopefully providing better access for the public to learn about new discoveries. But at least *The Hall of Horns and Teeth* assumes the visitor already has a certain basic understanding of fundamental dinosaur concepts. Dinosaur fundamental facts are not currently addressed or focused upon anywhere in our dinosaur exhibits. The new halls are being constructed in a reverse chronological order so the last one to open will be the first one visitors enter upon completion. It is possible that when the final exhibit opens in the summer of 2007 the entry way will contain some information about what I consider to be fundamental dinosaur information. However, until the complex is completed and even when it is, visitors, including school groups coming for tours, have a limited time to learn about dinosaurs during their experience at MOR. The better their background coming into the museum, the more they will learn from our exhibits.

Need for Updated MOR Dinosaur Educational Outreach Materials

The Education Department at MOR existed long before I became a part of it two and a half years ago. During years past, other educators have produced excellent (at the time) resources for teachers and the public. However, just as the *One Day 80 Million Years Ago* dinosaur hall exhibit was installed in 1989 and not modified until last year (2005), the educational materials created to accompany it and reflecting the current scientific understanding at the time of development have also not been updated recently. These materials include a book called *Dinosaurs* (subtitle ironically reads *The Very*

Latest Information and Hands-on Activities From the Museum of the Rockies) by Liza Charlesworth and Bonnie Sachatello Sawyer, a former MOR educator, published in 1995 and a dinosaur educational outreach trunk created at about the same time. The book is now out of print and out dated and the trunk and the materials it contains are mostly out-of-date. Despite this, the trunk is rented very regularly throughout the school year and the book is still loved and being used as a resource by teachers I interviewed for this project.

In my job, I find it necessary to make myself aware as best I can of the types of dinosaur resources and materials that are available at the level of the public and for educators (such as school teachers, or people like me in informal education). Although I have found a few wonderful resources (mentioned later throughout this paper) that incorporate new research in paleontology and the idea that science is a dynamic process in an accessible manner, I have also found many out-of-date, incorrect and fictional resources still in circulation in addition to the out of date MOR dinosaur educational resources. It is important for amateur dinosaur enthusiasts and educators to be able to access accurate and up-to-date information about new discoveries.

It is important to note that information about emerging dinosaur research is available, just not at a level most non-paleontologists or, at least, non-scientists can understand. Much of this research is published in scientific journals, although occasionally some of it is deemed newsworthy for the public, but presented in an often either too complex or conversely, oversimplified manner. Resources like academically written books such as *The Dinosauria*, (Weishampel, Dodson and Osmólska. (Eds.). 2004) a compilation of the most comprehensive knowledge of dinosaur paleontology to date, are used as references by paleontologists and some specialized educators like me. I

would definitely consider most paleontology textbooks and *The Dinosaura* (Weishampel, Dodson and Osmólska. (Eds.). 2004) to be too technical for anyone not immersed in paleontology. Even books like *Dinosaurs Under the Big Sky* (Horner, 2001) are written at a level that some might understand but others would not—or their length, depth and specific subject matter deters educators with limited time. The field of paleontology is so vast and the research done by an individual scientist is so specialized that often only major or controversial discoveries ever reach the general public.

Development of Updated MOR Dinosaur Educational Outreach Materials

Despite the limitations of my job, I finally started the process of developing new dinosaur educational outreach materials in the past nine months. My first project is to develop new dinosaur outreach trunks. The trunk project started as an opportunity to create educational outreach materials to reflect the content of *The Hall of Horns and Teeth*. However, I quickly realized that, as mentioned above, the concepts in that hall assume the visitor already has a certain amount of background knowledge about dinosaurs. I decided I needed to first create materials to address that background knowledge before I could expect anyone to comprehend more advanced concepts. I decided to create a *Dinosaur Basics Trunk* (working title) that focuses on fundamental dinosaur paleontology concepts and later an *On the Brink of Extinction Trunk* (working title) that focuses on the research in *The Hall of Horns and Teeth*. As I launched into the *Dinosaur Basics Trunk* project, I realized that I had to determine *what* the fundamental concepts people needed to know about dinosaurs were to be able to advance their

knowledge. I created an outline for the trunk based on *what I thought* were the most important fundamental dinosaur paleontology concepts that people needed to know.

MSSE Capstone Research Project

In working with Dr. William Hug, my graduate committee advisor and professor in the MSU education department, I discovered that I was making assumptions about what concepts needed to be addressed (W. Hug, personal communication, January 2006). My MSSE capstone project idea grew from the fact that I was basing the content of my educational outreach materials on my assumptions. I do not want to base my work off assumptions. This does not match my values. I needed to find a way to gain insight into people's conceptions about dinosaurs. I needed to create a tool that would allow me to pinpoint people's misconceptions so that I could focus on those areas and design the most helpful educational outreach materials possible. Through this project I developed that tool and used it to learn from teachers.

Coming into this project, I had already created an outline for the *Dinosaur Basics Trunk* I was starting to create. I used that to develop an initial list of fundamental dinosaur concepts, which was then revised several times through interaction with colleagues and advisors. Although the list of fundamental dinosaur concepts I have chosen for this project may not be exhaustive, I think it is fair to say based on my interaction with specialists in the field of paleontology, and my experience as a museum educator at MOR that the concepts addressed in this project are more or less agreed upon as important.

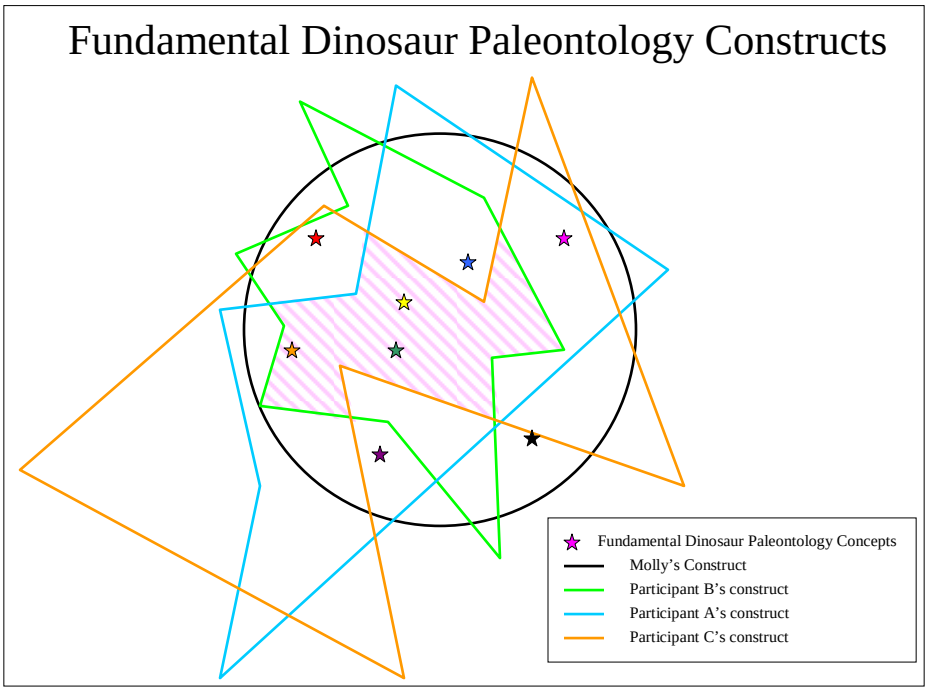
I then used those concepts to develop questions to address teacher conceptions of dinosaur paleontology (process explained in depth in the Methods section below). The combination of those concepts and the questions that address them compose the research tool I then used throughout the rest of the project. I used the tool to guide me through the process of in-depth interviews with four elementary school teachers from the Bozeman School District.

I chose to do a small number of in-depth interviews for this project to test the tool I had developed and its ability to pinpoint these specific teacher's misconceptions about dinosaurs and simultaneously collect and analyze that data. Interviews are time consuming and invasive for teachers, especially during the spring semester as they get very busy. I was lucky to find four willing participants who spent a significant amount of time with me and were very honest about their understanding of an intimidating subject.

The participants in this project were chosen because they are teachers who were currently, had in the past, or will in the future likely impart their knowledge about dinosaurs to young children. Elementary school teachers were selected because I wanted to know what they know about dinosaurs so that I am aware of the kind of information that is being passed on to kids through school. I purposefully did not select children for this interview because, although I might have been able to get at their misconceptions using the tool I developed, I really wanted to know what they (the children) were learning from school. Children of that age are learning about dinosaurs from all sorts of different sources. Teachers may also be, but they are likely not seeking out dinosaur information for the fun of it as young children do.

The process outlined above and detailed below gives me a better understanding of extent and confines of each individual teacher's fundamental dinosaur paleontology construct. Figure 1. illustrates what I mean.

Figure 1. Fundamental Dinosaur Paleontology Constructs



The black line indicates what I think the construct of fundamental dinosaur paleontology should be. Inside it fall all of my fundamental dinosaur concepts. Different colored lines represent participants A, B, C (D was purposefully left off for ease of interpretation) and indicate how the teachers I interviewed may have a different construct of that idea—sometimes inside and corresponding with my construct and my concepts, sometimes outside of my construct and concepts and different from my perception. The concepts inside the area where all of the participants' constructs overlap with mine represent the intended discoveries I made during this project. I was able to see exactly how those teachers understood or did not understand those concepts. Areas where the

teachers' constructs overlap outside of mine represent unintended discoveries. These are concepts that came up during this project that I was not expecting to find.

As a result of this research I hope to be able to develop updated educational materials about paleontology at MOR in which the concepts addressed are deemed important by paleontology and educational experts and also address areas of teacher misconception. Ideally these educational materials will help elementary educators understand fundamental concepts in paleontology and pass that information on to their students. Understanding the fundamentals in paleontology will potentially allow both teachers and students to pursue further research and study in paleontology and also gain a deeper understanding of MOR paleontological exhibits when they visit. Through new educational materials I also hope to convey the idea that all fields in science are perpetually advancing and with that comes new understanding about each topic. I hope educators and students alike will come away with the perception that they are learning about a process, not absolute fact, and that they can aspire to become a part of the process of science.

CONCEPTUAL FRAMEWORK

Museum Research

Learning in Museums

Research done by John H. Falk and Lynn D. Dierking (2000), who literally wrote the book on learning from museums, shows that visitors do learn from their museum

experiences, but maybe not in the way that we traditionally view learning. Learning in a museum is free form learning or learning that takes place as an individual visitor's experience plays out. Each visitor's experience is different before, during and after each visit and making meaning from the museum experience involves all of those contexts (Falk & Dierking, 2000).

Learning in museums occurs within three major contexts. First is the personal context or the influence of an individual's background before entering the museum and the course of her personal experience during and after the visit. Many nuances in an individual's life may cause her to notice something in a museum exhibit (even without being completely aware of it) or to recall a certain exhibit later during another circumstance. The second context for learning in museums is the social context. This means who an individual may interact with during a given museum experience and the type of experience that causes her to have. A student with a school group may have a very different experience visiting the same exhibit with her class than if she visited with her parents and younger brother. Finally, the last context of a museum visit is the physical context which relates to the physical world around the individual visitor. What exactly did the visitor see during his museum experience? What areas of the museum did he visit? All three of these contexts exist within the context of time. A given visitor's museum experience may be looked at as the visitor's pre-visit experience, the visit itself, and anytime post-visit that reference to the museum experience is made (Falk & Dierking, 2000).

To some extent, I currently view my job at MOR as a translator between the high level science in our exhibits and the level of understanding of the public. Part of my job is

to create materials for in exhibit use that bridge the gaps between the existing understanding and the new discoveries at the time of their museum visit. This is not to say that a visitor without a background in paleontology will learn nothing in our dinosaur halls. During a single museum visit, each visitor creates his or her own unique experience. As they wander through a museum, visitors may notice and retain pieces of information on which even they themselves were not aware they were focusing (Falk & Dierking, 2000). In some respects this free form learning experience can be thought of as the beauty of museums, but many times school (and other) groups tour a specific museum exhibit with the goal of learning particular information. Such is often the case with the dinosaur exhibits at MOR.

Museum learning is different from our traditional view of learning in other ways as well.

> While it is general, particularly in a school context, to think of learning as meaning cognitive or conceptual change, Schauble et al. (1996) remind us that learning in a museum context "includes outcomes like an expanded sense of aesthetic appreciation, the development of motivation and interest, the formation and refinement of critical standards, and the growth of personal identity" (p.24). This understanding of learning is consistent with a sociocultural view in which social interaction, cultural norms, and a range of tools and methods are used when assimilating ideas and information. (as cited in Griffin, 2004, p. S60)

Learning, in one way or another, is always going on when a visitor enters a museum. The learning taking place for an individual in a museum is complicated and impossible to fully document and understand—even by the learner.

Museum Learning Opportunities and Effectiveness

In the words of Griffin (2004), "While museums provide the requisites for free-choice, socially mediated, constructivist learning, this does not necessarily mean that

such learning is being allowed to take place" (p. S64). Certain opportunities in a museum enhance or constrain a visitor's learning capabilities.

Exhibits and Tours. Exhibits are the main focus of most museums, MOR included. Exhibits need to be designed knowing that visitors of all ages, backgrounds and knowledge levels will peruse them. Well designed exhibits with goal oriented interactive components throughout are the most effective at providing the best environment for stimulating visitor free choice learning.

Studies have shown (Griffin, 2004) that the open ended nature of the museum experience, where visitors are free to wander through the museum at their leisure, guided by their interests fosters free choice learning and is also a desirable characteristic that creates a positive experience for the visitor. In fact, one study by Meehan, & Jay in 2003 (as cited in Griffin, 2004) showed that after recording conversations between students allowed to direct their own museum visit over 80% of their conversations qualified as "learning talk," or learning related conversation. Docent guided tours of museum exhibits have been found to limit this free choice learning experience because they limit visitors pursuing their personal interest and making decisions about what to focus on and therefore can be detrimental to the visitor's learning. Some kind of structure such as tours provide is necessary when groups of school children tour a museum. An alternative to docent led tours of exhibits would include modification of traditional tour structure so that students had more control over their experience, but that control of the group is still maintained (Griffin, 2000).

Interactives in Exhibits. It has been proven time and again through educational research that people absorb more information and more readily retain knowledge through

multi-sensory learning (Bransford, Brown & Cocking, 2000) Museums are unique learning environments because of the open ended possibility for multi sensory learning through exhibits on any subject matter. The potential for multi-sensory interactive components for any given exhibit is limited only by the attitude, imagination and budget of the exhibit designer.

Interactive activities in exhibits must be thought through carefully to be effective. Gammon, (as cited in Griffin, 2004) described four types of less than effective interactive activities in a museum:

> Activities where there is no obvious reward or motivation for continuing
> Activities poorly matched to the abilities of the audience
> Activities that make visitors look foolish
> Activities that preclude social interaction
> (as cited in Griffin, 2004, p. S62)

Sue Allen (2004) of the Exploratorium in San Francisco, California states, "…it is not enough that an exhibit has a culminating point or experience that is rewarding to visitors; *every intermediate step* in the visitor's experience must be sufficiently motivating that they make the choice of continuing to invest time and attention there" (p. S18). If exhibits are not engaging enough, throughout, visitors may lose interest and move on (Allen, 2004).

Museum Educational Outreach Learning Opportunities and Effectiveness

Although, as John H. Falk and Lynn D. Dierking (2000) have shown, it is impossible to predict or control the experience of any visitor to any museum exhibit research has shown that visitors, including school teachers and students, can gain more from their museum experience if they arrive for their visit prepped for learning through pre-visit educational outreach materials (Griffin, 2004). In fact, not only does the research show that pre-visit materials are effective, but Hein found that teachers, "were

not keen to prepare materials for field trips due to lack of time, and the logistical issues were off-putting" (as cited in Griffin, 2004, p.S65). So it is essentially up to museum educators to help teachers and students prepare for their museum experience by providing pre-visit educational materials. Pre-visit outreach materials can take on any number of creative forms, but the key is teacher professional development—museums working with schools to "help[ing] teachers help themselves" (Xanthoudaki, 1998 as cited in Griffin, 2004, p. S65). With a better fundamental understanding of the subject matter, teachers and students will be able to enjoy a richer experience during their museum visit.

Best Practices in Museum Learning

Through my consultation of the research I have determined the best in museum practices for exhibits is to provide visitors with carefully designed interactive, multi-sensory (Bransford, Brown & Cocking, 2000) displays where each interactive is well thought out (Gammon, 2001, as cited in Griffin, 2004) rewarding and each is as intriguing as the next (Allen, 2004). Tours of exhibits should be modified to best combine structure for the group, social interaction and individual visitor input about where to go and what to see (Griffin, 2004). These practices should provide the best opportunity for visitors (individuals and groups) to enjoy, remember and learn from their unique museum experience.

Attributes of the best museum outreach materials offered by museums are summarized well by Lebeau et al. (as cited in Griffin, 2004). Regardless of the form they take the outreach materials should connect to school curriculum, extend both pre- and post- visit, integrate material into other school disciplines, and should be mainly student

focused. These materials will be put to best use if an effort is made to work with teachers instead of relying on teachers to read museum provided written materials.

Dinosaur Research

Dinosaur Misconceptions and FAQ's

I found several relatively recent sources that speak to the top dinosaur misconceptions where many of the concepts I address appear. Most, if not all of the concepts addressed in the four sources I focus on in this section are related to one or more of the fundamental dinosaur concepts from the list I created for this project. That list can be viewed in Appendix A for comparison.

The United States Geological Survey (USGS) compiled a pamphlet titled *Dinosaurs: Facts and Fiction* available online or hard copy through the USGS Store, that covers frequently asked dinosaur questions, or concepts about which learners frequently need clarification (retrieved on January 12, 2006 from http://pubs.usgs.gov/gip/dinosaurs/) The USGS list can be viewed in it's entirety (list page only—online each list item links to an answer page) as Appendix B and compared to my list of concepts (Appendix A). A few examples of key concepts expressed on the USGS and their counterparts on my list include:

> Did all the dinosaurs live together, and at the same time? (retrieved on January 12, 2006 from http://pubs.usgs.gov/gip/dinosaurs/)
>
> Fossil evidence shows that different dinosaurs lived in different places and time periods during the Mesozoic Era. (my list)
>
> and

> Are all fossil animals dinosaurs? (retrieved on January 12, 2006 from http://pubs.usgs.gov/gip/dinosaurs/)
>
> Many different kinds of animals lived during the Mesozoic Era with the dinosaurs such as mammals, reptiles and amphibians. (my list)

Another reputable source, the Smithsonian Museum of Natural History (NMNH) Department of Paleobiology compiled a list of the *Top 10 Misconceptions about DINOSAURS* (retrieved January 12, 2006, from http://www.nmnh.si.edu/paleo/faq/html). Again, the NMNH list can be viewed in it's entirety in Appendix C, but I will provide a few comparisons with my list of fundamental concepts as above:

> Archaeologists dig up dinosaurs. (retrieved January 12, 2006, from http://www.nmnh.si.edu/paleo/faq/html)
>
> Paleontology is a scientific process that requires people to work together doing different tasks. (my list)
>
> and
>
> Dinosaurs represent failure and extinction. (retrieved January 12, 2006, from http://www.nmnh.si.edu/paleo/faq/html)
>
> Fossil evidence shows that over animals' body structures change over time (generations). Scientists now see clear relationships between body structures (like wishbones) of dinosaurs that lived in the Mesozoic Era and birds that live today. (my list)

A third list, complied by www.enchantedlearning.com is called *Top 8 Myths About T. rex* (retrieved January 12, 2006, from http://members.enchantedlearning.com/subjects/dinosaurs/dinos/trex/Myths.shtml?p). Although the list, which can be viewed in Appendix D is specific to the *T. rex*, several points correspond to larger scale "myths" in paleontology, and my independently compiled list of fundamental dinosaur concepts. For example,

> T.rex did not live during the Jurassic period. It lived millions of years later, during the late Cretaceous period, roughtly 85 to 65 million years ago. (retrieved January 12, 2006, from http://members.enchantedlearning.com/subjects/dinosaurs/dinos/trex/Myths.shtml?p)
>
> and
>
> T. rex did not fight Giganotosaurus (a giant meat-eating dinosaur from South America). They would have needed a ship and a time machine to do this. They lived on continents that were separated by a sea and they also lived millions of years apart in time (Giganotosaurus lived much earlier). (retrieved January 12, 2006, from http://members.enchantedlearning.com/subjects/dinosaurs/dinos/trex/Myths.shtml?p)
>
> Fossil evidence shows that different dinosaurs lived in different places and time periods during the Mesozoic Era. (my list)
>
> or,
>
> T. rex did not eat cave people. The dinosaurs did not live at the same time that cave men did. Primitive people evolved roughly 63 million years after T. rex went extinct. (retrieved January 12, 2006, from http://members.enchantedlearning.com/subjects/dinosaurs/dinos/trex/Myths.shtml?p)
>
> Fossil evidence shows that dinosaurs lived on earth during the Mesozoic Era, approximately 248 to 65 million years ago. (my list)

My favorite current dinosaur educational resource for teachers and the public is an illustrated children's book called *Boy, Were We Wrong About Dinosaurs* by Kathleen V. Kudlinski (Kudlinski, 2005). This book, in a fun and playful way, addresses both the fact that science changes, and each of several major fundamental concepts about dinosaurs that our understanding has changed (and continues to change) about over time. Below I paraphrase some of the major themes of this book, and relate them to the fundamental concepts from my list to which they are similar.

> In the past, scientists made what we now know to be mistakes when studying dinosaurs. (Kudlinski, 2005)

> When studying fossils, a person has to carefully separate actual observations from inferences based on those observations. (my list)
>
> and
>
> We can learn about dinosaurs by studying the insides of their bones under magnification. (Kudlinski, 2005)
>
> Observing fossils can provide us with physical scientific evidence about past life on earth. (my list)
>
> and
>
> Scientists used to think dinosaurs were more like reptiles, now they have evidence that they were more like birds. (Kudlinski, 2005)
>
> Fossil evidence shows that over animals' body structures change over time (generations). Scientists now see clear relationships between body structures (like wishbones) of dinosaurs that lived in the Mesozoic Era and birds that live today. (my list)

It seems to me, that variations of the same major concepts come up repeatedly as questions and misconceptions that people have about dinosaurs. Although my list may not mirror others exactly, my concepts are still at the heart of the other lists I researched.

Teacher Research

Teacher Learning of and Attitudes Towards Science

The research that I looked at indicated what I have also observed—many elementary school teachers (pre-service or otherwise) do not necessarily understand science content and are often intimidated by it and their past experiences in learning science (Smith, 2000). When pre-service elementary school teachers are pursuing their credentials to become teachers they take a combination of education methods and subject

matter content classes. Since elementary school teachers teach about all kinds of topics, they do not necessarily specialize in science.

In her 2000 study, Deborah C. Smith recognizes that the pre-service teachers in her class have the above mentioned problems with learning science. She has organized her senior level university class in such a way that students must address their past experiences learning about science and then work through their intimidation to gain a deeper understanding of the process of science and some science content matter. It is especially important to address the students' past experiences with learning science as they are apt to teach this way themselves. For example, Smith states:

> …most of my TE [teacher education] students are young women and these experiences have been inextricably woven into their identities about who they are, whether they belong in scientific arenas, and what they can do. This has implications for their ability and willingness to see themselves as successful science teachers in the future, and for their abilities to see girls in their classes as potentially successful in science. (Smith, 2000, p. 33-34)

One method that Smith (2000) uses to teach science process, content and methods of teaching science to pre-service educators is to have them identify barriers to children's understanding of a certain science topic. The students' then investigate these misconceptions for themselves until they have a clear understanding of what is really happening.

When such care is taken in the students' learning process the result is often that students come away with a better understanding of science, a new confidence in understanding science content and a much healthier understanding of how to teach their students about science (Smith, 2000).

Teachers and Museum Field Trips

According to researchers such as Gottfried (as cited in Griffin, 2004) many teachers see field trips as an enriching experience or something out of the ordinary rather than a component of their curriculum. As stated above, research has also found that teachers don't have much interest in preparing materials for field trips (Hein, as cited in Griffin, 2004). It is little wonder then, that most school groups I have known at MOR either request a docent led tour, or busy the students with worksheets (there are some worksheets, called scavenger hunts, created by MOR educators before my employment there or occasionally submitted by an ambitious teacher available on the MOR website). Both tours and worksheets rate very low in terms of productive learning time spent in a museum (addressed above in Museum Research section). It is the museum educator's job to work with teachers and strive to create better opportunities for learning, structure and curriculum connection on museum field trips.

The most interesting piece of information I found during my review of research related to teachers, science and museum learning is that many teachers (and students) do not view their time spent in museums on field trips as learning unless they fill in a worksheet. Griffin (as cited in Griffin, 2004) found in a 1994 study that:

> There was a strong feeling among students and teachers that learning was related to school activities and in particular in involved reading and writing. Overwhelmingly, both teachers and students indicated that worksheets were "necessary" on field trips. Students said in interviews that they preferred not to use worksheets, and yet commented: *but you wouldn't learn anything if you didn't*. There seemed to be a strong belief that *just looking around*, although they enjoyed it, did not count as learning. (Griffin, as cited in Griffin, 2004, p. S64)

I found this research very intriguing as it potentially makes my job more difficult. The work I do as a museum educator if I attempt to follow current museum best practices

and create non-traditional field trip opportunities may not appear educational to teachers and students. Or, perhaps if teachers view a field trip as a fun day (as at least one of my interviewees did) it won't matter to them whether or not the field trip is organized in a traditional manner and teachers and students may learn from their experience and without realizing it.

METHODS

The sections below detail the methods I used to complete this project. I start out by describing my interpretation of the concepts in my research question. I then present the research tool with which I obtained the data for this project and explain in depth about how it was created. Next, I explain the interview processes including interview participant selection and characteristics and changes made to my methods as a result of my pilot interview. I then explain the data analysis procedures I used, the types of data I collected and how my data collection strategy relates back to my research questions.

Research Concepts

Research Questions

How will a better understanding of elementary teachers' conceptions of dinosaur paleontology change the way I develop dinosaur paleontology museum educational outreach materials?

How will I be able to gain a better understanding of teachers' conceptions of dinosaur paleontology?

As stated in my research question, I am seeking a *better understanding* of elementary teachers' conceptions of dinosaur paleontology. By this I mean that my current understanding is based on assumptions, information ranging from literature to hearsay in the museum world and surface level, cursory information that I am able to gather through my limited interaction with teachers through my job as a museum educator. By interviewing real teachers about this topic using a carefully constructed list of questions based on a carefully constructed list of concepts (my research tool), I can stop making assumptions about at least what those particular individuals know, understand, think or believe about dinosaur paleontology. After having completed in-depth examination of teachers' knowledge of dinosaurs, I can use indicator questions that in short time frames quickly assess whether the knowledge of the current teachers I'm working with is similar to those I've studied in more depth.

Elementary teachers' conceptions about dinosaur paleontology refers to what a given teacher knows, understands, thinks or believes about the topic in question at the time of the interview. Although the teachers selected for this interview were chosen because they had requested a dinosaur hall tour at MOR (selection process detailed below), they did not necessarily currently teach about dinosaurs in their classroom (as I learned through the interviews) and were not asked or encouraged to research dinosaurs prior to the interviews. Some examples of what I told some of the participants at the beginning of the interview include:

> What I'm hoping to get from you today, though, is just your thoughts on the questions I ask you. They're science kind of questions but, for our purposes today, no right or wrong answers. I just want to know what you think. (Ward, Participant A interview, March 30, 2006)

> I have a series of questions here for you and I really just am looking for honestly what you think, what you know, what you believe, what your opinion is kind of thing on these and like I said before it will be, um, collected data to sort of see where various people who teach elementary school and, and hit on dinosaurs, are, you know, where their, their knowledge stands with this topic. (Ward, Participant B interview, April 13, 2006)

Dinosaur paleontology, for the purpose of this research project can be defined as any information referring to dinosaurs, fossils, the process of fossilization, the process of finding, excavating, prepping and mounting fossils for museum exhibits, the process of studying fossils and learning from them, geologic time (especially focusing on the length and position of one time relative to another and what did or did not exist during each time), evolution of animals before, during and after the time of the dinosaurs, characteristics of dinosaurs, the job of a paleontologist, etc.

When I state that I may *change the way I develop* dinosaur paleontology museum educational outreach materials I am referring to the idea that my current method of developing these materials may not be the best way to address the needs of the audience I am trying to reach.

Museum outreach materials may vary somewhat from museum to museum but at MOR the current range of outreach materials includes educational outreach trunks (shippable containers with a collection of themed activities and most of the materials needed to complete the activities in a classroom along with other resources such as books, DVDs and CD-ROMs), online resources (downloadable information and

activities), publications (the most recent examples include *Dinosaurs Under the Big Sky* by Jack Horner (Horner, 2001)—an adult level book with fairly scientific content from 2001 and *Dinosaurs* (Charlesworth and Sachatello-Sawyer, 1995)—a teacher's guide to dinosaurs with activities and information.

Data Collection Strategy

The main data collection strategy used in this research project was semi-structured interviews with elementary teachers from the Bozeman School District using questions developed to address fundamental dinosaur concepts specifically. Through this method, I was able to collect several kinds of data aimed at answering my research question. The purpose of these interviews was to go in-depth with a few teachers to understand their thinking. The first step in this process was to articulate key concepts fundamental to an advanced level understanding of dinosaur paleontology which serve as the endpoint for teaching learning. The second step was to assess the level of understanding that these teachers are currently working with in order to better understand any misconceptions they might have. The third step which is on-going consists of the transformations in my thinking as a museum educator about how to move teachers from their current level of understanding to that articulated in the key concept documents. The following sections describe the procedures in more detail.

Development of Key Dinosaur Paleontology Concepts for Educators

With my expertise and input from MOR paleo-artist and paleontology expert Mr. Michael Holland and Dr. Hug I was able to design interview questions based directly on

fundamental dinosaur concepts and thus create a research tool to help me find out exactly what teachers knew about each specific concept and then compare their conceptions to what is currently understood to be scientifically accurate. I referred to this tool continuously during the interviews and again during my analysis of the data collected. I was then able to create a judgment as a museum educator about whether or not these teachers understood the concepts that I deemed to be crucial to understanding dinosaur paleontology. Appendix E lists in bold each fundamental concept I was interested in followed the interview questions I used to address the teachers' understanding of them. Because the interviews were semi-structured, I was then able to follow up on each question with other questions to clarify the teachers' answers.

Initial Concept Lists. The interview questions in my research tool in Appendix E are a product of many revisions of the initial list of fundamental dinosaur questions that I created based on my work with the *Dinosaur Basics Trunk*. Shortly after establishing my goals for this project, I worked from the outline for that trunk, my own knowledge as a museum educator from experience and research, and my research done for this project and concentrated on making a list of what I believed to be the most critical dinosaur paleontology concepts necessary for further understanding and study of dinosaurs. Here is that initial list:

1. Fossils provide physical scientific evidence of past life on earth.
2. Fossils can provide some kinds of information, but cannot tell us other information.
3. Dinosaurs are a group of animals with certain characteristics that lived at a certain time in history.
4. Not all dinosaurs lived in the same time or place and other animals lived with the dinosaurs.

5. The science and process of paleontology includes many steps and many people with different jobs and tasks.

After the compilation of that initial list, I met with Dr. Hug for feedback. He suggested adding more detail to the concepts so that when questions were created from them, I would have better evidence about whether or not the concept was truly understood. The following list was the product of that revision process (W. Hug, personal communication, January 2006).

1. Fossils provide physical scientific evidence of past life on earth.
2. Observing fossils can provide us with information about past life on earth.
3. Scientists have to determine between observations and inferences when studying fossils.
4. Fossil evidence shows that dinosaurs lived on earth during the Mesozoic Era, approximately 248 to 65 million years ago.
5. Fossil evidence shows that different dinosaurs lived in different places and time periods during the Mesozoic Era.
6. Dinosaurs are terrestrial animals that lived during the Mesozoic Era and whose legs were underneath their bodies, rather than splayed to the sides.
7. Other animals that are not called dinosaurs also lived during the Mesozoic Era.
8. Birds evolved from dinosaurs.
9. Paleontology is a scientific process that requires people to work together doing different tasks.

By adding detail I also increased the number of concepts in the list because each one was more specific. Concept number eight was not a product of this detailed revision, but a concept that I deemed important enough to be added although it had been overlooked in the earlier list. After a cycle of emails with Dr. Hug, I came up with this further modified list.

1. Fossils provide physical scientific evidence of past life on earth.
2. Observing fossils can provide us with information about past life on earth.
3. When studying fossils, a person has to carefully separate actual observations from inferences based on those observations.
4. Fossil evidence shows that dinosaurs lived on earth during the Mesozoic Era, approximately 248 to 65 million years ago.

5. Fossil evidence shows that different dinosaurs lived in different places and time periods during the Mesozoic Era.
6. Dinosaurs are terrestrial animals that lived during the Mesozoic Era and whose legs were underneath their bodies, rather than splayed to the sides.
7. Many different kinds of animals lived during the Mesozoic Era with the dinosaurs such as mammals, reptiles and ???
8. The fossil evidence found so far reveal changes in animal body structures that allow scientists to see clear relationships from dinosaurs in the Mesozoic Era with birds that live today.
9. Paleontology is a scientific process that requires people to work together doing different tasks.

Paleontology Expert Input. I then asked Mr. Michael Holland, the very knowledgeable and widely respected paleo-artist at MOR to also create a list of what he thought to be the most critical dinosaur paleontology concepts necessary for further understanding and study of dinosaurs for comparison with mine. I feel it is important to explain that although I have access to the assistance of many highly regarded paleontologists through my job, I chose to seek the help of Mr. Holland for the following reasons, 1) Mr. Holland has an extensive background in dinosaur paleontology through both his education (a combination of biology, paleontology and art) and through his practical experience (over 10 years of experience working in the paleontology department at MOR), 2) Mr. Holland and I have worked closely before due to circumstance at the museum, and 3) of the many paleontologists available to me, Mr. Holland is the one I have known the best and most importantly, through my work with him I have come to appreciate his ability to approach any question I have without bias or ego, and to provide a clear and well thought out answer based on his knowledge, research and affiliation. Mr. Holland has a clear understanding of the MOR stance on controversial issues in paleontology, but he is a critical thinker by nature and always considers both sides of an issue.

Mr. Holland and I discussed and compared his and my ideas during a lengthy car trip in January 2006. Because of this, I do not have recorded data from our conversation. However, from this conversation it was clear to me that Mr. Holland's and my initial lists of fundamental dinosaur concepts were quite similar. The major point of difference between them involved the definition of a dinosaur. Mr. Holland suggested that dinosaurs did live during the Mesozoic Era and that they are animals whose legs are anatomically underneath their bodies versus splayed to the side (like a crocodile), but Mr. Holland did not necessarily agree that all dinosaurs have to be exclusively terrestrial, (though he does acknowledge that this is the most widely accepted view) and also thought the definition of a dinosaur should include a clause about evolutionary skull structure.

Mr. Holland's argument about dinosaurs not necessarily being terrestrial was that we may still find an animal with all the other characteristics of a dinosaur that lived the majority of its life in the water. Mr. Holland also feels that feathered dinosaurs that could fly (thus no longer being strictly "terrestrial") could cause some confusion, as the line between "dinosaur" and "bird" is not entirely clearly defined. I saw his points, but..."I saw his point, but, I also think that such an assertion places a level of importance on other characteristics that paleontologists believe define dinosaurs that I am not aware exists nor am I comfortable with. As far as I know, other paleontologists with whom I have interacted or whose publications I have read do not make this assertion—this was the first time I had heard it. For now, I am retaining the word terrestrial in my definition of a dinosaur because despite Mr. Holland's reasoning; at the time of this project my understanding of dinosaurs is that they lived on land and similar creatures that swam or

flew (until the evolution of birds) are considered to be swimming or flying reptiles, not dinosaurs.

Skull structure, as Mr. Holland pointed out, is an important piece of an advanced definition of a dinosaur. Although extremely important, studying and identifying the various openings in the skulls of animals is, in my mind, an advanced concept. For this project, I left skull structure out of the fundamental concept addressing the characteristics of a dinosaur. I agree with Mr. Holland that it is an important characteristic, but I disagree that it is fundamental. I think it is too advanced to be included in my list of dinosaur fundamental concepts.

After receiving Mr. Holland's input, I felt like, for the most part, my list of important concepts had been verified by an expert and that I had sound reasoning for not including the changes that the expert did suggest. Following this interaction with Mr. Holland, I continued to slightly modify the wording of my concepts, but made no other major changes in their content. Dr. Hug continued to guide me through the process of refining the wording of these concepts and the development of associated questions.

Development of Questions

With a completed list of concepts, I was able to create a question focusing on each individual concept that I felt directly addressed it. With Dr. Hug's assistance, I focused on turning each concept statement in my list into an open ended discussion question (not a closed yes or no question) that offered the interviewee a chance to talk about their knowledge base in each particular area objectively. Dr. Hug provided me with resources such as portions of *Learning in science: The implication of children's science* (Osborne,

R., & Freyberg, P., 1985) to help me understand both the process of designing appropriate and valid questions and following up on those questions during an interview scenario in a way that did not bias the participant's answer. It didn't take me long to come up with the list of questions, which can be viewed in Appendix F. The concepts and questions together constitute my research tool as it was approved by Dr. Hug. This tool served as an answer to my sub-question as to how I would be able to gain a better understanding of teachers' conceptions of dinosaur paleontology and a starting point for my interview process.

Interviews

Participant Selection

With Dr. Hug's, help, I received permission through Montana State University to proceed with my study as long as each participant signed a Participant Consent Form (for participation in human research at Montana State University) (see Appendix G) Each of the participants did sign this form, however, due to participant confidentiality rules I have included a blank form as an example. I have copies of the actual signed participant forms on file and have given a copy to each participant as well.

After permission was granted by MSU to proceed with the study, I met with Bozeman School District Assistant Superintendent, Dr. Marilyn King to ask for permission to contact Bozeman elementary school teachers to potentially participate in an interview. I received approval to contact teachers I identified through searching the MOR docent-guided tour records the names of any teacher from any Bozeman School District

elementary school who had requested a guided tour of our dinosaur exhibits during the past five years (process detailed below) and request an interview. I first sent out a letter to selected teachers on MOR letterhead explaining my project, how it fit into my job as a museum educator and how it could potentially benefit participants directly by eventually providing them with improved dinosaur educational resources (see Appendix H). I then followed up on the letter with phone calls to the teachers to set up interview times and locations.

My participant selection method, as mentioned above, was to search through the MOR computer database for any Bozeman School District elementary school who had requested a guided tour of our dinosaur exhibits during the past five years. Francie McLean, the Director of Education at the museum keeps records of all the docent guided tour requests in File Maker Pro on her computer. I was able to bring up just the records of dinosaur hall tours and then sift through them by school to locate records of Bozeman elementary school tour requests. These request forms contained the names of the requesting teacher.

The logic behind this process was to try to identify teachers who would potentially be covering dinosaur paleontology in their classrooms. As it turned out, this was not necessarily the case. Selecting interviewees via this method did, however, serve as a route to providing me with insight into the Bozeman School District curriculum, teacher's perceptions of it, and where or if dinosaur study does fit in.

I limited my search to the past five years of tour records to narrow the field of participants and to also to attempt to identify teachers likely to still be teaching in the

district. I identified ten teachers through this search (several had requested tours multiple years). Of the ten, one was recently deceased so my original list of potential interviewees consisted of nine Bozeman School District elementary school teachers.

Of that original list of nine teachers I ended up interviewing four. Some of the other teachers were too busy to be interviewed and some said that they did not teach about dinosaurs but had just been the one to call and set up the dinosaur tour and so declined an interview. All of the teachers were difficult to reach because of their work hours and the fact that they are in the classroom most of the day. Some of the teachers and I played phone tag for weeks and never were able to establish a time and place for an interview, although they were willing to participate.

Participant Characteristics

All of the participants who provided data through interviews during this study are elementary (kindergarten through fifth grade) teachers from the Bozeman School District in Bozeman, Montana. Their confidentiality is protected in this study and they will be referred to only as Participant or Teacher A, B, C and D throughout this paper. The Bozeman School District consists of six elementary schools, two middle schools and two high schools. The four teachers I interviewed represent three of the elementary schools in the Bozeman School District. They are all female, middle-aged and currently represent kindergarten, first, second and third grade classrooms. Many of them also have experience in elementary grade levels other than the one they are currently teaching. Some of them also have experience teaching in other schools in and outside of the state of Montana. All were very helpful and wonderful to work with.

All of the teachers I interviewed had taught about dinosaurs at some point in their career, but only one of them (Participant D) was actively teaching about dinosaurs (at some point during the school year) at the time of this interview.

Bozeman is not a large town and I have contact with many of the local teachers through my job at the museum. Of the participants in this study I knew one of them quite well and had worked with her on previous occasions, I was an acquaintance of another and was familiar with the names of the other two.

Pilot Interview

My first interview, although used for data collection, also served as a pilot test for my list of questions. I quickly learned whether my questions, as written, invoked responses containing the kinds of information I was seeking, whether the order in which I asked the questions created any limitations, and whether the number of questions I asked was feasible for a teacher's busy schedule. Although I tended to try to clarify my questions possibly more quickly than clarification was actually necessary during the interviews, I felt that the questions were at an appropriate level for the teachers to understand and that my clarification probably wouldn't have been necessary if I had just stopped talking and allowed time for a response. For example, during my initial interview I asked the following question, "Anything particular that you notice about this fossil in particular? I mean, any, like, when you're just observing it do you notice, what catches your eye, I guess" (Ward, Participant A interview, March 30, 2006). Later in the same interview I also asked, "I'm curious what you think, what kind of physical evidence we need to be able to know this information that is portrayed in the movie clip? What kinds

of information, physical evidence do we have to, to find as paleontologists to be able to say these things?" This type of questioning is evident in each of the interviews I completed. I don't see evidence that this was problematic in the sense that it changed or swayed the answers the teachers gave, but it certainly shows that I was nervous as an interviewer.

I did learn something about the order of my questioning from my pilot interview. I had initially loosely ordered my concepts and questions by what I deemed to be the most basic concept to the most advanced. I probably also thought about the order in which I would present these concepts to a learner. However, there were definitely logistical problems with the ordering of my questions that I did not foresee. One of my questions asked the interviewee to watch a short video clip from the movie *Walking with Dinosaurs* (Haines, Lynch and James (Producers), 1999) that showed a mother *Tyrannosaurus rex* and her offspring and to then answer a few questions about it. Later in the interview I gave the participant a blank sheet of paper with a clipart image of a *Tyrannosaurus rex* in the center and asked the participant to describe what she thought should be surrounding the animal in terms of environment and other animals. During the pilot interview, Participant A proceeded to look over my shoulder at the movie screen paused on a frame where a *Tyrannosaurus rex* stood surrounded by Cretaceous plants and environment where I had stopped it after the clip which included references to other animals that lived contemporarily and describe what she saw. I quickly learned to move the movie clip section of the interview after the *Tyrannosaurus rex* environment/contemporary question. Below is an excerpt from that interview transcription:

> MJW: You taught me to not do this first [video—Participant A could see *T. rex* on screen surrounded by environment while doing exercise]. Boy, I learned that.
>
> A: Yeah! I was going to say! Oh yeah, I can refer to that. Oh yeah, I can do that.
>
> MJW: As you're looking at this picture. Well, I learn, I live and learn. Okay. Alright, then on to the next question. (Participant A interview, March 30, 2006)

As for the number of questions I had prepared and the length of the interview, it depended on how much time the teacher was willing to devote to the interview and also the answer given whether or not I could ask all my questions in each interview. I was met with resistance from some teachers after I made initial contact through the letter which suggested that I might need up to one hour of their time. I was pleasantly surprised after the pilot interview to find that I could successfully collect all the data I was looking for during a 30 minute period. But that very much depended on the individual participant. All of my other interviews lasted longer (approximately 45 minutes for the actual interview and sometimes 15 to 30 minutes of the teacher talking to me afterwards). In one case (Participant C interview) this was partially due to several interruptions during the interview (phone calls and student's parents stopping in), but it was also partially due in that interview and the others to the teacher's enthusiasm and interest in talking and asking questions about dinosaurs. Occasionally, a participant would provide the answer to a later question unknowingly in her answer to another question and so became unnecessary to ask that question when it came up because I already had the data. Because of this variation between each interview, the actual questions I asked differed somewhat from interview to interview, but all followed the format of the semi-structured interview questions I developed (Appendix F).

Except for Teacher A, who came to the museum and was interviewed in a quiet room, all the teachers were interviewed at their schools. Teachers B was interviewed in her classroom after school had ended for the day. Teacher C was interviewed in her classroom in the late afternoon on a day students had off from school. There were many parents and teachers working on hallway displays in the building (hence so many interruptions). Teacher D was interviewed in the teacher's lounge at her school at the end of a school day. Her interview was briefly interrupted a few times by other teachers and a janitor entering the room.

Data Analysis Procedures

The data I collected exists as digital recordings on a Zen Creative Nano MP3 player (also to be burned onto CDs) and transcriptions of the interviews I produced as Microsoft Word documents. I used a qualitative data analysis procedure compiled and outlined by Dr. Bill Hug (retrieved May 12, 2006, www.montana.edu/billhug/teaching/ARreportoutline.php) to identify trends and major categories among the transcribed data. In this section I provided detailed information about each step of that process.

Understanding the Research Question

The first step in the qualitative data analysis procedure was to thoroughly establish my understanding of my research question. What kind of information am I truly seeking by asking the question, "How will a better understanding of elementary teachers' conceptions of dinosaur paleontology change the way I develop dinosaur paleontology

museum educational outreach materials?" I feel that by listening to elementary teachers answer specifically designed questions, and also by hearing and interpreting other comments and questions that these interviews bring up, I should be able to have a much better idea about the level and extent of my audience's knowledge and interest level in the topic of dinosaurs and I will be able to use that information to change my methods of developing educational outreach materials to better meet their needs. I also feel that the creation of a carefully developed tool such as my research concepts and related questions can be tested through this project and potentially serve as a useful device in the future to quickly glean an understanding of other teachers, students and visitors conceptions of dinosaur paleontology.

Understanding the Conceptual Framework

Next, I needed to come to a clear understanding of the conceptual framework in which my research takes place. In summary of my understanding of the contextual framework in which this project exists, I believe that 1) high level information about dinosaurs and current discoveries is available through publications and museum exhibits, but 2) resources about basic dinosaur concepts as we now understand them based on that science are difficult to find. So, I think that 3) in my position as a museum educator I need to work to bridge the gap between misconceptions based on old science and currently accepted scientific understanding and to do this it is important to 4) pinpoint what these misconceptions are so that I can 5) develop educational materials that address appropriate concepts at a fundamental level of understanding (especially to be used as pre-visit educational materials for school field trips. Since this project is helping me

develop tools to pinpoint those misconceptions, it is necessary and fits into my conceptual framework. This project also serves as an initial step in bridging another gap—between MOR and schools.

Reading and Labeling the Data

After I felt like I had a clear comprehension of the background and reason for my research, I read and reread the interview transcriptions looking for important themes to emerge. I labeled general themes and concepts as they were discussed by each interviewee. Some themes emerged as obvious answers to the questions I asked, but others popped up throughout the interview unexpectedly. Using this technique, I was able to identify eight major assertions that I feel are repeatedly manifested throughout the different interview transcripts—many of which were not necessarily clear to me before this process of analysis.

Unitizing the Data

Once the general themes in the transcriptions were labeled, I physically cut the sections that I had identified apart with scissors and created piles on the floor of like concepts that showed up throughout each interview and in many cases throughout most or all of the interviews. Each pile still focused on a single main theme that was being addressed in that particular section such as, “comparative anatomy,” “bird/dinosaur conceptions,” “evolution/cladistics,” or “dinosaur definition.”

Establishment of Categories and Assertions

At the end of the cutting and piling session I had over twenty categories established in piles on the floor. Nearly all of those categories had more than one reference from one or more of the interviews represented. I then could easily identify connections between most of the concepts and compress the many piles into relatively few (eight) piles expressing a larger idea. I was amazed by the way the data seemed to scream the categories to me using this method. For example, I felt that the data collected in the piles labeled, “comparative anatomy,” “bird/dinosaur conceptions,” “evolution/cladistics,” and “dinosaur definition,” were collectively indicating that although these teachers may struggle with evolution terminology, they are trying to use comparative anatomy to teach about dinosaurs (and other animals) but they don’t understand the dinosaur/bird/reptile evolutionary connection (tied directly to the definition of a dinosaur) well enough to be able to use comparative anatomy to successfully teach about this subject. I am convinced that the evidence indicated the categories that I discovered. I felt like I had reached a saturation point and these categories were what the data was telling me.

Statements like the one above came out of the next phase of the qualitative data analysis procedure. I placed the piles for each category inside separate folders and on the outside of the folder wrote a statement that connected all of the concepts inside. I came up with four major “intended discovery assertions” that reflect teacher’s conceptions of fundamental dinosaur paleontology in relation to my questions from this procedure (with much data to support each) and four more “unintended discovery assertions” (discoveries

that I had not necessarily expected my research tool to uncover, but nonetheless very interesting). These will be discussed in detail in the Data, Analysis and Interpretation section to follow.

Types of Data Points—Data Triangulation

Although this project used only one major data collection strategy, interviews, I was able to collect numerous data points through those interviews that suggest different kinds of evidence for my assertions. Through one method of data collection I obtained data about 1) specific teacher misconceptions about dinosaurs as related to my research tool, 2) information and teacher perceptions about currently utilized dinosaur educational resources such as books, magazines, videos and educational outreach trunks and 3) information about these teacher's perception of the Bozeman School District curriculum and how dinosaur paleontology does or does not fit into. All three of these lines of evidence suggest the need for and ways that I can use my expertise as a museum educator to provide better educational resources for teachers.

Another way I triangulated data was using each of the different teachers as an individual data source to triangulate for common misconceptions found in these four teachers.

Not only did my research tool allow me to pinpoint teachers' internalized misconceptions about dinosaur paleontology, but their mention throughout the different interviews of dinosaur educational resources they use helped me gain insight in to why these misconceptions were being perpetuated and the need for updated educational

resources addressing those misconceptions, and in what format those materials would best be received. Teachers talked about their use of specific children's books, puzzle books, magazines, videos, television shows and outreach trunks during their interviews. For the most part, resources were mentioned in association to some other question I had asked, but occasionally I used a follow up question to learn more about a specific resource. I was especially interested to note that more than one of the teachers mentioned out-dated dinosaur educational materials from MOR. This data provided interesting information about how old and how accurate the resources available to these teachers are, where some of the teacher's and student's misconceptions are potentially coming from, and what kinds of sources teachers trust for valid information about dinosaurs.

Also without specific prompting, but inherent within an answer to some question I asked, at some point during each interview the teachers provided interesting commentary about the way the Bozeman school system works and their opinions about the curriculum they are required to use. These statements provide insight as to how and when dinosaurs are or are not addressed in elementary schools in the Bozeman School District and how the Bozeman School District curriculum is perceived as limiting for these teachers to teach about dinosaurs in their classrooms.

Data Collection Strategy Relationship to Research Question

Through semi-structured conversations with local elementary teachers I have been able to gain insight about not only teacher's conceptions about dinosaur paleontology, but also what kinds of restrictions and limitations teachers perceive they are faced with and what kinds of resources teachers use and seek when approaching the topic of dinosaurs.

A small amount of time spent with several teachers has provided information that will help me better understand where the knowledge level and misconceptions of the audience for the educational outreach materials I create and a better understanding of how those materials can and will be used.

DATA, ANALYSIS & INTERPRETATION

The data that I gathered during my interviews with four Bozeman School District elementary teachers led me to the following intended and unintended discoveries that give me a better understanding of these individuals' conceptions about dinosaur paleontology. By intended discoveries I mean information my questions were designed to tell me, and by unintended discoveries I mean additional patterns that emerged as I analyzed the data. Listed below are the four assertions which relate closely to the concepts that I deemed important to a solid fundamental understanding of dinosaur paleontology (labeled Dinosaur Definition and Evolution, Physical Evidence, Geologic Time, and Paleontological Process), and four more assertions that are apart from fundamentals of dinosaur paleontology but that are nonetheless extremely interesting and relevant to me in my job (labeled Teacher Confidence, Perception of Curriculum, Dinosaur Size and *Tyrannosaurus rex* Image). After each assertion I address the evidence that led me to this statement and then what that evidence means to me. In other words, how the evidence will change the way I develop dinosaur paleontology museum educational outreach materials.

Intended Discovery Assertions

Dinosaur Definition and Evolution

Assertion I. Although these teachers may or may not struggle ethically with the use of evolution terminology, they are trying to use comparative anatomy (a concept inherent to the theory of evolution) to teach about dinosaurs (and other animals), but they have misconceptions about what a dinosaur is and they do not have a clear understanding of relatively recent research findings such as the dinosaur/bird/reptile evolutionary connection (based at least in part on their use of outdated resource materials) and so are not able to use comparative anatomy to successfully teach about this subject.

This is a loaded assertion, but after carefully reviewing my data, I believe that all of these concepts and misconceptions are related. The following interview questions were designed to get at the teachers' conceptions about the definition of a dinosaur and dinosaur evolution:

1. What do you think makes a dinosaur a dinosaur?

2. When you hear the word *extinct* what comes to mind? Are all dinosaurs extinct?

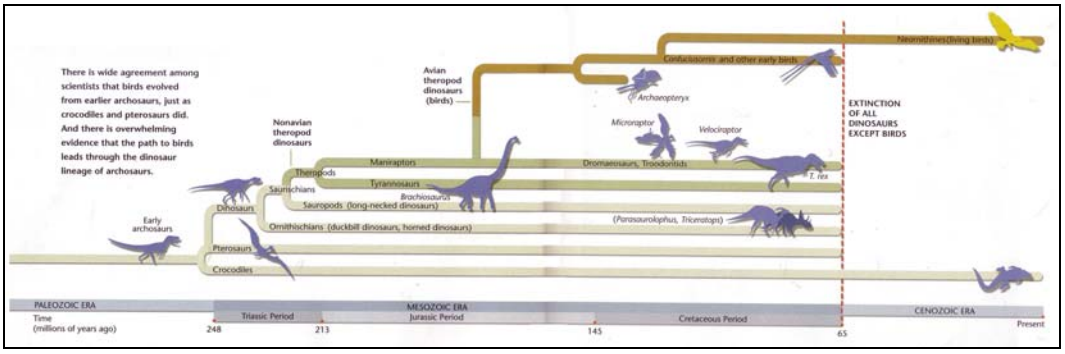
3. One or more of the following may be used. Here is a statement: "Birds are dinosaurs." When you hear this, what do you think about? Here is a statement: "Birds came from dinosaurs." When you hear this, what do you think about? Here is a statement: "Birds evolved from dinosaurs." When you hear this, what do you think about?

However, evidence for the above assertion was collected not only from the teachers' answers to these questions, but also through other comments throughout their interviews.

Comparative anatomy is an inherently evolutionary way of thinking—using skeletal anatomy of extant (existing) animals to determine which are most closely related to extinct animals as a way to gain insight into possible superficial appearance (i.e. color) and behavior (i.e. caring for young). It is now widely accepted in the science world that

dinosaurs evolved into birds, not reptiles (i.e. crocodiles) because of more than one hundred points of similarity between bird and dinosaur skeletal anatomy. More specifically, scientists have been able to determine that modern birds evolved from a specific type of dinosaurs, the theropods, and among these even more specifically maniraptors called dromaeosaurs such as *Velociraptor*. Reptiles (i.e. crocodiles) evolved around the same time as the first dinosaurs, but down an entirely separate evolutionary path. Reptiles (crocodiles) are the closest *living* relative to *birds* (because all other dinosaurs are extinct), but the closest living relative to extinct dinosaurs are birds (avian dinosaurs), *not* reptiles. These relationships are shown in Figure 2. (Sloan, 2005). This is an important concept to grasp because comparing dinosaurs to lizards is like comparing apples to oranges, instead of apples to apples.

Figure 2. Dinosaur, Reptile and Bird Evolutionary Relationships (Sloan, 2005, p. 16-17)



Because the teachers have heard about birds being related to dinosaurs, but do not necessarily understand the relationship, they are unsure of the definition of a dinosaur. I believe that some of this misunderstanding comes from teachers' understanding of the Greek roots of the word dinosaur (*dino* means terrible and *saurus* means lizard).

Participant A. Although Participant A stated that she did not teach about evolution in the classroom, she made several comments that made me, and also her realize that she actually does use evolutionary concepts when teaching about dinosaurs. Teacher A had a decent understanding of what a dinosaur is. Participant A was the only teacher to list off important characteristics when asked, "What do you think makes a dinosaur a dinosaur?"

> A: Well, we teach the four characteristics of a dinosaur, so lets see. Uh, live on land. Have feet that go, um, straight underneath them. Live on, feet straight under… Lived through the Mesozoic Era. And then we talk about their skulls having the diopsis [Participant A mispronunciation] in them.
>
> MJW: Oh, Great. Okay.
>
> A: Yeah. So those are our four, is there a fifth one? I don't remember. (Participant A interview, March 30, 2006)

Participant A also indicated a fairly clear understanding of dinosaur evolution. She talked about dinosaurs and birds being related in a coherent manner. However, she also talked about using animals such as horses to teach students about comparative anatomy. Although horse evolution could be used to teach students about the concept of comparative anatomy, horses would not be an appropriate comparison to dinosaurs.

Participant B. Participant B is an example of a teacher who is greatly confused by the limited knowledge she has about the relationship between birds, dinosaurs and reptiles. Teacher B's response to the question, "What do you think makes a dinosaur a dinosaur?" indicates obvious confusion.

> B: Um hmm. Well, at one time I might say a reptile, but, I don't say that anymore because I know that birds are dinosaurs, so and there are dinosaurs, obviously dinosaurs and, you can answer this question for me because I [laughter] cause I, just from watching movies there probably were dinosaurs that were mammals,

> right? And not reptiles? You can't tell me? (Participant B interview, April 13, 2006)

Although Teacher B has heard about birds and dinosaurs being related, she does not understand enough about the bird/dinosaur connection. She is also confused about where reptiles fit into the picture. In the following exchange she indicates that dinosaurs evolved into lizards and does not mention birds at all.

> MJW: And are all dinosaurs extinct?
>
> B: I, I have to say no cause I think that we consider some of the animals today in that category. But, I don't know what they are?
>
> MJW: Hmm. What would you say? I mean-
>
> B: I'd say the lizard. I mean, I would say, you know, those and I don't know why I always come back to reptiles, but I know that there are reptiles and I want to say the iguana, or what's the lizard with the frills? You know?
>
> MJW: Oh, uh, that one that runs on water, thing?
>
> B: I mean, my gracious, they look like dinosaurs
>
> MJW: They do! Sure.
>
> B: So, I would say that those are probably dinosaurs. You know. (Participant B interview, April 13, 2006)

Not only does the above quote indicate a dinosaur evolution misconception for Teacher B, but also a misconception about how we study evolution in general. By saying, "they look like dinosaurs," she is indicating that evolutionary connection conclusions come from superficial comparisons, not skeletal comparisons.

A statement that Teacher B made when I asked her about her about her understanding of geologic time further exposes her misconceptions about dinosaur evolution. She said, "I mean there are horses that are related to dinosaurs, there are birds

that are related to dinosaurs and so how do we find all of that? How do we know all of that? Maybe that has to geological time," (Participant B interview, April 13, 2006). She has included horses in the same evolutionary branch as dinosaurs. Technically, since every living thing evolved from a common ancestor dinosaurs and horses are distantly related, but in the context that this statement was made, that is not what is being implied.

Participant B was also confused by historical dinosaur names and their Greek roots. The word *saurus*, Greek for "lizard" is inherent in many dinosaur names and the word dinosaur itself which literally means "terrible lizard." Continuing the exchange above, Participant B asks:

> B: And what, you're not going to tell me the definition, cause what does dinosaur mean again? Does it mean?
>
> MJW: Well, I'll tell you when we're done.
>
> B: It's something lizard, right?
>
> MJW: Well, yeah, traditionally the word, yes, translates, but, that's an old word, too, so.
>
> B: That's an old word, yes. (Participant B interview, April 13, 2006)

Finally, Teacher B also brings up Pterosaurs, or flying reptiles and indicates further confusion about how these are related to birds and dinosaurs.

> MJW: "Here's a statement, "birds are dinosaurs." When you hear this, what do you think about? So, "birds are dinosaurs."
>
> B: I think about, um, again, the evolution of the dinosaur. I think about Pteranodon [participant mispronunciation Toronodon] or Pterodactyl. They had wings and they flew and did we somehow come to that? And then there's also, I don't know the name of it, but I know I read about a dinosaur that did have feathers. (Participant B interview, April 13, 2006)

Participant B mentioned that she is not currently teaching about dinosaurs in her classroom (see section Perception of Curricula below) but that when she did, she used resources from MOR, specifically the dinosaur trunk. Her confusion about the concepts addressed in this section and her comment that dates the dinosaur trunk are clear indications that MOR's dinosaur educational outreach materials need to be updated.

> B: When I first started teaching first grade, which is, that's why I say in the last ten years, that's about how far I am, um, I did do a large dinosaur unit, I even purchased, or not purchased, but, rented a trunk from the Museum of the Rockies where the kids had the actual equipment, and they had skulls, it was wonderful, I have pictures of it if you want to see in my…
>
> MJW: I, we still have it. I run that program. (Participant B interview, April 13, 2006)

Participant C. Teacher C said she didn't talk about evolution in her classroom, but did indicate that comparing animals today to animals in the past is a potential way to learn about them. She also answered my question in a manner that directly indicated her confusion.

> MJW: "What do you think makes a dinosaur a dinosaur?"
>
> C: Now, this is really difficult for me because I've been learning this from visiting the museum that mammals were introduced during the dinosaur time, you know, evolution started coming through, food started changing, the animals started changing to adapt with that and, um somethings [?] dinosaurs were, and somethings they tell me today that have evolved like birds, and of course crocodiles look like an old dinosaur, we think of scales and now I think furry and I could think feathers so that's a toughie for me. (Participant C interview, April 14, 2006)

It is interesting to note, that other comments indicating misconceptions about the definition of a dinosaur were made without this teacher noticing what she was saying. I found this to be evidence a misunderstanding of the fundamental definition of a dinosaur.

When Participant C was discussing the *T. rex* image she said, “He doesn’t look like he’s a water dinosaur, to me,” indicating that she didn’t consider being terrestrial to be a characteristic of a dinosaur (Participant C interview, April 14, 2006).

Participant D. Teacher D was able articulate a fairly clear understanding of the evolutionary relationship between dinosaurs and birds based on the following exchange:

> MJW: Okay. Well, we’ll, we’re getting close to done so it’s not too bad here, when you hear the following statement, tell me what you think, and I’m going to actually, probably throw three of them at you. Um, the first one is, “birds are dinosaurs.”
>
> D: Birds, um, birds have probably evolved from dinosaurs, from a certain type of dinosaur. I’m trying to think, um, theropods and sauropods, no, ornothiscians and sauriscians, and then I’m trying to thing where, so one type of the bird-hipped dinosaurs, um that the birds have evolved from one of the classifications of dinosaurs, not from all dinosaurs. (Participant D interview, April 20, 2006)

However, Participant D expressed a misconception that she thought Pterosaurs, or flying reptiles were birds after being asked to describe what might be seen in a picture with a *T. rex.*

> MJW: Were there birds [when *T. rex* existed]?
>
> D: There were. There were like Pteranodons and Pterodactyls things like that, I think at that time that this guy would have been alive. (Participant D interview, April 20, 2006)

By analyzing the data collected throughout these interviews it has become clear to me that even the teachers with the greatest understanding of the evolution of dinosaurs still harbor some confusion about evolutionary connections between birds, reptiles and dinosaurs, and therefore the very definition of a dinosaur. Although teachers agree that science is always changing, they also provided inadvertent evidence that they were not

aware of many recent research advances (evidence of grass at a certain location during the Mesozoic Era, discovery of preserved *T. rex* soft-tissue, discovery of bone tissue indication of sex of *T. rex* specimen). They made many references to dinosaur topics that they focus on in the classroom that are considered old hot topics in the research world (*Maisaura*, Choteau, dino-parenting).

The above evidence shows that teachers are either do not understand the relationship between birds, reptiles and dinosaurs, or that they are not accessing appropriate materials to educate themselves about that theory. It is clear that when these teachers are teaching about dinosaurs in their classrooms, they are trying to use the evolutionary concept of comparative anatomy to help children understand dinosaur anatomy, characteristics and behavior. Although I am happy to see teachers using comparative anatomy as a teaching tool, it is critical that teachers compare dinosaurs to the correct extant animals for the comparison to have any meaning. Because teachers are clearly not using comparative anatomy correctly when teaching about dinosaurs in their classrooms, I need to create materials for teachers that showcase the physical evidence linking birds and dinosaurs, explain the evolutionary connection between birds, reptiles and dinosaurs (to alleviate the misconception that dinosaurs evolved into reptiles).

Because our understanding of dinosaurs and their evolutionary relationships is still changing, it is hard to choose a hard and fast definition for the word dinosaur. However, based on our current understanding of dinosaurs there are several characteristics we can name that define dinosaurs, and animals with other characteristics that we can say are not dinosaurs. Of the teachers in this study, only one was able to list

off any of these characteristics. I need to provide materials that clearly indicate what does make a dinosaur a dinosaur based on our current understanding. I need to be clear to my audience that dinosaur is a fluid term and it cannot have a permanent definition. As changes are made to the definition of a dinosaur in the scientific world, I need to make sure dinosaur educational outreach materials reflect these changes and keep teachers up-to-date.

Teachers need to become aware of new cutting edge science as it happens. It is clear that teachers are not accessing good, up-to-date materials through the museum or any other sources that I was able to identify through this interview process. As a museum educator, I have done a lot of searching for dinosaur educational resources and have found few that I would consider to reflect current scientific understanding. Instead, the evidence shows that teachers are relying on old publications and outreach materials from MOR such as *Dinosaurs* (Charlesworth and Sachatello-Sawyer, 1995) and the existing MOR dinosaur trunk and other out-dated sources for information and resources. I need to make available to teachers sound dinosaur educational materials as I find them—updating and replacing old materials in our dinosaur trunk. I need to be responsible for creating user-friendly cutting edge dinosaur educational outreach materials for the museum as the research produces new results. This may mean a research update for teachers in the form of a newsletter of some sort—something that would be published on a frequent and ongoing basis. Hopefully, by introducing new materials, resources and research to teachers at a level that they can understand, I will encourage teachers to move on from the hot topics of the past and create enthusiasm for whatever current hot topic we may

discover and inherently indicate that science is a dynamic process from which everyone can learn.

Physical Evidence

Assertion II. When prompted, these teachers are good at coming up with what kinds of physical evidence are needed to know something (observation versus inference), but they do not seem to focus on the need for physical evidence (observation) or to focus on recognizing inferences without a lot of prompting. These teachers do not focus on fossils being physical evidence of life in the past.

One of the most fundamental concepts that I think it is important for anyone to understand about dinosaur fossils, or fossils in general is that, although observing fossils can provide us with physical scientific evidence about past life on earth, when studying fossils, a person has to carefully separate actual observation from inferences based on those observations. In a world where fact and fiction are hard to discern (docudramas on TV, Hollywood movies in theaters), educators must be skeptical about what they learn and their educational sources.

During my interviews I showed the participants a video clip (except Participant B—I did not have a laptop computer available to me on the day of the interview to show the clip) from a British Broadcasting Company (BBC) production called *Walking With Dinosaurs* (Haines, Lynch and James (Producers) that showed a *Tyrannosaurus rex* mother and babies exhibiting certain behaviors. At one point during the clip the narrator states that, “They [the babies] will remain under their mother’s protection for at least the next two months.” After viewing the clip I asked participants what kind of physical evidence paleontologists would need to find to be able to make such a claim. The question clearly got the interviewees thinking, but each was able to put together a well

thought out answer about specific fossil evidence that could lead to this kind of knowledge.

I was glad to see that with prompting, the teachers were able to understand that in good scientific practice, scientists must observe physical evidence (fossils) in order to make inferences from them. In other words, there has to be some basis for statements like the one above to be made and not be pure fiction. Unfortunately, dinosaur and other educational resources are not always accurate or trustworthy. In a field like paleontology where the average person's background knowledge is limited, it can be hard for a person to know whether a resource is trustworthy or not. I chose this particular clip to illustrate a statement being made that we don't have physical evidence (fossils) to back up. None of the teachers recognized this without some prompting, and although they said that they are critical of their educational resources, I can see that it is easy to mislead them. Teachers need to learn to place more importance on the scientific process of observing hard evidence and separating observation from inference or fiction.

Further evidence that these teachers are not placing enough importance on observation based on physical evidence comes from their answers to my questions, "I'm interested in what you think of when you hear the word fossil," and, "What would you say we can learn from fossils?" In this case, it is not what the participants said, but what they didn't say that leads me to believe that fossils are not being presented and observed as physical evidence and a prime opportunity for students to learn to think critically and participate in the process of science is being missed.

Participant A. When I asked Participant A, "I'm interested about what you think when you hear the word fossil? What comes to mind?" she answered, "A fossil…well, a

dinosaur fossil because of the state we live in. And it's a specimen of an animal that lived long ago," (Participant A interview, March 30, 2006). Although the word specimen does indicate a physical object, she did not indicate that a fossil provides physical evidence about the past.

After Participant A watched the video clip I asked her:

> MJW: Um, when it, when it comes to that behavioral aspect that's discussed in this, um, they mention a few things like, you know, that the baby might not survive, the mother might eat the baby, the mother takes care of the babies for two months.
>
> A: Right.
>
> MJW: Can you think of any kinds of physical evidence that will lead us to those sorts of conclusions?
>
> A: Hmm… [pause] Unless the babies had grown enough in, in two months that would allow them to be relatively independent and you had fossils that showed from the first stages, from the hatchling to the juvenile to a semi adult that would be about the only thing I could think of is finding that, um, I just can't think of anything besides that.
>
> MJW: Um hmm. Okay, well that's fair enough. Um, sort of as a follow up to this too, as a teacher, how do you decide whether or not to trust information that you find about dinosaurs that you are going to share with your students? Do you take that into consideration?
>
> A: I do take that in consideration. In fact, I tell them, I said do you know what science is changing so much that what they think is true today may not be true in two years because they found more information they have better microscopes, they have, you know, new finds that let them know what's going on so I always say, you know, look at it but remember its probably not 100% true, that there could be something else that would come along that could disprove that so it's only an idea, a theory that somebody has. (Participant A interview, March 30, 2006)

I think it is important to note that although Participant A made a valid attempt to think of physical evidence that could tell us about the behaviors shown in the video clip; she paused thoughtfully for a significant length of time after I asked the question as if she

had never stopped to think about that before. I also thought it was interesting to note that my question about trusting information spurred Participant A to talk about informing her students *about* changes in science—but not about what those changes are or how or why our thinking might have changed.

Participant B. Teacher B unfortunately did not have the opportunity to view the video clip and answer questions about it. I was able to ask her about fossils, however. The following is our exchange:

> MJW: I'm interested in what you think of when you hear the word fossil?
>
> B: Oh. Past. The past.
>
> MJW: The past?
>
> B: Remains of the past (Participant B interview, April 13, 2006)

Again, as in the case of Participant A, the use of a word like remains may indicate a physical object, but there is no indication that fossils are physical evidence from which we can observe and learn.

Participant C. Teacher C also focused on fossils as physical objects, but not evidence. She mentioned rocks, "rocks making fossils," fossil fuels and dinosaur bones in her answer (Participant C interview, April 14, 2006). After viewing the video clip, Participant C did state that the clip she had just watched was a docudrama, indicating that, "that means they [the movie makers] take some extra stretches." (Participant C interview, April 14, 2006). I was glad to see that she offered up the idea that the movie was not completely scientifically accurate. I then asked her:

> MJW: Do you, can you think of, of ways that science would be able to give us that information about the behavior side of it?

> C: It's very possible if they found some young ones with the mother, they would be able to verify that these were how big, and maybe how mature they were. It's very possible that finding them without their mother, when they were on their own. They could make some inferences there, maybe. (Participant C interview, April 14, 2006)

The above exchange does indicate that not only was this participant capable of working backwards to come up with examples of viable physical evidence when prompted, she was thinking about observing that hypothetical evidence and then making inferences from it.

Participant D. This interviewee clearly had the best understanding of the importance of a fossil as physical evidence. When I asked her, "I'm just interested to know what you think of when you hear the word fossil?" she responded, "When I hear the word fossil I think about, um the collection of fossils that I have in my classroom and ones that students have, have brought for me. I think about evidence of plants and animal life from millions and millions of years ago," (Participant D interview, April 20, 2006).

I was intrigued by Participant D's assessment of the following question:

> MJW: But when it comes to the behavioral aspects, things like, um the way that the mother interacts with the young or things like that. How might we be able to know about that by the physical evidence that we find. What kind of fossils would we have to find?
>
> D: Well, I think you would have to find. I think that a lot of its guess work based on current behavior of animals. I think that, you know, paleontologists probably compare current behavior of like animals, animals most like dinosaurs and then say well they did this, then probably they do this too. Um, but as far as actual physical evidence I would suspect maybe, how would they know? Um, you know, perhaps they found a mother and three babies that size, and when they said two months, that they stay with her for two months, how the heck did they know that? Maybe they've never found older babies fossilized with a mother. And they always find older teenagers or whatever off by themselves. So I figure that's how they know at what age the mother no longer takes care of the babies. Um, and, as far as, like the behavior with the three, you know animals picking on one. Survival of the fittest, I think that's probably just based on, you know, animal

> behavior throughout the history of the earth. (Participant D interview, April 20, 2006)

From her answer to this question, including her intonation as she articulated her answer it was clear that the question truly made her think critically about what kinds of evidence would be needed to make some of the statements from the video.

Although I was impressed by the participants' ability to work backwards and determine what kinds of evidence could potentially lead to these inferences about dinosaur behavior, it worried me that none of participants seemed to wonder whether or not scientists had, in reality, discovered the kinds of fossil evidence they had just describe to me. Without this prodding, the participants seemed content to watch this BBC docudrama and accept the information that it provided them. The teachers need to place more emphasis on the idea that we learn about the past from physical evidence provided by fossils, and *how* we can learn from fossils. Their students need to know that there is a difference between what we observe from that physical evidence and what we think our observations might mean so they gain a better understanding of how science works and why we know what we know about dinosaurs. I need to develop activities for teachers to use with their students that emphasize observation versus inference.

When asked, the participants did indicate that they think twice before trusting dinosaur educational resources. But it was clear to me that it is difficult for teachers to discern currently accepted scientific fact from fiction, observation from inference for this scientific topic, especially without more knowledge about what kinds of physical evidence truly have and have not been discovered. Although I find nothing wrong with using fun and engaging materials such as docudramas or Hollywood movies in the classroom, I strongly believe that they need to be used to teach about science, not only for

fun. This means that I need to develop educational activities to accompany such resources that offer teachers opportunities to use these materials to their greatest teaching potential.

It disturbs me that it appears that teachers are not placing emphasis on this fundamental concept in paleontology. Not only is physical evidence the key to what we know about the past, this is also a prime opportunity for teachers to be encouraging students' critical thinking and understanding about how science works.

Geologic Time

Assertion III. Geologic time is hard for both these teachers and their students to understand, but the teachers think it is important for both to have at least a relative understanding of it.

Because fossil evidence shows that dinosaurs lived on earth during the Mesozoic Era, approximately 248 to 65 million years ago and dinosaurs are defined in part as terrestrial animals that lived during that time period, at least a very basic understanding of geologic time is critical for studying dinosaurs. Although the concept of geologic time is mind boggling to humans of all ages, it is important for anyone studying the past to have at least a relative understanding about how geologic time is defined and broken down and about when different things existed relative to each other.

The teachers I interviewed had varying understanding of geologic time, but none of them was very confident of their own understanding. They all knew that dinosaurs and humans had never co-existed, and had some conception that the time of the dinosaurs was divided up, but were unsure of the details beyond that. The teachers all agreed that some kind of understanding of geologic time was important for their students.

Another part of the interview that was meant to examine the participant's understanding of geologic time was when I gave the participant a blank sheet of paper with nothing but an image of a *Tyrannosaurus rex* in the center and asked them, "What do you think should go around this *T. rex*? Many different kinds of animals lived during the Mesozoic Era with the dinosaurs such as mammals, reptiles and amphibians. Also, the climate was generally warmer and more humid than the climate of Montana today creating an environment for more lush and tropical vegetation. The purpose of this question was to see if the teachers had any conception about what other kinds of dinosaurs, animals and plants would have coexisted with a common and popular dinosaur like *T. rex*. Despite a preoccupation among the teachers about whether or not the image of the dinosaur was, in fact, a *T. rex* (discussion to follow), I was able to learn that the teachers did not have a good conception of what other dinosaurs and animals existed during the same time period.

Participant A. Participant A knew that the Mesozoic Era is composed of the Triassic, Jurassic and Cretaceous periods, but admitted that beyond that her understanding of geologic time was "nebulous" (Participant A interview, March 30, 2006). When I asked her what other animals might be contemporary with the *T. rex* on the paper she replied:

> Uh, lets see, what would be with a *T. rex*? Oh, could have been *Alberto-Albertosaurus* or something. I knew that *T. rex* wasn't around when our *Triceratops* were around here. I think that there were *Albertosaurus*, although try to convince kids of that. Gosh. Um, I'm, you know, I'm not familiar with the animals at that time except for those two species because we they really are, are dealing with Montana… (Participant A Interview, March 30, 2006)

This answer was interesting to me since she specifically stated that she knew *T. rex* and *Triceratops* were not contemporaries, but those are two of the main dinosaurs showcased in *The Hall of Horns and Teeth* at MOR as living in what is now eastern Montana during the latest Cretaceous period.

Participant B. When I asked, "Can you give me a sense of your understanding of geological time?" Teacher B answered:

> Right. You know, I don't know much about it other than, um, I know that there are different periods that the dinosaurs lived in, and different dinosaurs lived in the different, you know, periods. Um, and I know about our time, you know, which is present. (Participant B interview, April 13, 2006)

Despite her statement above, Teacher B went on to describe many facets of the environment that might have been surrounding the *T. rex* image on the paper. She included things like seashells, mollusks and fish in addition to vegetation and terrestrial animals. This is important, even if she didn't realize it, because fossils such as shells and fish bones provide clues to the environment, indicating water in the form of oceans, rivers or lakes. These kinds of fossils help create a clearer picture of what life was like at a certain time and place and fossils of this type found in the Hell Creek formation are showcased in *The Hall of Horns and Teeth*.

Participant C. Teacher C and I had two interesting interactions regarding geologic time. First, in association with the question about what kinds of things would surround a *T. rex* on a blank sheet of paper:

> MJW: Sure. Um, and also if this is a *T. rex*, can you name any other particular types of dinosaurs that you would expect to find with him? In his area? I guess, I guess what I mean by that is physical location and also time?

> C: Well, and that would be a toughie for me, because I know there are three, as my children have told me, there are three different times of dinosaurs. Unfortunately, I have not studied dinosaurs extensively, and I'm not sure whose in what period and because Hollywood has mixed them and pulled them together, no. (Participant C interview, April 14, 2006)

Although Teacher C indicated that she doesn't have a clear understanding of the time of the dinosaurs and what co-existed, I was excited that she realized that Hollywood is partially to blame for her and other's confusion. Not that what Hollywood had done is a good thing, but it takes critical thinking to identify that and seek the truth rather than accept it.

Secondly, I asked Teacher C:

> MJW: Can you give me a sense of understanding of geological time? And by that I mean from now all the way back through history. How does that, does that overwhelm you? Do you feel like you have a sense of what things might have lived together, or how far apart they lived?
>
> C: If I, if I, if I were teaching this, I could tell you yes. But since I'm not touching on that anymore, its not, it doesn't come to my mind as quickly as it could. However if I was looking back through and I started refreshing my mind because I was an archaeology major at one time and changed finding out that I may not find a job, so I changed to teaching but I have just a little bit of background but I was looking for men, so I didn't go as far back, and so I do understand that there are layers, and there's evolution and there's layers and layers of things that have shifted. Um, there are ways of dating, I know there are ways of dating and finding what's older, what's younger and I do realize that a lot of these things weren't here at the same time and had different times of points of extinction and different theories, and they are theories of what actually happened. (Participant C interview, April 14, 2006)

Teacher C is the only one of the four teachers to mention layers of rock in association with geologic time. Although not addressed specifically through my questions, this concept is key for understanding how geologic time and dinosaur

paleontology are related. We determine which dinosaurs were contemporaries based on the age of the layers in which they are found.

Participant D. I found the following interaction especially interesting:

> MJW: If he is a *T. rex* any idea what other kinds of dinosaurs might have been contemporary with him?
>
> D: Well, I think he was in the Cretaceous period, so we have Triassic, Jurassic and Cretaceous, and so he would have been, um, well, I can tell you *Compsognathus* was not cause he was early, I mean, let me see, with *T. rex*, well, *Maia*, *Maiasaura*, and I'm thinking *Allosaurus*, um. *Edmontosaurus*, I'm not sure, nah, maybe not that one. I don't know about that one. I'm not sure. Um, if you come visit with me in about three weeks I would know more about that because we're just coming back, we're just starting next week. (Participant D interview, April 20, 2006)

Although she does have some relative knowledge of when different types of dinosaurs lived, the one dinosaur that Participant D decides probably did not co-exist with *T. rex*, *Edmontosaurus*, is the only dinosaur she mentions that is currently on display at the Museum of the Rockies as a contemporary of *T. rex*.

It is reassuring that the teachers realized that different dinosaurs lived in different places and time periods during the time of the dinosaurs, but somewhat disturbing to find that they only have a vague conception of which dinosaurs were contemporaries, and what other kinds of animals and vegetation existed alongside the dinosaurs. Although I wouldn't expect the average person to be able to list off when all the dinosaurs lived over about a 180 million year span, something as simple as a coloring book page can place two dinosaurs together that in reality lived further apart in time than a human being and a *T. rex*.

This evidence shows that teachers admit to not fully comprehending geologic time, but see the importance of gaining a better understanding of the topic because they believe it is important for their students to comprehend, at least in a relative manner. I have also tried to teach the concept of geologic time to students in the past and have found it difficult not only because it is hard to comprehend, but because I have not yet found a really good activity or resource to help illustrate it. Based on this evidence, it is clear that for teachers and students to gain the fundamental understanding of geologic time that they need to successfully learn about dinosaurs, they need innovative ways of learning and teaching about the subject. I need to develop educational materials that help teachers and their students gain a fundamental knowledge what geologic time is, and when in geologic time different animals and plants existed relative to each other.

Paleontological Process

Assertion IV. Teachers have a good understanding of the paleontological process (but possibly not good resources to teach about it). Teachers do not see other participants in the paleontological process as paleontologists.

Paleontology is a scientific process that requires people to work together doing different tasks. The paleontological process provides insight into the dynamic nature of science and the scientific process (making hypotheses based on physical evidence). I included this concept in my study because I do believe it is important to understand how the science is done from fossil discovery to museum exhibit and all the steps in between. It is important for people to understand *how* we know what we know.

When asked about the paleontological process, all the teachers I interviewed had a fairly clear understanding of the steps from the discovery of a fossil to a museum exhibit.

This actually surprised me a little bit as I wasn't aware this was such common knowledge. Based on my interpretation as a MOR educator, I do not think it is something they are learning directly from the Museum of the Rockies exhibits and tours (some steps are addressed but not the entire process). I have also looked for good resources that address the paleontological process at an introductory level and only recently have I found one that I liked very much—*Monster Bones* (Bailey and Lilly, 2003). The only resources specifically related to this topic mentioned by the participants during the interviews include the MOR publication *Dinosaurs* (Charlesworth and Sachatello-Sawyer, 1995) and a mention of a book by Aliki by Participant D (Participant D interview, April 20, 2006) which I assume to be, *Digging Up Dinosaurs* (Aliki, 1988) which does cover the paleontological process. This is not to say that there isn't good information on this topic available, just that I have yet to find it and it is something I seek out since I too, teach people about the paleontological process. So, although I am happy to know that these teachers do understand the process, I will continue to try to provide good resources about the steps in the paleontological process to help teachers convey this information to their students.

While addressing the paleontological process with teachers, I also asked whether or not they felt that all of the people involved in the process were paleontologists. All four of them did not. I found this interesting because in a community with a famous paleontologist (Dr. Jack Horner) the perception is that someone in his position is a paleontologist, but other people who excavate the fossils, transport the fossils, prepare the fossils, reconstruct the dinosaurs, study the fossils and educate the public about the fossils are not paleontologists. After working in a museum alongside all of these people who live

and breathe dinosaur science day in and day out I guess I would disagree. I think of all of them as paleontologists. I think children should be open to this possibility, too as it opens up many career possibilities within the field of paleontology.

Unintended Discovery Assertions

Teacher Confidence

Assertion I. Sometimes these teachers exhibit very little confidence in their ability to understand dinosaurs and sometimes they come across as overly confident about dinosaur paleontology and they do not know when they are wrong.

Although this falls into the Unintended Discovery Assertions category, I find the evidence for and consequences of this assertion to be extremely interesting and troubling as an educator. A bi-product of my attempt to determine these teachers' conceptions about dinosaur content was evidence that an individual teacher can be both too confident and not confident enough in her understanding of dinosaur paleontology at any given moment. By this I mean, through statements and intonation during the interviews, I developed a sense that at times teachers felt like they knew a lot about what I was asking them and spoke confidently even if their answers were wrong and at other times they seemed intimidated by me and the vast knowledge of the subject matter that they thought I had. Each participant exhibited this behavior at some time during their interview. Although it is impossible to understand the nuances of the participant's inflection through words on a page, most of the quotes I have used as evidence of content misconceptions in the Intended Discovery Assertions section above are also evidence of this assertion. An extreme example is given here. I asked Teacher B:

> MJW: What do you think, what do you think you could learn from this [fossilized *Maisaura* metatarsal]? From this particular bone, or from fossils in general?

> B: You know, I, I, you'd have to, I think you could obviously figure out, maybe what kind of dinosaur it was by the shape of it. Maybe you could figure out just by looking at the type of bone that it is, or maybe looking on the inside what they ate? Maybe? Um, maybe because of the size you could figure out what dinosaur it came from, um. Probably wouldn't be that easy to find that out, but just like I said because of the size of it. Uh, what part of the body that the bone came from because of the shape of it. (Participant B interview, April 13, 2006)

Even on paper this quote suggests indecision and lack of confidence in her answer, although I thought some of her points reflected relatively advanced thinking, for example, the idea of studying the inside of the bone to gain information. Later in the interview Teacher B said in a completely confident manner:

> B: …I mean there are horses that are related to dinosaurs, there are birds that are related to dinosaurs and so how do we find all of that? How do we know all of that? Maybe that has to do with geological time. (Participant B interview, April 13, 2006)

I used this quote above to help illustrate Teacher B's confusion about dinosaur evolution. In the way she articulates this statement, she is indicating that it is a fact that horses are dinosaurs are related and she accepts this and doesn't even pause. She has just blatantly vocalized a huge misconception and doesn't even realize it.

This is one extreme example of a pattern I identified over and over during each of the interviews and again when I was transcribing each interview recording. Of course, I don't expect the teachers I interviewed to have a completely exhaustive background knowledge about dinosaurs and be able to articulate current scientific understanding flawlessly, but when major errors in scientific thought are passed along as fact, it is hard for students to gain a clear understanding of the subject.

I need to encourage teachers to question their understanding and seek explanation rather than preach incorrect information. This means helping teachers gain a better understanding of fundamental dinosaur concepts and emphasizing the importance of saying, “I don’t know.” Teachers don’t have to be dinosaur experts; that is the job of the paleontologists and educators at institutions such as the museum. And we want to be used as that resource. This model sets a good example for students who can learn more about how and why we have or have not learned the answer to their questions.

Perception of Curriculum

Assertion II. Teachers perceive teaching about dinosaurs to be a problem in the Bozeman School District elementary curriculum because of lack of time, the use of science kits and perceived curriculum limitations and are frustrated because they view dinosaur paleontology as important. Also, teachers tend to increase their content knowledge about a subject they are teaching when they are teaching it—they are not as knowledgeable about dinosaurs if they are not teaching about them. Possible solutions to this perceived problem could be integrated units about dinosaurs or dinosaur science kits.

All four of the teachers I interviewed had something to say about teaching about dinosaurs in the Bozeman School District. As mentioned earlier in the Context section of this paper, national and state standards and local school district curriculum based on these standards provide structure for teachers to follow when designing and teaching their classes. The data I collected through the interview process suggested that the teachers perceive the Bozeman School District curriculum to be limiting as far as teaching about dinosaurs is concerned. The indicated their frustration with this because all agreed that interest level is high about dinosaurs among elementary school students and that this interest provides a natural hook to use dinosaurs to teach about the process of science and other scientific concepts. Dinosaurs are a topic that teachers would like to be using to teach about science.

Two out of the four teachers are currently or had recently been and were planning on again in the near future including the study of dinosaurs in their classrooms despite perceived limitations from the curriculum. They feel like it is an important and popular enough subject not to be ignored—but they are doing it at the cost of another science unit. One of these two teachers mentioned her worry about getting reprimanded about doing this. The other two teachers include dinosaurs when they can—as part of other lessons and as a special treat for students.

Participant A. Teacher A had recently changed grades that she was teaching. She had been teaching an extensive unit about dinosaurs at the second grade level in the past, but was currently not planning on focusing on dinosaurs, assuming that her replacement would follow in her footsteps. She was very upset when the new teacher did not include dinosaurs because she places great importance on the subject of dinosaurs as a window into our regional history. Teacher A indicated that she would reinstate the study of dinosaurs in her own classroom to compensate.

> MJW: Do you think paleontology is important? And then, why or why not?
>
> A: I think it is particularly here in Montana when we have so many dinosaurs, or, you know, mostly for us it's dinosaurs, um, that that's part of history that kids need to know about and are very interested in and from there it's a good way of teaching them science and scientific terms and something that they're really interested in. Um, I'm bummed that the district doesn't do more with it. I really am. The teacher that took my place said I'm not teaching dinosaurs and I must have looked aghast. And she said to me, it's not in the curriculum. I said, I don't care! I said, here we are with the museum in our backdoor and all this and you're not doing it? And she said, no. And so I feel, so now I'm thinking I have another year that those kids have had dinosaurs and I will put it in the fourth grade curriculum when those second graders come up because it's something that is Montana's heritage, why would it be something I wouldn't teach just because it's not in the curriculum? I mean, that just about blew me away. (Participant A interview, March 30, 2006)

I asked Teacher A about the incorporation of the dinosaur units she taught. Her perception was that teaching about dinosaurs does not fit into the Bozeman School District Curriculum.

> MJW: Do you use it [the dinosaur unit] to address any of the standards that are in the curriculum, or is it separate or, if you, um, sorry this is a loaded question, if you did, where would you fit it? Where would you put it?"
>
> A: Well, with the school district it doesn't fit anyway.
>
> MJW: I doesn't really fit. (Participant A interview, March 30, 2006)

Then, in the answer to the same question, Teacher A brought up the science kits that elementary teachers are supposed to be using to teach about the science concepts in the curriculum.

> A: That's the problem. Because they've gone to those kits. And so, we have one, um, what we teach soils, which is really too difficult for them. And then we do a, one on plants—plants, insects and soils—that's one kit. And then measuring and weighing, that's another kit. And then, it hasn't been that long but I can't remember what the third one is! Um, so what we did is we took the plants, the insects and the soils and we combined it. And it was supposed to be like a twelve week, well we cut that off we do it that and then the extra six weeks we have that's when we do our dinosaurs.
>
> MJW: You just actually do it separately and it doesn't really address anything in particular.
>
> A: We do. It doesn't address any of what the district science goals are. And we just take in at it that's a fact but this is something we need to do in our principal supports that. (Participant A Interview, March 30, 2006)

Participant B. Participant B also talked about the fact that she used to teach about dinosaurs but has not for about 10 years. She talked about using the science kits (Foss kits, which is the term she uses are specific brand name of some of the science kits), the time the kits consume and the importance of paleontology, as well.

> B: I do not teach about dinosaurs anymore and here's why, because I have to do the Foss kits. And those take a lot of my time...I haven't done dinosaurs, quite honestly in about four years. Because when I moved here then, I lived in [another Montana town] then, we started these Foss kits. And I just felt like the only way we were going to see dinosaurs, boys and girls, is if we go to the museum and we have taken tours, which they learned a lot but you can only do so much in that one day. (Participant B interview, April 13, 2006)

It is interesting to note that she mentions the science kits taking up a lot of her science teaching time, and also that although she does use MOR as a resource; it is a one time deal. One day of dinosaur instruction with no context and she knows it.

I was intrigued by Teacher B's reasoning for why paleontology is an important subject for children to be exposed to. She was the only one of the four teacher to mention exposure to the widest diversity of topics possible at a young age may encourage children to be dreamers and to pursue those dreams into adulthood as careers.

> MJW: Um, do you think paleontology is important? Um, I mean, in the big picture if kids never learned about paleontology, um, are they missing out? And, if you think it's important, why?
>
> B: …I think it's extremely important. I don't know what other people think. And I'm not a scientist, and you know those kinds of things, but, um, the other thing is, I know this sounds kind of crazy but, I think kids need to be exposed to everything to find their niche and there are some kids that will take that and say that's what I'm going to do.
>
> MJW: Um hmm.
>
> B: That's what I'm going to do, I'm going to study dinosaurs. Or, you know, whatever, I think we just need to expose kids to everything that we can.
>
> MJW: Sure. Sure.
>
> B: So they know where to go with their lives. (Participant B interview, April 13, 2006)

It is interesting to note that this is how Dr. Jack Horner got his start in the field of paleontology. Many other friends of mine who are workers in the field have also attested

to an early interest in dinosaurs that was nurtured and developed throughout their childhood. These people have never lost their sense of excitement about the world or their ability to wonder at nature and seek explanations through science.

Participant C. I contacted Teacher C to participate in this project in the manner that I described in the Methods section, the same as the other teachers. This teacher was curious as to why I would have chosen her for a dinosaur interview, and when I explained my methods she told me that she had requested a dinosaur hall tour because, "We do both tours. I mean, while I'm there [at MOR], while I'm there why not do it all? We do the observatory [planetarium], the dinosaur tour and the pioneer tour," (Participant C interview, April 14, 2006). Teacher C was not focusing on dinosaurs in her classroom but I found the reason why interesting, she was "assuming" that someone at a higher grade level in her school was covering dinosaurs and she said, "we've been asked not to step on the toes of other people's curriculum and take the wow out of it early, I've pretty much kind of stayed off of it a little bit," (Participant C interview, April 14, 2006). I found this interesting because she was the only teacher from her school that came up in my search for Bozeman School District elementary teachers who had requested a dinosaur hall tour in the past several years, except for one other teacher who was deceased. Teacher C was her replacement, suggesting that if tours of the dinosaurs at MOR are any indication, no other teachers are focusing on dinosaurs in this school either. When asked, Teacher C told me she would like to be teaching about dinosaurs. She said it's, "definitely a hot topic," (Participant C interview, April 14, 2006)

Another interesting point made by Teacher C came about when she was discussing what might have surrounded the *T. rex* on the blank page. I asked her, "Do

you feel like you have a sense of what things might have lived together, or how far apart they lived? Teacher C answered, “If I, if I, if I were teaching this, I could tell you yes. But since I’m not touching on that anymore, its not, it doesn’t come to my mind as quickly as it could,” (Participant C interview, April 14, 2006). Teacher C makes an important point that should be stated clearly. Teachers are responsible for teaching about multiple topics throughout the course of a school year. They also change grades which they teach over the course of a career and therefore also change subject matter. Teacher D also hinted about this issue in her interview (see below).

Participant D. Teacher D also made a comment that I thought was interesting related to her knowledge of dinosaurs. When I was asking her about the *T. rex* image and what dinosaurs might have been his contemporaries, she said, “Um, if you come visit with me in about three weeks I would know more about that because we’re just coming back, we’re just starting next week,” (Participant D interview, April 20, 2006). As a teacher myself, I understand that with so many topics to cover it is hard to stay current on all the subject matter all the time. However, I do think that if these teachers were confident in their background knowledge about dinosaurs they would incorporate that knowledge into their other lessons more readily even if they are not teaching major units on dinosaurs.

Participant D was the only teacher I interviewed who was incorporating a serious study of dinosaurs into her school year at present. Her school has developed an integrated unit where students read about dinosaurs, write about dinosaurs and learn dinosaur spelling words to help find the time to include the subject in their school year. Even so, when I asked her, “do you fit it [dinosaurs] in your curriculum? Do you cross it over and

make it work with what you are supposed to be teaching? Or is it a added icing? She responded:

> D: Well, we're trying to. [This grade] is supposed to be teaching animal habitats and we're supposed to be ordering these live, let's see snails, and, um, hermit crabs, and not hermit crabs, what are those little? Fiddler crabs. And what's the third animal. And every year we resist and this year we didn't do it and we're waiting for somebody on high to tell us we're in big trouble. But we can't do both. (Participant D Interview, April 14, 2006)

Teacher D and her co-workers view the study of dinosaurs and the science as important enough to make changes to the Bozeman School District curriculum perceived limitations even if it potentially jeopardizes their jobs.

Since the evidence is showing that Bozeman elementary school teachers perceive a problem with teaching about dinosaurs, one or both of two things need to change; the system needs to be modified to include dinosaur study, and/or teachers need to develop a new outlook about the system. If it is possible to help teachers incorporate dinosaur study into their classroom, it might also alleviate some of their frustration with the system and help them to become better teachers.

Lack of time in any classroom in this day and age is a real problem. Science is not the only subject taught in elementary school and as Participant D put it, "We cannot do science every minute of the whole day," (Participant D interview, April, 20, 2006). I even find this to be true in my job. From my experience and discussions with my graduate committee advisor, Dr. Bill Hug, I have come to realize that every topic in science has an advocate and that advocate is vying for their topic's inclusion in the school curriculum. With that kind of competition it is a challenge for your platform to get attention. However, in the case of dinosaurs, at least based on my interviews and my experience

from my job as a museum educator in a multi-topic museum, getting people (especially young children and their teachers) excited about my topic has not yet been a major obstacle. All the teachers I interviewed expressed strongly that paleontology is an important topic for a variety of reasons and I could sense their enthusiasm for dinosaur study and their frustration with their perception of the school system. Participant D expressed it the most passionately:

> MJW: …do you think teaching paleontology to these young kids is important? I mean, what is it that paleontology contributes to society that makes it worth your time to focus on that so hard?
>
> D: Well, I'll tell you the biggest thing is the interest level. Oh my gosh. You know, I can't wait to start teaching it because the kids are just, they're in the palm of your hand and they just love it and they eat it up and it teaches them about scientific process and it just happens to be dinosaurs which they have a huge interest in, so, take that and go with it. Because, you know, one of our kits in school is chemistry and we investigate these five white solids and well, that's okay but are they interested in that like they are interested? Do they like to add the water and vinegar? Yeah, they do, but you know for the whole picture, are they as interested in that as they are in dinosaurs? Uh uh. So it's a natural, bait is quite the word that I'm looking for there, but, uh, hook.
>
> MJW: Sure. It's a hook.
>
> D: Um hmm. It's a natural hook. And there are so, you know they can look at adaptations, animal adaptations, and earth history and you know there's so much, I just think it's so powerful. (Participant D interview, April 20, 2006)

With that kind of enthusiasm out there for the subject, it is a shame that for whatever reason dinosaurs are not necessarily a focus in these classrooms, that those I interviewed who do teach about dinosaurs are doing it on the sly and waiting to get caught, and those who are not would love to be.

Three out of the four teachers I interviewed brought up the fact that the use of science kits mandated by the Bozeman School District has filled the time in school

allotted for science study, and therefore study of dinosaurs no longer fits into the curriculum. My understanding is that currently, there is no science kit that focuses on dinosaurs.

I have little power to change the Bozeman School District curriculum, although based on this study I have decided to do more research on the system. However, this may be a case of, if you can't beat 'em, join 'em. These teachers may have a different understanding, but my interpretation of the standards and the curriculum that is more specific, yet still based upon them is that developing an understanding of certain concepts, such as the characteristics of organisms, the life cycles of organisms or organisms and environments is the goal for students. Why can't some of these organisms be dinosaurs and some of the environments be ancient?

I am not proposing that the word "dinosaur" necessarily appear anywhere in the Bozeman School District curriculum (although I wouldn't argue against it either). I am proposing that I create a well designed collection of resources and activities incorporating national and state educational standards, such as the one mentioned above, organized in such a way that teachers could potentially use it as a way to teach about dinosaurs in their classrooms, but still cover all required elements of their curriculum. And, if done correctly, the study of dinosaurs can also easily help students develop abilities necessary to do scientific inquiry and develop understanding about scientific inquiry (also a national educational standard for K-4) why not allow teachers and children to indulge in a topic they love? These educational outreach materials could take the form of a bound published book (like the *Project WET Curriculum and Activity Guide*) (Project WET, 1995) and/or

an outreach trunk similar to what we have had in the past, but designed more along the lines of the science kits mentioned by the teachers that are used in classrooms. Participant B was particularly excited about the idea of my making such a kit, although the words don't show it as well as her intonation did.

> MJW: And I'm starting to wonder if that's the direction that this project will take me is to the school board saying can we make a kit, I mean, if that's the way it's going to work, you know-
>
> B: Oh I would love it! [sharp intake of breath] (Participant B interview, April 13, 2006)

I think the key for a kit like this to be used to it's fullest potential at least in the Bozeman elementary schools would be to host teacher workshops demonstrating and explaining how this educational resource can be incorporated into their classrooms as seamlessly as possible, and to provide teachers sound fundamental training about the dinosaur topics that they and their students need to understand. If teachers then bring their students to the museum for a visit, they will be much better prepared to learn about the more in-depth dinosaur research that MOR and other institutions showcase.

Changing a school district's curriculum is a governance issue that I don't know if I can influence. But I can play a role in helping teachers incorporate dinosaur paleontology back into their classrooms, especially if they are willing to change the way they view the system. I can develop dinosaur educational materials that specifically address the national and state standards so that if teachers use them, they are still covering the required bases. If the school district insists on using science kits to teach

ensure science educational goals are met, I can create a dinosaur kit that specifically addresses national and state standards and fits into the curriculum.

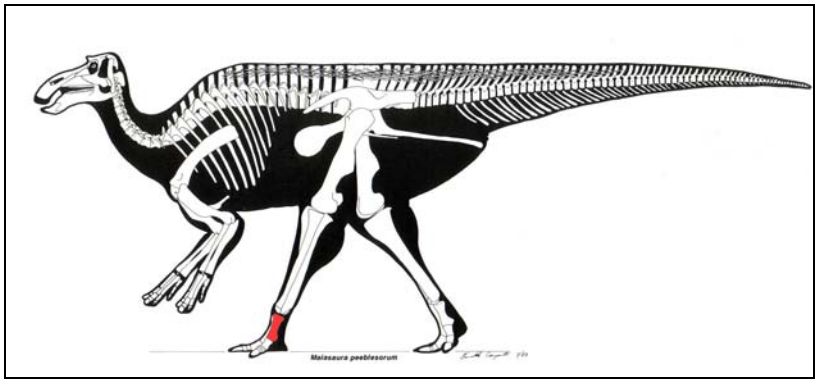
Dinosaur Size

Assertion III. These teachers have a misconception about dinosaur size.

An interesting product of my interview question for all four teachers that used a fossilized *Maiasaura* metatarsal (foot bone) as a prop was the discovery that all of these teachers tended to think small when observing the fossil.

Figure 3. Photo of *Maiasaura* Metatarsal Fossil

Figure 4. Location of Metatarsal within *Maiasaura* Skeleton



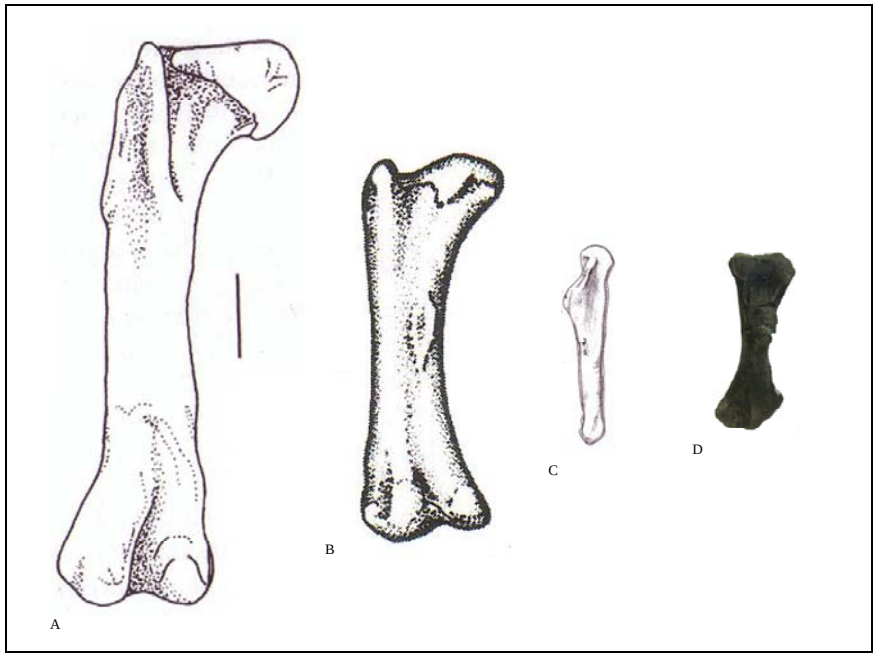
All four participants' first impression was that the bone I showed them was perhaps a femur (upper leg bone) or an arm bone. In teaching at the museum, I also find that kids often think the metatarsal is a femur, probably due to it's shape (to an untrained eye, both have a classic bone shape—wider on the ends than in the middle), but in reality the dinosaur that this bone belonged to, and many other dinosaurs are much larger than the teachers' and children's minds seem to want to entertain.

I have always found this interesting because the *Maisaura* metatarsal fossil is much shorter than my own femur. Dinosaurs can be as large as a house or as small as a chicken but although dinosaur skeletons with femurs similar to the length of this one have been found, dinosaurs of such small size would almost certainly be too light to have such as sturdy femur. Their femurs would be much more slender.

Figure 5. Maisaura Metatarsal Fossil Compared to an *Orodromeus* (small *Velociraptor*-like dinosaur) Femur (Scale bar=10cm)

Only one teacher, Participant A, guessed at the type of dinosaur, saying, "I suspect it's probably from an arm of a *T. rex* or the leg from a *Triceratops*," (Participant A interview, March 30, 2006). I found this especially interesting because although a *T. rex* does have relatively very short arms compared to its body, a *T. rex*, *Triceratops* and many other dinosaurs have much, much larger femurs than the length of the fossil bone I brought in. Figure 6 compares the size and shape of a (A), *T. rex* femur, a (B) *Triceratops* femur and a (C) *T. rex* humerus (upper arm bone) to my (D) *Maisaura* metatarsal.

Figure 6. Comparison of Bone Sizes and Shapes (Scale bar=20cm)



The implications of this unexpected evidence indicate that I need to place greater emphasis on the skeletal structure of dinosaurs and the size of different dinosaurs in relation to humans. When discussing dinosaurs with any audience, I should not assume that they understand the scale of the animal relative to themselves or other dinosaurs.

Tyrannosaurus rex Image

Assertion IV. These teachers were confused by my *T. rex* image.

For one of my interview questions I gave the participant a blank sheet of paper with the image of a *T. rex* in the center and asked them, "What do you think should go around this *T. rex*?" I was surprised to find that three of the four interviewees were sidetracked either in their answers to that question and/or later during the interview by the image itself. Confusion reigned about whether or not the animal on the page really was a *T. rex,* which can be viewed in Appendix F.

Participant A. Interestingly, Teacher A made no indication that she did not think the dinosaur was a *T. rex*.

Participant B. When I mentioned, in passing, that the animal on the page was a *T. rex* during this section of the interview, Teacher B immediately asked, "Is that a *T. rex*," (Participant B interview, April 13, 2006). She had thought it was a raptor but did not elaborate on what made her think that. In retrospect, I should have followed up with more questions about that, but at the time it didn't seem important.

Participant C. After several minutes of discussing the image with no indication as to the type of dinosaur, Teacher C mentioned that she also thought it was, "probably more of a raptor family," (Participant C interview, April 14, 2006). I asked her why and she said, "Because my kids tell me a lot about raptors," and went on to talk about how raptors have become more popular than *T. rex* of late (Participant C interview, April 14, 2006). Later in the interview after she had viewed the video clip with a computer generated image of a *T. rex*, she revisited the issue saying:

C: This looks more like a juvenile.

MJW: The little ones or the big one?

C: No, this one. [points to T-rex on paper discussed earlier]

MJW: Oh that one.

C: Its skull is different, it's flatter. (Participant C interview, April 14, 2006)

Participant D. Instead of asking Teacher D, "What do you think should go around this *T. rex*?" I worded the question:

> MJW: This blank piece of paper except for the dinosaur in the middle, well first of all, I'm curious to know what you think about the dinosaur, if you have any idea what kind of dinosaur that is, and then secondly, what would you imagine would be around this dinosaur, say that you were able to go back in time and take a snapshot with the dinosaur in the middle- (Participant D interview, April 20, 2006)
>
> After discussing a few other aspects Teacher D stated:
>
> D: Well, I don't know if this is a *T. rex* or not, he's definitely got short, um, arms and he's definitely a massive sort, *Allosaurus*, or I don't know which one, the kids, my students would know, but, um, they are very good at that… (Participant D interview, April 20, 2006)
>
> More discussion ensued but shortly Teacher D brought the *T. rex* up again saying:
>
> D: I really don't think he is a *T. rex*, his head doesn't look, his arms do, and I don't think he's a *T. rex*. I think he's somebody else.
>
> MJW: He looks a little skinny, doesn't he? I, the reason I asked you that mainly is I have had quite a few people who thought he was a raptor.
>
> D: Oh. (Participant D interview, April 20, 2006)

Again, in retrospect I wish I had asked Teacher D to explain her reasoning further, but I did not. I am left to wonder why three of the four teachers I interviewed clearly did not see a *T. rex* where I did.

VALUE

After implementing the questions in my interviews, I felt that these questions were successful in providing me with the information I was seeking. I now have evidence that updated dinosaur educational outreach materials are desperately needed and what concepts those materials should specifically address. I definitely view the data collection strategies that I used as a positive way to change the way I create educational outreach

materials about dinosaurs and for other topics in the future.. In this section I elaborate on the value of this project to myself, MOR, teachers and the world of science education.

Personal Value

I am a critical thinker by nature, so basing time consuming and important educational endeavors off of assumptions goes against my values. As I started to develop a new dinosaur educational outreach trunk and other materials for the museum, I realized that for me to be comfortable in my approach, I needed to change the way I determined what kind of content should be addressed in my educational outreach materials. Before this study my methods for developing any kind of educational materials included identifying *what I thought to be* the most fundamental, important and interesting concepts about the subject matter, and then creating activities to address each of those points as the objective. Although I still believe that creating fun, creative, dynamic activities addressing the fundamental concepts of any topic is key, I have learned from this study not to make assumptions about what those concepts are, but to do the research and be sure that I am truly addressing the needs of my audience. I did find that most of my assumptions about misconceptions were close to being accurate through this project, but I was able to pinpoint the specifics of those misconceptions and gain a clear understanding of four individual's perceptions of dinosaur paleontology. I also discovered unexpected misconceptions and uncovered nuances in the data through careful analysis that would have otherwise been missed.

Through this process I also created a valuable research tool and a model that I can trust and use in the future to be able to evaluate individual dinosaur misconceptions

relatively quickly. The concepts and questions associated with my research tool may change over time as science advances, but I have gained the expertise to be able to develop such a powerful educational inquiry tool again in the future. I will now be able to modify my research tool as necessary and use it to measure teacher misconceptions about dinosaurs as more discoveries are made and incorporated into the new dynamic MOR dinosaur exhibits. I am also now capable of creating similar research tools for other fields of study and creating better educational outreach materials based on true perceptions rather than assumptions.

Another value of this project for me was to find out how great the need is for updated dinosaur educational materials, both in general and from MOR specifically. I had already realized that our materials were in need of updating and I have been planning on undertaking that project, but based on the references to out of date resources that these teachers are currently using in their classrooms, I feel a new sense of urgency to design these materials and get them into circulation. I will now be raising the priority of the dinosaur trunk projects in my job and I am thinking about a possible publication to replace *Dinosaurs* (Charlesworth and Sachatello-Sawyer, 1995).

It was valuable for me though this project to learn firsthand teacher perceptions of the importance of dinosaur paleontology and how it fits into the Bozeman School District elementary curriculum. A lot of assumptions are made in a museum about why visitors are coming. Hard evidence is needed to actually be able to make claims. I certainly did not know how large of a problem and limitation teachers perceive the organization of their curriculum, materials and time to be. I just assumed that because groups were

coming for tours, they must be studying dinosaurs at school. I now see that it is up to me as a museum educator to be thinking about how and if teachers can and will use the materials I create, not just the content the materials address. I also now have new insight about the importance of teacher workshops and the influence I could have on my understanding of what teachers need and want along with their understanding of what MOR has to offer through even a little interaction. I now plan to host training workshops for teachers when my new dinosaur trunks are completed so that they not only have quality materials, but they also know how to use them.

Finally, I can see an added value in this project in the educator connections it creating and enhancing. Not only did I have the opportunity to get to know four local elementary teachers, I have also established a contact at the Old Trail Museum (OTM) in Choteau, Montana—another dinosaur museum thinking about creating a dinosaur educational outreach trunk. After discussing my project and my job with a contact at the OTM, we decided we needed to collaborate and I am planning a trip to Choteau for later in the summer.

Value for MOR

My place of employment will benefit from my partaking in this project. Because of my research, I will be able to create better quality educational materials based on teacher input and circulate them under the Museum of the Rockies name. Also, the new and renewed collaboration opportunities addressed above will also benefit the museum.

Value for Elementary School Teachers

The elementary school teachers involved in this project, and potentially many other school teachers in the future, will benefit from the fact that once I am able to pinpoint their dinosaur misconceptions using the research tool I developed in this process, I can provide them with much more useful and better quality educational outreach materials for use in their classrooms. Their students will potentially benefit indirectly, as well. Teachers will also benefit from much more frequent teacher workshops that I plan to design and implement as a follow up to this project to better insure teacher understanding of dinosaur fundamental concepts. Finally, teachers will benefit from the fact that I now realize just how crucial it is update dinosaur educational outreach materials regularly as new scientific discoveries are made.

Value of this AR Project to General Knowledge in this Area

There is much agreement that the study of dinosaurs at a young age opens doors for children in science. My project verified that fact to me through interviews with four individuals in the field of (science) education, and also opened my eyes or opened them wider to some obstacles that might be keeping teachers from focusing on this topic—including teacher misconceptions about dinosaur content, outdated resources and perceived curriculum limitations. Verification and further clarification of dinosaur misconceptions in four individuals may not upend the world of dinosaur education, but the tool I created for this project will help me to gather more data about dinosaur misconceptions for other teachers. The more evidence I amass about dinosaur misconceptions, the more potential that information has to change how it is presented by educators.

Another observation I made throughout this project was the lack of these four teacher's focus on *how* we know what we know in science, or the process of how science is done. Despite the fact that the these teachers seemed well aware of the various steps involved in the process of paleontology, I did not get the sense that they are focusing on these in their teaching. They may spend some time teaching about excavating or casting, but they do not seem to do much with the kind of science that is done in the basement of MOR everyday. I have thought since I started my job that most kids want to be a paleontologist but they don't really know what one is or what one really does. I think it is valuable for science educators to realize the potential for this kind of teaching in dinosaur and other science education. If elementary teachers are focusing on content (facts) not process, it is up to science educators like me to provide the appropriate resources for teachers to change their ways.

New Questions

Any study leads the researcher to new questions. The largest question I have at the end of this study is about whether or not my assertions would hold true across a larger section of the elementary educator population. I believe that the research tool I created in for this project could help me to answer that question. I may follow up this study with a questionnaire for elementary educators around the state based on my interview questions. I feel that the more I can learn about the nuances and extent of these dinosaur misconceptions, the better quality dinosaur educational outreach materials I can create for teachers in Montana and eventually beyond.

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APPENDICES

APPENDIX A

Fundamental Dinosaur Concepts

Fundamental Dinosaur Concepts

1. Fossils provide physical scientific evidence of past life on earth.

2. Observing fossils can provide us with physical scientific evidence about past life on earth.

3. When studying fossils, a person has to carefully separate actual observations from inferences based on those observations.

4. Fossil evidence shows that dinosaurs lived on earth during the Mesozoic Era, approximately 248 to 65 million years ago.

5. Dinosaurs are terrestrial animals that lived during the Mesozoic Era and whose legs were underneath their bodies, rather than splayed to the sides.

6. Fossil evidence shows that different dinosaurs lived in different places and time periods during the Mesozoic Era.

7. Many different kinds of animals lived during the Mesozoic Era with the dinosaurs such as mammals, reptiles and amphibians.

8. Fossil evidence shows that over animals' body structures change over time (generations). Scientists now see clear relationships between body structures (like wishbones) of dinosaurs that lived in the Mesozoic Era and birds that live today.

9. Paleontology is a scientific process that requires people to work together doing different tasks.

APPENDIX B

United States Geological Survey Dinosaurs: Facts and Fiction

United States Geological Survey Dinosaurs: Facts and Fiction

USGS
science for a changing world

By Ronald J. Litwin, Robert E. Weems, and Thomas R. Holtz, Jr.

Few subjects in the Earth sciences are as fascinating to the public as dinosaurs. The study of dinosaurs stretches our imaginations, gives us new perspectives on time and space, and invites us to discover worlds very different from our modern Earth.

From a scientific viewpoint, however, the study of dinosaurs is important both for understanding the causes of past major extinctions of land animals and for understanding the changes in biological diversity caused by previous geological and climatic changes of the Earth. These changes are still occurring today. A wealth of new information about dinosaurs has been learned over the past 30 years, and science's old ideas of dinosaurs as slow, clumsy beasts have been totally turned around. This pamphlet contains answers to some frequently asked questions about dinosaurs, with current ideas and evidence to correct some long-lived popular misconceptions. Although much has been discovered recently about dinosaurs, there is still a great deal more to learn about our planet and its ancient inhabitants.

- When did the first dinosaurs appear on Earth?
- Are all fossil animals dinosaurs?
- Did people and dinosaurs live at the same time?
- Where did dinosaurs live?
- Did all the dinosaurs live together, and at the same time?
- How are dinosaurs named?
- What was the biggest dinosaur? What was the smallest?
- How many types of dinosaurs are known?
- Were dinosaurs warm-blooded?
- How long could a dinosaur live?
- What did dinosaurs eat?

- How fast could dinosaurs walk or run?
- Did dinosaurs communicate?
- Why did some dinosaurs grow so big?
- Which was the smartest dinosaur?
- What colors were dinosaurs?
- Were dinosaurs social animals?
- When did dinosaurs become extinct?
- Why did the dinosaurs die out?
- Where can I find more information about dinosaurs?

(Retrieved on January 12, 2006 from http://pubs.usgs.gov/gip/dinosaurs/)

APPENDIX C

Smithsonian National Museum of Natural History Department of Paleobiology

Top 10 Misconceptions about DINOSAURS

Smithsonian National Museum of Natural History Department of Paleobiology

Top 10 Misconceptions about DINOSAURS

1) Dinosaurs represent failure and extinction.
2) Dinosaurs and "humans" coexisted.
3) Dinosaurs were either all hot-blooded or all cold-blooded.
4) The word dinosaur means "terrible-lizard."
5) Whatever you read in the latest "dinosaur book"
   or see on T.V. or in the movies must be true.
6) Dinosaurs all lived and died at the same time.
7) Mammals arose after the dinosaurs, and helped
   drive the dinosaurs into extinction by eating dinosaur eggs.
8) An asteroid (or comet) killed the dinosaurs.
9) All big reptiles from the prehistoric past ["Monsters"]
   are dinosaurs.
10) Archaeologists dig up dinosaurs.

(Retrieved January 12, 2006, from http://www.nmnh.si.edu/paleo/faq/html)

APPENDIX D

Enchanted Learning Top 8 Myths About *T. rex*

Enchanted Learning Top 8 Myths About *T. rex*

People have many misconceptions about *Tyrannosaurus rex*. Here are a few of them.

1. *T. rex* did not live during the Jurassic period. It lived millions of years later, during the late Cretaceous period, roughly 85 to 65 million years ago.

2. *T. rex* was not the king of the dinosaurs (but its species name rex does mean king). Dinosaurs didn't have kings. It was the top predator in the food chain, but that isn't much of a distinction, since most positions in the food chain are equally important. The organisms at the bottom of the food chain (like plants and plankton) are more crucial to the survival of the whole chain; if they die, a major extinction can follow.

3. *T. rex* was not necessarily green. No one knows what color it was.

4. *T. rex* was not mean; it was just an animal that ate other animals in order to survive. Reptiles do not have complicated emotions.

5. *T. rex* did not fight *Giganotosaurus* (a giant meat-eating dinosaur from South America). They would have needed a ship and a time machine to do this. They lived on continents that were then separated by a sea and they also lived millions of years apart in time (*Giganotosaurus* lived much earlier).

6. *T. rex* wasn't the biggest dinosaur. There were many sauropods (long-necked plant-eating dinosaurs) that were bigger than it was. Also, there were (at least) two other meat-eating dinosaurs that were bigger than *T. rex*, *Giganotosaurus* and *Carcharodontosaurus*

7. *T. rex* did not eat cave people. The dinosaurs did not live at the same time that cave men did. Primitive people evolved roughly 63 million years after *T. rex* went extinct.

8. *T. rex* was not the smartest dinosaur. Many other theropods (like Dromaeosaurids and Troodontids) had a bigger brain-to-body mass ratio.

APPENDIX E

Research Tool

Research Tool

Fundamental Dinosaur Concepts (in bold)
Question(s) directly addressing that concept (numbered below each concept)

Fossils provide physical scientific evidence of past life on earth.
1. I'm interested what you think of when you hear the word "fossil".

Observing fossils can provide us with physical scientific evidence about past life on earth.
2. *Show participant dinosaur bone fossil.* What do you think this is? What do you think you could learn from this? What do you notice? What do you think it means? What would you say can we learn from fossils?

When studying fossils, a person has to carefully separate actual observations from inferences based on those observations.
3. *Show movie clip from Walking with Dinosaurs*. What do you think about the movie clip you just saw? What kind of physical evidence is needed for us to be able to know the information portrayed in the movie clip? As a teacher, how do you decide whether or not to *trust* information about dinosaurs?

Fossil evidence shows that dinosaurs lived on earth during the Mesozoic Era, approximately 248 to 65 million years ago.
4. Can you give me a sense of your understanding of geological time? Were humans and dinosaurs ever alive at the same time?

Dinosaurs are terrestrial animals that lived during the Mesozoic Era and whose legs were underneath their bodies, rather than splayed to the sides.
5. What do you think makes a dinosaur a dinosaur?

Fossil evidence shows that different dinosaurs lived in different places and time periods during the Mesozoic Era.
Many different kinds of animals lived during the Mesozoic Era with the dinosaurs such as mammals, reptiles and amphibians.
6. *Give participant a blank piece of paper with an image of a T. rex in the center.* What do you think should go around this *T. rex*? Draw and/or explain.

Fossil evidence shows that over animals' body structures change over time (generations). Scientists now see clear relationships between body structures (like wishbones) of dinosaurs that lived in the Mesozoic Era and birds that live today.
7. When you hear the word *extinct* what comes to mind? Are all dinosaurs extinct?
8. *One or more of the following may be used.* Here is a statement: "Birds are dinosaurs." When you hear this, what do you think about? Here is a statement: "Birds came from dinosaurs." When you hear this, what do you think about? Here is a

statement: “Birds evolved from dinosaurs.” When you hear this, what do you think about?

Paleontology is a scientific process that requires people to work together doing different tasks.

9. What characteristics do people who study dinosaurs (paleontologists) have?
10. What do you think a day is like for a paleontologist?
11. *Give participant a blank piece of paper with a fossil still in the field at one end and a museum mounted dinosaur at the other*. What do you think happens between finding a bone and a museum display? Draw and/or explain.
12. Do you think paleontology is important? Why? How would you say paleontology contributes to society?

APPENDIX F

Semi-Structured Interview Questions

Semi-Structured Interview Questions

1. I'm interested what you think of when you hear the word "fossil".

2. *Show participant dinosaur bone fossil.* What do you think this is? What do you think you could learn from this? What do you notice? What do you think it means?

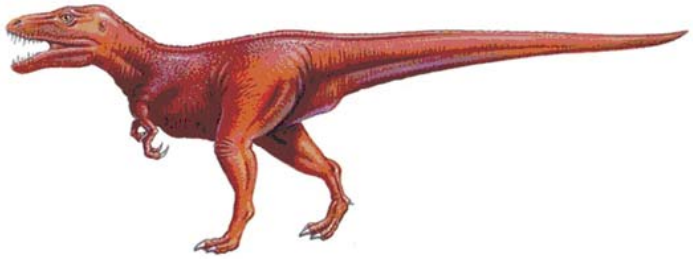
3. What would you say can we learn from fossils?

4. *Show movie clip from Walking with Dinosaurs*. What do you think about the movie clip you just saw? What kind of physical evidence is needed for us to be able to know the information portrayed in the movie clip? As a teacher, how do you decide whether or not to *trust* information about dinosaurs?

5. Can you give me a sense of your understanding of geological time? Were humans and dinosaurs ever alive at the same time?

6. What do you think makes a dinosaur a dinosaur?

7. *Give participant a blank piece of paper with an image of a T. rex in the center.* What do you think should go around this *T. rex*? Draw and/or explain.



8. When you hear the word *extinct* what comes to mind? Are all dinosaurs extinct?

9. *One or more of the following may be used.* Here is a statement: "Birds are dinosaurs." When you hear this, what do you think about? Here is a statement: "Birds came from dinosaurs." When you hear this, what do you think about? Here is a statement: "Birds evolved from dinosaurs." When you hear this, what do you think about?

10. What characteristics do people who study dinosaurs (paleontologists) have?

11. What do you think a day is like for a paleontologist?

12. *Give participant a blank piece of paper with a fossil still in the field at one end and a museum mounted dinosaur at the other.* What do you think happens between finding a bone and a museum display? Draw and/or explain.

13. Do you think paleontology is important? Why? How would you say paleontology contributes to society?

APPENDIX G

Participant Consent Form

Participant Consent Form

PARTICIPANT CONSENT FORM
FOR PARTICIPATION IN HUMAN RESEARCH AT MONTANA STATE UNIVERSITY

Improving Science Teaching, Learning, & Education Support Systems

You are being asked to participate in a research project that seeks to understand how science is taught and learned in order to improve science education.

1. The purpose of this study is to gain an understanding of and improve the use of various science education curriculum materials, science teaching methods, and the support that would improve the teaching and learning of science.
2. You have been selected because of your role in our community as an educator.
3. If you agree to participate you will be asked to complete a survey and/or verbally answer questions about science teaching and learning, your use of science education resources, your understanding of science concepts, and your teaching of science education concepts. This will take between 15 - 60 minutes of your time.
4. The risks for participating in this study are minimal. There are no anticipated physical risks associated with your participation. All information you share will be kept confidential minimizing any social risks associated with your participation.
5. There are no tangible benefits for your participation in this study such as financial compensation.
6. You may choose not to participate or to withdraw your consent at any time without penalty. Your decision to participate/not to participate in this study will not result in any benefits or disadvantages.
7. This project does not use any external funding sources.
8. There are no costs for participating in this project.
9. Any personal information collected with the survey or interview will be deleted, masked, and/or otherwise changed to ensure confidentiality consistent with professional standards for this kind of research. The data will be kept confidential and secured in locked offices or in password protected computers. No one outside the principal investigator and approved research staff will have access to the data. In research papers, funding proposals, or other public presentations resulting from this study, your name will not be used and any identifying characteristics or personal information that could be used to identify you will be deleted or masked. Your responses will be tallied and combined with all other respondents as summative/cumulative data. Your privacy will be protected to the maximum extent allowable by law.
10. In the event your participation in this research directly results in injury to you, please contact appropriate community emergency services. Montana State University cannot be held responsible for injury, accidents, or expenses that may occur as a result of your participation in this project. In addition, Montana State University cannot be held responsible for injury, accidents, or expenses that may occur as a result of traveling to and from your appointments at the site of data collection.

11. Please feel free to ask any questions regarding this study prior, during or after your participation. You may contact:

Molly Ward, Education Coordinator, Museum of the Rockies, 600 W. Kagy Blvd., Bozeman, MT 59717; 406-994-5282
J. William Hug, Ph. D., 118 Reid Hall, P.O. Box 172880, Bozeman, MT 59717; 406-994-5953

12. If you have questions or concerns regarding your rights as a study participant, or are dissatisfied at any time with any aspect of this study, you may contact – anonymously, if you wish – Chair Institutional Review Board, Montana State University, 960 Technology Blvd., Room 127, Bozeman, Montana, 59717. For information and assistance, call 406-994-6783.
13. Your participation in this study is confidential and voluntary.

AUTHORIZATION: I have read the above and understand the discomforts, inconvenience and risks of this study.
I, _____ *(name of subject)*, agree to participate in this research. I understand that I may later refuse to participate, and that I may withdraw from the study at any time. I have received a copy of this consent form for my own records.

Signed:_____Date:_____

Witness:_____Date:_____

Investigator:_____Date:_____

APPENDIX H

Letter to Bozeman Elementary School Teachers

Letter to Bozeman Elementary School Teachers

March 8, 2006

Dear Educator,

In the spring of 2005 the Museum of the Rockies was able to open our doors to school groups free of charge through the generosity of private donations. The museum has recently raised enough money to continue this program at least through the 2007 calendar year. We hope that you and your students will take advantage of this amazing opportunity and visit the museum in the upcoming school years.

You have received this letter because you and your school group toured the dinosaur hall at the Museum of the Rockies at least once during the past five years. In an attempt to fine tune the museum's offerings I am now asking for your help. I hope that you will participate in the study outlined below to help the museum offer the best opportunities for you and your students in the future.

As the Education Coordinator at the Museum of the Rockies, it is my job to design or update our educational offerings. I am also finishing my graduate degree in the Master of Science in Science Education (MSSE) program through Montana State University (MSU). My graduate committee chair and advisor is Dr. Bill Hug from the MSU Education Department.

For my final project I would like to interview local elementary school teachers who teach about dinosaurs and paleontology in their classrooms. I am seeking information that will help me design better tours, outreach materials and workshops for teachers and their students. My goal is to be able to convey the most important information about the science of paleontology in a way that teachers and students can best use it.

I am asking you to donate approximately 45 minutes to one hour of your time and sit down with me for an interview. I am interested to find out what you think and what you understand about certain aspects of paleontology. I will ask you questions to which there are no right or wrong answers. The goal of the interview is only for me to understand how you perceive the past. By collecting this data from many participants I hope be able to better understand the level and types of information to be included in various educational outlets at the museum. Shortly after the data is collected I will offer a workshop about dinosaurs and paleontology incorporating what I have learned from your responses. Participants in the study will be invited to attend the workshop free of charge.

You will receive a follow up phone call from me shortly after you receive this letter. I hope to schedule interview times and locations at that point. I hope that you will be available and interested to help me with this project. Thank you.

Sincerely,

Molly Ward
Education Coordinator
Museum of the Rockies
600 W. Kagy Blvd.
Bozeman, MT 59717
(406) 994-5282