# FIELD SCIENCE EXPERIENCES IN PALEONTOLOGY:

# SHAPING SCIENCE STEWARDSHIP

# IN HIGH SCHOOL LEARNERS

by

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# DEDICATION

To my wonderful students and the freshman class of 2022 at The Webb School of California and Vivian Webb School. Thank you for always inspiring me as your teacher and lab manager. You all have taught me so much.

“It is important to remember that we must take the responsibility to preserve the fossils on the land for future generations.” – Ninth Grade Student Participant

“Speak to the Earth, and it shall teach thee.” – a favorite Biblical quote of the late and inspirational Webb teacher Raymond M. Alf

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# ABSTRACT

How do field science experiences shape a sense of conservation and stewardship in learners? This study analyzed separate groups of female-identifying and male-identifying 9th grade high school students (*N*=80) on their first field paleontology experience at Rainbow Basin Natural Area, California. Likert-style surveys and written self-reflections indicate relative consistency in pre- and post-treatment responses student-to-student, through when paired with qualitative responses, the power of science stewardship and a personal sense of connection to public lands becomes markedly apparent. Future studies in the realm of science stewardship in field paleontology will help illuminate the impact of field paleontology on science learners.

# INTRODUCTION AND BACKGROUND

## Field of Curiosity

Young children often gravitate toward topics of intense scientific interest, such as dinosaurs and other extinct creatures. The curiosity and capacity children have for very specific knowledge within a science is an experience to which many parents can relate, and to which many career scientists can personally attest. Specific knowledge in a science, including intense curiosity about dinosaurs, can aid in the development of structured knowledge. Gobbo and Chi (1986) connected intense bouts of interest in science with the strengthening of cohesive analogical knowledge - that is, the ability to directly compare two items or features of an item. Glasner (1984) reported the development of analytical skills and improved memory in young learners who were keenly interested in a science. Beyond helping young students build a strong science knowledge base and develop analytical skills, a childhood self-education in science and subsequent school-based projects can increase communication skills, and help students connect in-school learning with out-of-school interests and experience (Bryson, 1994; Katz, Chard, & Kogan, 2014).

Yet as children grow older, some of this innate curiosity appears to wane. By the time those same young children reach high school, many are convinced their questions aren't good enough; that they do not have the academic tools or confidence to seek reaffirmation of their curiosity; or that they have been taught ineffectively. Sir Ken Robinson's TED talk, 'Do schools kill creativity?', highlights the connection between a fear of being 'wrong' and the loss of creativity in modern education (Robinson, 2006).

Along with a fear of being 'wrong' comes a fear of asking questions, which squashes the creativity needed to drive new ideas in science, and to solve new and pressing global problems. Too often, this author has witnessed anecdotal evidence of each of those unfortunate claims – inside and outside of the classroom. Too often, high school students appear to have lost the innate scientific curiosity, creativity, and excitement about asking deep questions, and by proxy, have lost some of the excitement that fuels a love of studying science – especially in public schools. It brings to mind a secondary point: if students appear to have lost their interest in and enthusiasm for the sciences, how then are their attitudes toward science caretaking, compassion, and protection – 'science stewardship' – affected?

This leads to the underpinning of this work, where I ask the following questions:

1. Will engaging in outdoor activities that have their roots in observation and curiosity alleviate some of these motivational issues?
2. Are these issues truly present in a study sample?
3. And, what do students gain from such an endeavor – especially with regard to their understanding of science stewardship?

In order to explore these questions, ninth grade independent school students participated in two-day field paleontology excursions and were asked to self-reflect on their experiences through a series of survey questions and written free response. In addition, interviews were conducted to help understand the impact of field science experiences as science motivation tools, and particularly, motivation for students to become science stewards. I hypothesized that participation in field paleontology experiences, albeit brief ones, will increase student outdoor enthusiasm, science motivation, and science stewardship. A comparison group of ninth grade students who elected to participate in a tenth grade honors paleontology course will serve as a vehicle for exploring motivation to continue in a dedicated paleontological science course. Through analysis of student paleontological learning experiences on public lands, we can gain a more cogent understanding of how place-based learning and field science impact student compassion for the natural world and its resources, interest in science, and science stewardship. Ultimately, the next generation of science policy-makers and scientists will need to bridge all three of these attributes, as well as reach across partisan divides, in order to balance the environmental, scientific, and economic issues that play out in tandem on public lands, especially in the United States.

## Science Stewardship and Public Lands

The focus of this research is two-fold: to explore the power of field paleontology as a science motivator and engagement tool, especially for young women – who comprise approximately half of the surveyed student population; and, centrally, to tease apart the connection between science motivation and student attitudes toward science stewardship on public lands. An example of this kind of science stewardship is the care, conservation, and study of fossils within U.S. national monuments and other public lands. In order to outline the connection between public lands and stewardship, we need a clear definition of both terms.

Public lands in the United States include those lands managed by state and federal government agencies, and encompass sites managed by the National Park Service (NPS), Bureau of Land Management (BLM), U.S. Forest Service (USFS), the Army Corps of Engineers, U.S. Fish and Wildlife Service (USFWS), the Bureau of Reclamation, and state parks. Seventeen parks have been designated specifically to conserve paleontological resources located within their boundaries, and 252 other public land parcels are known to contain vertebrate or invertebrate fossils (Tweet & Santucci, 2018). Forty-five other fossil-bearing lands are designated as National Natural Landmarks (NNL) to conserve fossil resources specific to those sites (Santucci, 2017).

Stewardship has been broadly defined in the environmental conservation and stewardship realm as:

> The responsible use (including conservation) of natural resources in a way that takes full and balanced account of the interests of society, future generations, and other species, as well as of private needs, and accepts significant answerability to society (Worrell & Appleby, 2000).

For the purposes of this study, science stewardship is defined as the caretaking of scientifically important natural resources, and within that umbrella, I focus specifically on fossil stewardship on public lands. Science stewardship may also encompass the caretaking of ecosystems, organisms and their migrations, archaeological artifacts, and geologic formations.

## Science Stewardship in an Anti-Science Age

The issue of how scientific field study impacts science stewardship in young learners is particularly pertinent in the political climate under the Trump administration in the United States. On December 4th, 2017, the Trump administration issued a proclamation to drastically reduce the size of two national monuments: Grand Staircase-Escalante National Monument in southern Utah, by about 46%; and Bears Ears National

Monument, in southeastern Utah, by about 85% (Purdy, 2018). The educational impact of this reduction has yet to be assessed, and the long-term environmental and educational effects of this unprecedented rescinding of monument boundaries are currently unknown.

In an environment of anti-science policy, from the reduction of national monument boundaries to the denial of climate change and U.S. withdrawal from the Paris Climate Agreement, the study of the impacts of these changes to public lands and the corresponding scientific attitudes of the public is timely. Coupled with localized decline in student motivation to study science in the K-12 arena, worldwide (Krapp & Prenzel, 2011; Vedder-Weiss & Fortus, 2011), every action should be taken to support student interest in science, and to help students recognize the relevance and importance of natural protected areas and the scientific resources within them to their daily lives, and their futures.

What is the current status of science stewardship on public lands? If left to our own devices, how would the American public act, broadly speaking, on public lands, and how does the public perceive an intrinsic sense of science stewardship? One key piece of stewardship is the maintenance of public lands in a pristine state that allows for the continued enjoyment of future generations. The U.S. Organic Act of 1916 states in its establishment of the National Park Service:

> The service thus established shall promote and regulate the use of the Federal areas known as national parks, monuments, and reservations hereinafter specified by such means and measures as conform to the fundamental purposes of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations (Organic Act of 1916).

Contrary to the ethos of this statement, there exists an unfortunate history of vandalism in national parks in the U.S. (Foresta, 2013; Miller, 2018; Smith, 1954; Muir, 1901) and around the globe (Buckley & Pannell, 1990), which inherently speaks to the dangers of public disregard for natural spaces. What motivates visitors to public lands to conduct such acts of natural abuse? Vandalism and natural area abuse aren't the only issues that arise from friction between natural areas set aside for conservation purposes, and the beliefs and behaviors of the surrounding human populations. In developing countries, a cultural disconnection or sense of threat from government management of natural protected areas can also elicit strife between public land managers and local indigenous peoples (Bowonder, 1983; Hough, 1988). Indeed, in the United States there are echoes of the same mentality – driven by an economic and political furnace.

For example, in 2018 former Secretary of the Interior Ryan Zinke and his team fielded at least 20 new claims to mining rights in the former Grand Staircase-Escalante National Monument, including a successful bid by Canadian mining firm Glacier Lake Resources, Inc. at Colt Mesa (D'Angelo, 2018; Glacier Lake Resources, 2018). These mining claims appeared within seven months following the shrinking of Monument boundaries, and are among the mining and drilling efforts championed by conservative think-tank the Sutherland Institute, which played a crucial part in the rescinding of Bears Ears National Monument (Sutherland Institute, 2018). Sutherland Institute has also criticized federal management of Grand Staircase-Escalante National Monument (Anderson, 2018) in favor of a close-to-home, state-run management system. A study spearheaded by Colorado College has coordinated broad studies to take the temperature of public attitudes towards public lands in the western United States, including Arizona, Colorado, Idaho, Montana, New Mexico, Nevada, and Wyoming; an average of 66% of respondents (*N*=3200) reported that President Trump's shrinking of national monument boundaries is a 'bad idea', while an average 68% of respondents (*N*=3200) reported that rollbacks of laws that protect our land, water, and wildlife are 'serious' considerations (Colorado College, 2018). Is there a danger inherent in equating mining and drilling with vandalism and abuse of public lands, considering the natural resources these activities would potentially disrupt? Are mining and drilling economically-driven forces of vandalism that are accepted for their monetary and societal benefits to local economies? How do state and federal entities, the local public, and park employees balance the needs of economy with the conservation of public lands? And, how do we teach young people to be science stewards when the idea of how best to enact stewardship on public lands is already drawn in stark relief along conservative-liberal partisan lines, between economic and conservation lines, and among state-run versus federally-run stewardship motivators in the United States? When did we become so polarized?

How can we reach across the bipartisan aisle and reach compromises that achieve the wishes of environmental groups, Native nations both for and against monument land, economic entities, scientists concerned about natural resource damage and shifting permitting regulations, and local communities concerned about federal overreach in the United States? It seems reasonable to believe that the majority of visitors to public lands do not wish to vandalize or mistreat natural resources, regardless of political affiliation or opinion on public land management. However, disturbing accounts of such vandalism underscore the lack of compassion for natural spaces and their presence as natural areas set aside for the benefit of future generations. Some of these acts of vandalism and general disregard may be the result of conflicting and changing Park Service management policy, or yet again reflect a piece of an American cultural underbelly of materialism and natural destruction (Foresta, 2013). U.S. federal government shut-downs in January, 2019 led to increased reporting of vandalism, alleged destruction of natural resources, and general disregard for natural spaces in affected national parks and monuments, especially in Joshua Tree National Park.

How can science stewardship and increased motivation to understand our world through a scientific lens allow learners to build compassion for others, respect for natural spaces, and an understanding of why science matters? Field paleontology is one educational tool that can bring hands-on learning and real relevance to students from a wide variety of backgrounds, and is one method by which we can test questions on the impact of field study on science stewardship motivation on public lands. Without a baseline understanding of field science as an educational vehicle for science stewardship, answers to questions that explore the educational and societal impact of public land reduction on learners remain nebulous. It is my hope that this study will serve as part of the growing conceptual framework within which science stewardship and the impact of field paleontology on student learners can be assessed, and through which the importance of scientific resources on public lands, and the conservation of public lands, can be championed.

## Scope and Setting

I began teaching high school science in 2012, after earning my Master of Science in Museum and Field Studies from the University of Colorado at Boulder. During my time at Boulder I began to rekindle my interest in science outreach and education, which had been a lifelong endeavor that took me on several internship and career adventures in museums and field paleontology sites around the United States. Since becoming a public school teacher, and now an independent school teacher, I have developed a personal goal to help students find motivation and interest in science, whether they go on to become career scientists or not. This is spurred in part by my own formative educational experience, which mixed wonderful educators with less-than-stellar voices that seemed to discourage women in science and other forms of diversity awareness.

In high school I was selected for a field science scholarship that brought me out of my comfort zone to explore camping, field study, and scientific research first-hand. Reflecting on that experience, I find it even more important to help would-be scientists and science educators step into the great outdoors and learn to follow their natural scientific curiosity. This study seeks to analyze the benefits that outdoor field science education can provide students, especially those students who may find science, and the outdoors, distinctly uncomfortable or unfamiliar. How can we help students recognize, and achieve, their scientific self-worth?

I teach at The Webb Schools, an independent, non-parochial school located the foothills of the San Gabriel mountain range in Claremont, California. Today, young women and men learn together at the coordinate-model Vivian Webb School and The

Webb School of California, which together form the coeducational Webb Schools of California. The Webb School of California was founded in 1922, and Vivian Webb School was founded in 1981, inducting the first class of female students. Enrollment at Webb averages around 400 students total, a mix of 35% day and 65% boarding students, with 21% of students hailing from countries other than the United States. Students in the 2018-2019 academic year come from 12 U.S. states and 14 countries, and Webb emphasizes its 100% college acceptance rate, with a rigorous curriculum and highly motivated student body.

At Webb, students are encouraged by an inquiry-based, mastery-style curriculum to become adept at posing and answering their own scientific and social questions within their courses. A hallmark of the educational framework at Webb are independent student research projects in individual classes, as well as Unbounded Days, a biennial series of short courses that encourage unlimited thinking in a variety of topics of interest to faculty and students. Research projects in the science curriculum often culminate in school-wide poster presentations, participation in local and county science fairs, and in student presentations at regional and national conferences.

The Webb Schools also houses the Raymond M. Alf Museum of Paleontology on its grounds, the brainchild of the late Dr. Ray Alf, an inspirational teacher and paleontologist at Webb. Beginning in the 1930s, Ray Alf led Webb students – initially all male boarding students – on annual paleontology digs in the Miocene-age Barstow Formation near Barstow, California, or to other fossil localities in the Western Interior of the United States. Decades of Webb students have enjoyed the annual freshmen ‘Peccary

Trips', so named after the peccary skull fossil discovered on an early expedition led by Ray Alf. Today the Raymond M. Alf Museum is a designated federal repository of fossils from public lands, and is fully accredited by the American Association of Museums (AAM) – the only museum of its kind on a high school campus in the world (Lofgren, Liu, & Williams 2019).

Within this inspiring scientific environment, Webb students are encouraged to think broadly about the natural world, and more generally, to act with honor and moral courage, and to serve with a generous spirit. These words from the mission of the school tie in closely with the ideals of science stewardship – to protect and conserve natural resources for future generations. Since Webb students engage in original research throughout the school year, and often on fossils from their own field excavation and documentation, Webb is an excellent place to analyze the connection between research-based field work, field study and field learning experiences, and stewardship. Ultimately we seek answers to global questions that will positively impact future educators and students.

The foundation of this paper is set on three firmly interwoven strands: science curiosity, field science experiences, and science stewardship. An interest in and enthusiasm for science rests in many factors, including individual student gravitation towards one topic over another; parental, familial, and educational support for those interests; socioeconomic factors that allow for the prioritization of academic interests along with basic needs of security; availability of resources – including time as well as academic resources - to explore scientific topics freely; and a broader, societal appreciation for the importance and creativity of science. Field science experiences can allow the learner to recall childhood memories of outdoor play, as well as connect to fundamental principles of scientific exploration and curiosity, in a dynamic and often unpredictable natural environment. The sense of adventure, of being pushed out of a comfortable space, and even of camaraderie can make field science experiences rich formative tools that help support science enthusiasm and curiosity, regardless of the ultimate career goals of the learner. It follows that a sense of the importance of science stewardship and caretaking would likely grow if these field experiences are positive. And, perhaps in future longitudinal studies, the impact of these experiences on the number of students entering STEM careers can also be assessed.

## CONCEPTUAL FRAMEWORK

### Field Study and Field Science Education

Field study, the practice of engaging in the generation of questions and collection of data either outside the classroom in a natural setting (Levitt, 2016) or through a virtual substitute (Mistler-Jackson & Songer, 2000), can be a great engagement tool for students and serve as a modest science motivator (Levitt, 2016). In high school life and earth science classrooms, field study is often a requirement alongside lab-based activities. The U.S. Department of Education describes two Classifications of Instructional Programs (CIPs) that feasibly encompass field study or field science in the context of instructor training: outdoor education (CIP Code 31.0601) and environmental education (CIP Code 13.1338). Outdoor education is defined as:

> A program that prepares individuals to work as an educator, instructor or facilitator in parks, recreational facilities, camps and other outdoor settings. Includes

> instruction in leadership skills, wilderness survival skills, first aid, group processes, counseling techniques, environmental studies and instruction in recreational activities such as rock climbing, ropes courses, backpacking, kayaking and canoeing (U.S. Department of Education, 2010).

Whereas environmental education is defined as:

> A program that prepares individuals to teach environmental education at various educational levels as a K-12 classroom educator. Includes instruction in foundations of environmental education, instructional methods, and related content knowledge (U.S. Department of Education, 2010).

While these definitions are interesting in their own right, neither fully encompasses the definition of ‘field science education’ as explored in this work. Although many ‘field science education’ activities – though not all, in the case of virtual field experiences – are outdoor activities, instructional and situational variability necessitates a third definition that incorporates pieces of both outdoor and environmental education, and addresses the instruction of students, rather than the instruction of instructors. Here, ‘field science education’ is defined as:

> A program or course of curriculum that engages learners in the collection of scientific data in a natural setting or virtual equivalent, and may encompass aspects of hiking, camping, leadership skills, wilderness survival skills, environmental studies, development of digital skills, and the analysis and description of collected data for a broader audience (U.S. Department of Education, 2010).

Using field science education as a vehicle for student learning in the high school setting, we can probe questions on student science motivation and science stewardship, and we can expand our understanding of student curiosity about the natural world. Field paleontology education is the subset of field science education that forms the focal point in this particular study.

## Next Generation Science Standards

Within the context of the United States and Canada, the Next Generation Science Standards (NGSS) have been championed by many states and provinces as a scaffold map of science topic standards and skills, with each school year and grade level building upon those standards and skills. Three subdivisions within the NGSS include the Scientific and Engineering Practices, Cross-Cutting Concepts, and Core Content Standards. Each of these subdivisions seeks to connect science to broader applications across different fields of study, and to ensure students are learning core content in a logical and methodical way throughout their formative school years.

The Scientific and Engineering (S&E) Practices are used to emphasize the intermingling between scientific skills and scientific knowledge, stressing the importance of how science and engineering practices achieve scientific and engineering goals. Yet at the same time the S&E Practices underscore that science doesn't exist as a body of isolated facts and that students do develop and practice skills as they learn how to reason in a scientific context (National Research Council, 2012). The S&E Practices are:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)

7. Engaging in argument from evidence

8. Obtaining, evaluating, and communicating information.

It should be acknowledged that this list of practices is similar to the traditional model of the linear scientific method, so often taught in schools. The method of scientific questioning is far more branching and convoluted than any series of cookbook steps might imply. These practices emerged as a much more fluid series of steps to help students understand how scientific knowledge develops. The S&E practices can help students appreciate the wide range of approaches that can be used to “investigate, model, and explain the world” around them (National Research Council, 2012).

Cross-Cutting Concepts provide a framework for students to connect knowledge from various disciplines into a “coherent and scientifically based view of the world” (National Research Council, 2012). Often students are encouraged to connect one subject or course topic with an entirely different one, which can encourage the idea of subject matter existing in separate silos, with congruent ideas never meeting. Students are commonly expected to build cross-cutting knowledge without explicit instructional support (National Research Council, 2012). The ability to connect seemingly disparate ideas is fundamental to science and engineering; it encourages students to build critical thinking and problem-solving skills that promote learner confidence. The Cross-Cutting Concepts are:

Patterns

Cause-and-effect

Scale, proportion, and quantity

Systems and system models

Energy and matter: Flows, cycles, and conservation

Structure and function

Stability and change.

Course work in the sciences allows for multiple opportunities to engage in each of these concepts. For example, the use of patterns, scale, proportion, and quantity ties spatial perception and mathematical calculation to science topics, while principles of engineering design and biomechanics can be intertwined to analyze structure and function. Cause-and-effect is a common observational skill that leads to further questions and hypotheses, while stability and change can be applied to numerous science topics from deep time to physics to climate change. Systems and system models allow students to perceive the interconnectedness of various physical and environmental systems, while energy and matter concepts can be applied to all scientific subjects. By recognizing and evaluating the ways in which concepts interconnect, students and educators build scientific confidence and are ultimately provided a window into the broad relevance of science to the world at large.

Core Disciplinary Ideas are the unifying principles that are essential to understanding a particular subject at hand (National Research Council, 2012). The NGSS structures core disciplinary ideas into four major categories: physical sciences; life sciences; earth and space sciences; and engineering, technology, and the applications of science. Each category has its own scaffold of topics meant to ensure a progression of knowledge throughout a learner's formative school years, from grade to grade. Many

Core Disciplinary Ideas intermesh with field study in general and field paleontology in particular, which are outlined below. Examples of specific core ideas and S&E practices mapped within this project are included in Appendix B.

## When and Where Do Schools Use Field Study?

### NGSS and Inquiry-Based Learning

Field study encompasses a broad range of topics, and is not relegated solely to the sciences. For the purposes of this study, we focus on field science, particularly field paleontology as a learning tool. Where, then, does field paleontology implement the Next Generation Science Standards? And, more broadly, how does field paleontology encourage inquiry and scientific motivation in learners? Let's take a look at the three umbrella pieces of the NGSS to explore where field science study fits.

### Science and Engineering Practices

A field paleontology experience can give science learners the opportunity to employ each of the science and engineering practices. If learners are engaging in field paleontology to explore a specific question and hypothesis, then the act of field prospecting, data collection, and excavation can lend new information to those student-led questions and hypotheses. When field paleontology is incorporated into the context of a particular unit or course, and does not exist as a disconnected field activity for field activity's sake, then it can be a powerful tool to encourage student motivation to ask scientific questions. At the study school, 9$^{th}$ grade students participated in a two-day paleontology expedition where they prospected for new fossils in the Barstow Formation (Miocene-age, 23 to 5.3 million years ago) of southern California.

While the students may not have developed individual questions for research projects, the trip was strategically undertaken as a part of the freshman biology course unit on evolution (applicable content and practice standards in Appendix B). Following the trip, students were tasked with engaging in argumentation from evidence and communicating their findings on the evolutionary connection between known fossils and an intermediate fossil of their own design. Students reflected that their understanding of how to plan for a scientific field expedition was greatly enhanced by their field experience in the Barstow Formation, which aided in their construction of a detailed story of their proposed intermediate fossil organisms.

## Cross-Cutting Concepts

Students engaging in field paleontology most immediately begin to see patterns, whether direct patterns in the rock layers or patterns in the scale of evolutionary change. The scale of deep time is on display in the field, and students are encouraged to learn how to interpret the immensity of the geological time scale from a human perspective. Ancient ecological systems and trophic webs can be reconstructed from field paleontology, and the structure and function of organisms on the skeletal level can be analyzed. There are abundant opportunities for students to confront their preconceived notions of stability and change, when faced with evidence of evolutionary stability and change in the fossil record. Jumping beyond the list of cross-cutting concepts, field paleontology allows students to reflect on their own comfort zones, with many young learners experiencing camping and often primitive field conditions for the first time.

## Core Disciplinary Ideas

The core ideas that apply to field science depend upon the type of field work being conducted. In the realm of field paleontology, the specific disciplinary ideas that are more pertinent include the Core Disciplinary Ideas in the Life Sciences and the Core Disciplinary Ideas in Earth and Space Sciences, particularly those in grades 2 and 5 (primary), as well as grade 8 and 12 (secondary). Core disciplinary ideas relevant to field paleontology and field science in general are provided in Table 1.

Table 1
*Disciplinary Core Ideas in Life and Earth Science*

| |
|---|
| Disciplinary Core Ideas in Life Science: |
| Evidence of common ancestry and diversity - both genetic and morphological; fossils found on field paleontological experiences provide an important set of evidence for these concepts. |
| Natural selection and adaptation – field paleontology allows students to grasp morphological adaptations in fossil skeletons, especially when paired with dedicated instruction in evolutionary biology prior to embarking on a field experience. |
| Disciplinary Core Ideas in Earth and Space Science : |
| During key years such as Grades 2, 5, 8, 12 (U.S.) and Grade 4 (Ontario, Canada) - some of the places in which field paleontology serves students well include: |
| History of planet Earth - including relative ages of rocks; field paleontology offers direct field instruction on how to read Earth's history in the rock record. |
| Plate tectonics and large-scale system interactions – field paleontology allows students to unpack evidence for large-scale ecosystem interactions, and can allow students to explore the concept of plate tectonics by comparing fossils on different continents |
| Natural resources – field paleontology connects students with natural fossil resources on public lands, and gives a sense of immediacy to the protection of public lands |
| Human impacts on the planet – field paleontology helps students understand their own impact on the planet, and the broader effects of climate change and pollution on global ecosystems |
| Global climate change - fossil pollen, isotope ratios in ancient organic materials, and other signals of ancient climate change can give modern, anthropogenic climate change the context of deep time, while impressing the importance of modern action to prevent further climate change |
| Disciplinary Core Ideas in Physical Science - understanding chemical reactions and structure of biomolecules, relevant to modern techniques in fossil research |

## Educational Theory

Even though educational theory has leapt ahead in technology and pedagogical paradigms, Dewey's (1929) foundational work is nevertheless important to discuss in the theoretical underpinning of field study and science stewardship. In chapter four (p. 184-185) Dewey explains the connection between nature – physical objects in nature – with a sense of permanence and stability, not to mention the stories and meanings we attach to objects in nature. This sentiment emphasizes the psychological importance we place on public lands, and how differing political views will make public lands a celebrated entity or a scapegoat for governmental control over individual public interests (see section Science Stewardship in an Anti-Science Age above).

Another important theoretical underpinning seeks to understand the range and scope of outdoor education, which field education falls within. Higgins (2002) created a Venn diagram explaining the overlap between different types of outdoor learning, recreation, and development, using the hills of Scotland as his experimental ground (Figure 1):

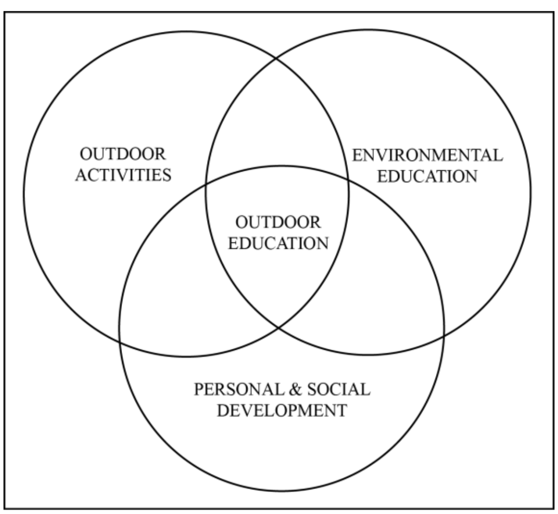


*Figure 1.* Range and scope of outdoor education (modified from Higgins, 2002).

Higgins helps to pinpoint the differences between outdoor recreation, personal and social development, and environmental education. Field education and field paleontology fit most snugly within the central 'outdoor education' area of the diagram, as the definitions of field education and outdoor education are nearly synonymous; while field paleontology education is, as defined in this work, a subset of field or outdoor education. I argue that field paleontology education is a mix of environmental education, outdoor activities, and personal and social development like any other type of outdoor or field education. Interestingly, Scotland was one of the first countries to formalize outdoor education (Higgins, 2002), so it provides a unique window into the development of outdoor educational theory, land use and ownership, a history of British rule and subsequent deforestation, followed by resurgence in adventure for the sake of adventure, and a rich history of outdoor education. Higgins' study on the formalization of outdoor education in the United Kingdom provides an example of the importance of structured, enthusiastic field education as part of the development of a scientifically-informed electorate.

## Experiential Foundational Research

What does learning look like in an outdoor field-based setting? Emo, Emo, Kimm, and Gent (2015) define learning from Ormrod (2011), as a "long term change in mental representations or associations as a result of experience". The experience, in this case, is the focus of their study; how "student learning [is] a product of the experiential interaction between person and environment" (Emo et al., 2015). The authors follow undergraduate college students throughout an eight-week research experience summer program. The convoluted pathway of learning was uncovered through student interviews and surveys, including student frustrations and failures, as well as successes – which each emerged in an unpredictable way. In studying this complexity, the authors sought to examine how this research-based learning environment might trigger more “complex phenomena” into being (Emo et al., 2015). This study included data from student daily written reflections, observations of interactions and work, and interviews (Emo et al., 2015). Such qualitative data can provide insight into more complex constructs, such as science identity. Students formed interpersonal networks for collaboration, and research focuses shifted and changed as students ran into issues of data availability or procedural over-complexity (Emo et al., 2015).

In a field-based setting, learning – and the acquisition of knowledge based on experiences – fits within the framework of experiential education. Experiential education emphasizes life-long learning and the inextricable connection between social responsibility, independent inquiry, and the integration of new learning into pre-conceived notions. Dewey (1938) outlined the need for a theory of experiential education, and how experience inspires curiosity in the learner while bringing the educational experience outside of the walls of the classroom to galvanize societal change. Describing prior knowledge and its impact on the world at large, Dewey says, “How shall the young become acquainted with the past in such a way that the acquaintance is a potent agent in appreciation of the living present?” (Dewey, 1938). In doing so, Dewey’s groundbreaking work laid the foundation for what we still grapple with today: engaging students with paleontology so that they remain motivated to appreciate natural fossil resources and public lands for years to come.

## A History of Paleontology Education in the K-12 Classroom

The focus of this paper is on paleontology education in the field, and how paleontology field education can serve as a vehicle for measuring science motivation and student motivation to be science stewards. It is necessary to build a thorough foundation in paleontology education research as it stands today, especially in the K-12 and experiential education realms. Science stewardship has a history of being studied in an environmental context, yet few studies have begun to scrape the surface of paleontology as a stewardship vehicle (Santucci, Newman, & Taff, 2016). Much of the current published work in paleontology education also places a heavy emphasis on undergraduate case studies, and less so in paleontology education within K-12 (Yacobucci & Lockwood, eds., 2012). Furthermore, anecdotes of learning paleontology in the classroom are often remembered through fond stories of favorite teachers, but these anecdotes remain largely outside of the academic literature.

Clary and Wandersee (2008) studied Earth Science teachers' perceptions of an autonomous field work assignment, within a nationwide (U.S.) graduate online paleontology course for teachers. The work describes the rubric used to grade the field work assignment, including field identification, a classroom activity to go along with the local field site, and an assessment to be administered to the teachers' own students (Clary & Wandersee, 2008). While this source focuses on teacher-students, and has little in the way of statistical analysis, it is important to include a source that describes how *teachers* view field work as a learning tool, and not just students in the K-12 realm.

The use of virtual fossils, which have been digitally scanned and can be uploaded and accessed freely, for classroom research has been a recent leap in the accessibility of fossil material for researchers and students alike – not to mention student-researchers. Rahman, Adcock, & Garwood (2012) describe a paleontological educational tool using digitized fossils and even 3D-printed fossils, with the models projected on a computer and used as an engagement device during a university community event. Many articles, including Rahman's, include the digital files needed to download and access, or print 3D fossils – thanks to open access of scientific resources. This is particularly important to consider at Webb, where students scan, upload and print their own fossil models from the original fossil material.

Case Study: Public school engagement with dinosaurs and paleontology education

In fall of 1989, teachers noticed something fascinating about their students at the Anna Frank School in Reggio Emilia, Italy. Like many young children, these primary school students occasionally brought in their favorite toys. Many of the five- to six-year-olds were bringing in dinosaur toys, and their play would spontaneously turn to dinosaurs. The teachers took this observation as an opportunity to help the children learn more about dinosaurs. As is common in the Reggio Emilia teaching style, a sub-group of the children took part in this dinosaur learning project, rather than the entire classroom; in this way, students participate in a small-group learning experience that "activates the most intense learning and exchange of ideas" (Rankin 1998). When coupled with a rotation of these small group topics throughout the year, each small group of students was able to become a subject matter expert and teach others. The group of students was selected based on interest in dinosaurs, and was spread across numerous linguistic and learning abilities, while being roughly equal in boys and girls.

The teachers, led by Carlina Rinaldi and Roberta Badodi, sought to brainstorm ways to scaffold the student projects in a way that led these young scientists to generate observations, ask questions, make suggestions, form hypotheses, and begin the initial direction of their independent study projects. A group mentality, rich with collaboration, infused the student work - encompassed by the phrasing, *io chi siamo* - 'I am who we are', common in the collaborative Reggio Emilia education paradigm of the day (Rankin 1998).

To begin, students were encouraged to draw dinosaurs in any way they liked, with students asking questions of one another and often changing their drawings based on observations and discussion with other students. Then the teachers asked open-ended questions about dinosaurs. Where did dinosaurs live? How are dinosaurs born? Are any dinosaurs alive today? In future classwork, students created dinosaurs out of clay, continued to discuss dinosaur biology, and ultimately were asked where they could go to get more information on dinosaurs. A visit to the local library led to a flurry of research and interest, followed by a final presentation of the student's choice.

Giving students the power of choice, in particular, was an effective method in maintaining engagement and excitement. Student presentations ran the gamut from clay and Styrofoam models, to shadow puppet re-enactments, to drawing a life-sized dinosaur. Each student had prepared for the final presentation by writing a letter of invitation to parents and family, and by preparing specific questions they could ask of their visitors to test knowledge their visitors may have gained. Students in the dinosaur project group then created a large exhibit to share with others in the school, allowing them to reflect on the steps it took to complete the project - what had worked well, and what had not. Reflection on the learning process allowed students to really solidify what they had learned, and how best to communicate their science to others (Rankin 1998). From this project, the Reggio Emilia technique of student-centered science projects, especially using dinosaurs as an engagement tool, gained international attention (Schroeder-Yu 2008).

## Science Education Accessibility for Underrepresented and Underserved Groups

A sub-question of this work addresses the leaky pipeline of science careers for women and minorities, as well as aspirations for science careers in young students, which have received some research attention (Tytler & Osborne, 2012). Even though the primary goal is to conduct a study on student attitudes toward science stewardship, that sense of stewardship can't exist without a broad basis of opinion from a balanced group of genders, backgrounds, and frames of thought. Acknowledging and working to break down the barriers that exist for many students to access paleontology field education, including time, financial support, interested teachers, and socioeconomic factors, is an ongoing process that studies on the impact of field science on science motivation and stewardship can begin to uncover. Perhaps even more than simple surveys, student and teacher interviews can, with dedicated effort, elicit thematic views on the crucial issues of accessibility to science education and science careers. When we listen to those who are in need of advocacy, and provide paths of mentorship and guidance to those who wish to learn, field science and field paleontology experiences – as well as science careers – can only become ever more enriched by the diversity and uniqueness of those who pursue them.

## Methodology Inspirations

Joseph Levitt's (2016) capstone research project on environmental science field work and its impact on motivation in science served as an early inspiration for this project. In addition, Bogner's (1998) study on short-term outdoor ecology education on long-term variables of environmental perspectives, was modified heavily to include values that relate to paleontology and science stewardship in public lands. Bogner studied 700 students in regional Bavarian schools and analyzed their responses before and after a trip to the Bavarian Forest National Park, Germany (Bogner, 1998). Earlier work by Bogner (1996) solidified the use of "preservation" versus "utilization" in the questionnaires, and his work lays out statistical methods, timing, and the structure of sampling entire classes rather than randomly sampled individuals. Later work by Bogner and Wiseman (2004) recommends avoiding a "short-term effect" by administering the post-test survey at least one month after initial participation.

Orstein's dissertation draft (2005) discusses the connection between hands-on experimentation and attitudes toward science. This is a great way to bridge hands-on experimentation in the classroom with hands-on exploration of the natural world in field science. Between methodology and analysis of data, this paper provides a series of steps to survey students, as well as details on t-tests and ANOVA to analyze results. The author used t-tests to see whether there was a difference in test scores between experimentation and non-experimentation-based classes, and ANOVA was used to determine whether there was a significant difference between the amount of experimentation students undertook in their classes, and their interest in science.

## Field Paleontology Education: Bringing the Strands Together

What is so special about field experiences in general, and field paleontology experiences in particular, that makes them eye-opening and even life changing experiences? From an early age, children can express such strong interest in specific topics, such as dinosaurs, paleontology, and Earth's deep past. Perhaps the answer to the transformative nature of field science and field paleontology education lies in the fundamental human desire for exploration, curiosity, and an answer to the various versions of 'why?' Whether a tool for implementing science standards in the classroom, a way to deepen our understanding of the efficacy of field study and field research, a way to implement new teaching techniques in the classroom, or a fond remembrance of an inspirational teacher, paleontology and the place-based nature of field science can set a learner's path towards an appreciation for life-long learning. If the power of discovery is intertwined with the power of the place in which discovery occurs, then it is encouraging to think that science stewardship on lands that belong to the common citizen will become second nature, and a sense of stewardship can be instilled in future generations.

# METHODOLOGY

Pinpointing student motivation in science, as well as motivation to be science stewards, will allow us to tackle issues of waning public interest in science or competing economic interests that hinder or reverse attempts to conserve scientific resources on public lands. In doing so, we can at minimum galvanize public discourse on the impact of natural spaces and field science education on student learning; ideally, we can inspire future policy-makers, educators, and scientists to appreciate the intangible value of natural spaces in ways that inform national and global cooperation to protect and conserve them. To get to the bottom of these important questions, this study asked three main research questions, tracked by a triangulation matrix (Table 2) with data sources for each question. All responses were conducted under the purview of the Montana State University Internal Review Board (IRB) (Appendix A).

## Research Questions and Triangulation

The research questions and triangulation matrix with regard to data collection techniques are as follows:

Table 2
*Data Triangulation Matrix*

| Research Questions | Data Source #1 | Data Source #2 | Data Source #3 |
|---|---|---|---|
| *Primary Research Question:* Does field science education enhance a sense of student science stewardship on public lands? | Student pre- and post-field survey | Student reflections | Student reflections |
| *Secondary Research Questions:* What are the science motivations of students in a field science course? | Student pre- and post- field survey | Student interviews | Student reflections |
| What factors impact student accessibility to science? | Student interviews | Student interviews | Teacher interviews |

<u>Research Question: ‘Does field science education enhance a sense of student science stewardship in public lands?’</u>

Pre- and post-field experience Likert-style surveys were administered (Appendix C) to gauge student understanding of science stewardship issues, knowledge of the intricacies of public lands and public land management, and motivation to conserve natural resources such as fossils on public lands. Statistical analysis included descriptive statistic comparison (mean, median, standard deviation) as well as inferential statistic comparison (paired t-tests and a comparison with Fisher’s Exact tests).

<u>Research Question: ‘What are the science motivations of students in a field science course?’</u>

Students were surveyed using a Likert-style survey instrument in order to better understand their rationale for taking a field science course in a school that offers one, as well as their overall motivations in science – for example, paleontology career aspirations or a desire to try a new subject. Self-reflections were also used to help decipher student motivations on a more detailed level.

Research Question: 'What factors impact student accessibility to science?'

In the interest of equity in access to science, it's crucial to discuss other factors that impact student motivation in science, including mentorship, career goals, socioeconomic factors, women leaders in science, technology, engineering, and math (STEM), representation of lesbian, gay, bisexual, transgender, and queer (LGBTQ) students and representation of students of color. Selected student surveys were used to tease apart some of the answers to these questions.

Student grades and test scores (ranked data) were not analyzed due to permissions from the school administration. Likert-style data were analyzed using paired t-tests (comparing pre- and post-survey) with an alpha value of p=0.05, and stacked bar graphs with percentage answers pre- and post-treatment were utilized to visualize spread. The paired t-tests were also compared with results from Fisher's Exact Test. This test provided a nonparametric method analogous to Pearson's chi-squared test, accounting for responses that had fewer than five responses. Each pre-treatment data set was sampled over the fall 2018 semester, with pre- and post-test surveys centered on field science education experiences, while post-treatment surveys and select interviews were tracked over the course of the spring 2019 semester. Approximately four months lapsed between pre- and post-treatment surveys; a minimum of one month's span between pre- and post-treatment is recommended to minimize "short-term effect" (Bogner & Wiseman, 2004).

Qualitative data such as self-reflections, journal entries, and interviews allowed themes to emerge organically, as students reflected on their experiences in paleontology and field experiences on a personal level. Responses were grouped into sets based on general themes of nature appreciation, paleontology motivation, attitudinal responses about outdoor life or camping, the value of science, teamwork and empathy, and the importance of conservation or science stewardship. The 12 Model of Attitudes of Paleontology on Public Lands (MAP-PL) Likert-style questions were grouped into five major themes: Nature Appreciation, Paleontology Motivation, Science Motivation, Science Stewardship, and Human-Nature Interaction (Table 3). By grouping questions thematically, subsets of questions and responses can be analyzed. Paleontology motivation and science motivation were separated to analyze motivation in general science versus paleontology specifically. Nature appreciation and human-nature interaction arose as separate themes to unpack student prior appreciation of nature activities versus understanding of general societal interactions with natural areas. Question 3 was specific to the students attending the Webb Schools. Finally, science stewardship questions attempt to shed light on responsibility and motivation for caretaking and conservation of scientific resources in natural areas.

Table 3

*Thematic Organization of Likert-Style Survey Questions*

| Question | Theme |
|---|---|
| (1) Camping and outdoor activities bring me joy. | Nature Appreciation |
| (2) The information we learn from field paleontology is worth the effort. | Paleontology Motivation |
| (3) Field paleontology is one of the reasons why I appreciate attending this school. | Paleontology Motivation |
| (4) Public lands such as national parks, national monuments, national forests, and other managed lands are important areas to preserve for future generations. | Science Stewardship |
| (5) Some protected natural areas that bear fossils must be disrupted, so that, for example, minerals can be mined or oil can be drilled. | Science Stewardship |
| (6) Humans have the right to modify the natural environment to suit their needs. | Human-Nature Interaction |
| (7) When humans interfere with nature, it often produces negative consequences. | Human-Nature Interaction |
| (8) Humans must live in harmony with nature in order to survive. | Human-Nature Interaction |
| (9) Public lands belong to all Americans, and therefore their management should be the responsibility of the federal government – rather than individual states. | Science Stewardship |
| (10) I can see myself choosing a career in paleontology. | Paleontology Motivation |
| (11) Increasing appreciation of fossil resources is a good way to get people personally invested in science. | Science Motivation |
| (12) Field paleontology makes me feel motivated to enjoy learning science. | Science Motivation |

Triangulation allowed the research to achieve an adequate level of credibility and confirmability through the use of multiple data types – quantitative, qualitative, open-ended written responses, and interview dialogue. Quantitative data from numerically-designated responses to Likert-style survey questions are analyzed through statistical methods such as paired t-tests, comparing pre- and post-treatment responses, using the statistics package software R Studio. Confidence intervals, p-values, averages, and medians were analyzed to test validity and reliability as well as reproducibility. Stacked bar-charts are provided to visually represent the spread of responses. Throughout the research process, reflexivity was an important goal; to achieve reflexivity, regular reflection on the research process was recorded through online course forums in the MSSE program.

Study Population and Curricular Timing

The study population was comprised entirely of 9$^{th}$ grade students, ages 13-15, mixed with female-identifying (*N*=46) and male-identifying (*N*=50) respondents. All students were enrolled in the required 9$^{th}$ grade evolutionary biology course at Webb, which includes in its first semester unit a mandatory trip to conduct paleontological field prospecting and fossil identification. The female-identifying student trip occurred on September 22 and 23, 2019, and the male-identifying student trip occurred on September 29 and 30, 2019. These field science experiences followed four course days discussing the nature of science and the process of scientific inquiry, as well as between four to six additional course days discussing the process of fossilization, comparison between modern and fossil vertebrate anatomy, the scale of geologic time, homology and analogy, and cladistics (Appendix D and E). Following the paleontological field experience, all students completed a project in which they designed their own paleontological field experience to collect a ‘new transitional fossil’ that allowed students to explore the nature of field work, as well as the evolutionary connections between extinct and extant taxa (Appendix D).

Likert-Survey Methodology

A total of 96 students were surveyed using the Likert survey instrument either pre- or post-treatment, and within that sample, a total of 78 students were surveyed both pre- and post-treatment (*N*=30 female-identifying, 38%; *N*=48 male-identifying, 62%). Minor-aged respondents were given parent-student Internal Review Board (IRB)-approved waiver forms and all data collected and used within this study corresponds with written consent via these waivers. All students were given the option not to take the Likert survey instrument and written self-reflection was not required. To minimize perception of teacher-student bias, surveys were distributed whenever possible by a teacher not responsible for direct instruction of the students being surveyed.

The survey instrument contains 12 questions in the Strongly Agree – Strongly Disagree format, without Neutral or No Response options (Appendix C). Questions were grouped thematically into five categories: Nature Appreciation, Paleontology Motivation, Science Stewardship, Human-Nature Interaction, and Science Motivation. Students completed paper-based surveys tracked by an alphanumeric identifier to maintain anonymity. Identifiers were assigned randomly based on alphabetic roster lists, separated into the female-identifying and male-identifying sub-groups. The dependent variable within this study is the treatment of a field paleontology experience, while the independent variable is the significant difference, if any, in responses pre- and post-treatment.

Paleontological Field Experience Itinerary

All students were tasked with bringing their own hiking and camping attire and equipment, although no tents were used during the field experience. All students were housed outside and slept on tarps with sleeping bags as is 'Peccary Trip' tradition. All male-identifying and all female-identifying freshman evolutionary biology students met at the Alf Museum on the Saturday morning of their trip, where initial Likert surveys were distributed. Students were transported by bus to Rainbow Basin Natural Area north of Barstow, California, and camped at Owl Canyon Campground. Rainbow Basin is, notably, a designated Area of Critical Environmental Concern as designated by the Bureau of Land Management (BLM), and so falls within the status of both public land and managed land where special attention is needed to protect and conserve natural resources and landmarks.

Students spent the first day of their field experience prospecting for fossils, hiking up to three miles in hilly high desert terrain, and identifying fossil fragments with the help of Alf Museum and Webb faculty. Total time spent actively prospecting on both trips was an average of five hours. Nighttime activities included reflection on the day's activities, campfire meals, and stargazing with faculty-led instruction. Sunday included a short morning reflection after breakfast but due to the heat of the day, students returned to campus via bus without a second day of hiking or prospecting in both weekend trips. For the girls' school trip, detailed post-reflections were conducted in the field on the night of their first field day. For the boys' school trip, post-reflections were conducted solely via written prompt at the end of the Likert post-treatment surveys. The annual Peccary Trips provide an excellent opportunity for students to interact directly with fossils and gain an understanding of the challenges and rewards of field work.

## DATA AND ANALYSIS

### Likert-Style Survey Instrument – Model of Attitudes of Paleontology on Public Lands (MAP-PL)

Likert-style survey questions and an open-ended response question allowed each student to reflect on their field experience. A lower number of female-identifying students (*N*=30, 65% of 46 freshman girls) were surveyed pre-treatment due to timing constraints prior to the treatment event. However, all female-identifying students (*N*=46) completed more detailed qualitative written responses immediately following their field experience and while still at the camp site; while male-identifying students (*N*=42, 84% of 50 freshman boys) completed much briefer pre-treatment reflections and even fewer (*N*=28, 56% of 50 freshman boys) brief post-treatment reflections. In total, respondents completed 78 pre- and post-treatment Likert-style surveys with questions on a scale of Strongly Agree, Agree, Disagree, and Strongly Disagree. Neutral or No Response options were not included in an attempt to elicit polarity from respondents. The open-ended free response question responses were grouped via thematic analysis.

Since Likert-style data are ordinal, discrete, and have a limited range, and the data sample size is not large enough to assume normal distribution, a nonparametric test is often chosen to analyze Likert responses converted to numeric values. However, the parametric paired t-test is utilized here since it is robust to violations of its assumptions of normal distribution and interval data. Strongly Agree converted to 1, Agree to 2, Disagree to 3, and Strongly Disagree to 4. Pre- and post-treatment responses were analyzed using a parametric paired t-test, and compared with non-parametric Fisher's Exact Test. Using an alpha value (p-value) of 0.05, the sum total group responses were analyzed per question.

Claims for each research question include:

Research Question: 'Does field science education enhance a sense of student science stewardship in public lands?' The null hypothesis is that the means are equal, and the alternative hypothesis is that the means will show a trend towards an enhanced sense of science stewardship on public lands. There is no statistically significant difference in the means for questions 4, 5, or 9, which each thematically seek to analyze science stewardship. Additional understanding of science stewardship was investigated using student interviews.

Research Question: 'What are the science motivations of students in a field science course?' The null hypothesis is that the means are equal, and the alternative hypothesis is that the means will show a trend towards increased science motivation of students through field science experiences. There is no statistically significant difference in the means for questions 2, 3, 10, 11, or 12, each of which thematically seek to analyze general science or paleontology-specific motivation. Additional factors impacting student motivation in science were explored using qualitative interviews with students.

Research Question: 'What factors impact student accessibility to science?' The null hypothesis is that the means are equal, and the alternative hypothesis is that factors such as enjoyment of outdoor activities will correlate with student accessibility to science – for example, question 1 explores enjoyment of camping, which is expected to correlate with greater enjoyment of field work. Questions 1, 6, 7, and 8 fall within the themes of human-nature interaction; these themes may impact accessibility. There is no statistically significant difference in the means for questions 1, 6, 7, and 8. Additional factors impacting student accessibility to science were explored using qualitative interviews with students and faculty.

Analysis of Pre- and Post-Treatment – Total Survey Group

Both descriptive and inferential statistics were used to assess the impact of the field experience treatment on survey respondents; the descriptive statistics include mean and median pre- and post-treatment, while the inferential statistic used is the paired t-test, compared later with the Fisher's Exact Test (Tables 4 & 5). Another aspect of descriptive statistics that allows us to dissect the data is the standard deviation pre- and post-treatment. Standard deviation allows us to describe how much the observations differ from the mean (Table 4).

Table 4

*Descriptive and Inferential Statistics for Treatment Group*

| Question # | Paired t-test P-Value | Standard Deviation Pre-Treatment | Standard Deviation Post-Treatment | Median Pre-Treatment | Median Post-Treatment | Mean Pre-Treatment | Mean Post-Treatment |
|---|---|---|---|---|---|---|---|
| (1) Camping and outdoor activities bring me joy. | 0.086 | 0.78 | 0.75 | 2 | 2 | 2.17 | 2.03 |
| (2) The information we learn from field paleontology is worth the effort. | 0.230 | 0.60 | 0.75 | 2 | 2 | 1.85 | 1.91 |
| (3) Field paleontology is one of the reasons why I appreciate attending this school. | 0.117 | 0.72 | 0.86 | 2 | 2 | 2.15 | 2.30 |
| (4) Public lands such as national parks, national monuments, national forests, and other managed lands are important areas to preserve for future generations. | 0.496 | 0.44 | 0.60 | 1 | 1 | 1.26 | 1.30 |
| (5) Some protected natural areas that bear fossils must be disrupted, so that, for example, | 0.381 | 0.75 | 0.90 | 3 | 3 | 2.96 | 2.85 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| minerals can be mined or oil can be drilled. | | | | | | | |
| (6) Humans have the right to modify the natural environment to suit their needs. | 0.103 | 0.61 | 0.85 | 3 | 3 | 2.87 | 2.70 |
| (7) When humans interfere with nature, it often produces negative consequences. | 0.748 | 0.67 | 0.75 | 2 | 2 | 1.96 | 1.94 |
| (8) Humans must live in harmony with nature in order to survive. | 0.349 | 0.66 | 0.75 | 1.5 | 2 | 1.58 | 1.66 |
| (9) Public lands belong to all Americans, and therefore their management should be the responsibility of the federal government – rather than individual states. | 0.556 | 0.94 | 0.85 | 2 | 2 | 2.38 | 2.30 |
| (10) I can see myself choosing a career in paleontology. | 0.694 | 0.87 | 0.82 | 3 | 3 | 2.95 | 2.99 |
| (11) Increasing appreciation of fossil resources is a good way to get people personally invested in science. | 0.734 | 0.60 | 0.66 | 2 | 2 | 1.97 | 1.94 |
| (12) Field paleontology makes me feel motivated to enjoy learning science. | 0.590 | 0.75 | 0.88 | 2 | 2 | 2.01 | 2.04 |

*Note: N*=78 pre-treatment, *N*=80 post-treatment

Percent responses pre- and post-treatment also come with the caveat that simple comparison of sum total percentages may not elicit underlying statistical significance. However, it is interesting to note that the percent of survey respondents answering “strongly agree” increased in each case post-treatment, with the exception of question 8 (Figure 2, Table 5). Boxplot spreads can be corroborated with the descriptive statistics and allow a visual representation of the consistency in select medians for question 1 (Figure 3), question 4 (Figure 4), question 6 (Figure 5), and question 11 (Figure 6).

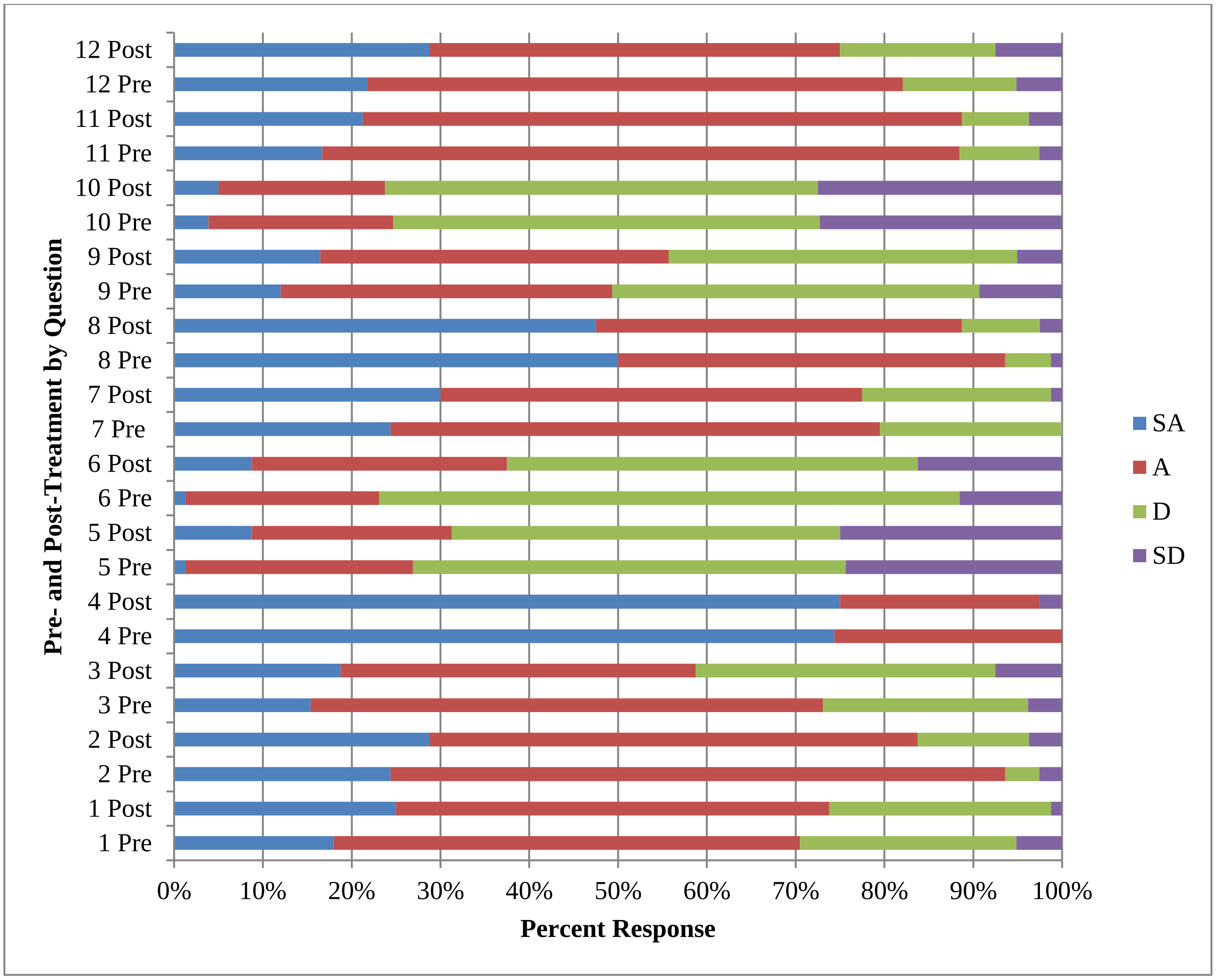


*Figure 2.* Pre- and post-treatment survey responses by question: treatment group, (*N*=78 pre-treatment, *N*=80 post-treatment).

Table 5

*Pre- and Post-Treatment Survey Response Percentages by Question: Treatment Group*

| | **1 Pre** | **1 Post** | **2 Pre** | **2 Post** | **3 Pre** | **3 Post** | **4 Pre** | **4 Post** |
|---|---|---|---|---|---|---|---|---|
| **SA** | 18% | 25% | 24% | 29% | 15% | 19% | 74% | 75% |
| **A** | 53% | 49% | 69% | 55% | 58% | 40% | 26% | 23% |
| **D** | 24% | 25% | 4% | 13% | 23% | 34% | 0% | 0% |
| **SD** | 5% | 1% | 3% | 4% | 4% | 8% | 0% | 3% |
| | **5 Pre** | **5 Post** | **6 Pre** | **6 Post** | **7 Pre** | **7 Post** | **8 Pre** | **8 Post** |
| **SA** | 1% | 9% | 1% | 9% | 24% | 30% | 50% | 48% |
| **A** | 26% | 23% | 22% | 29% | 55% | 48% | 44% | 41% |
| **D** | 49% | 44% | 65% | 46% | 21% | 21% | 5% | 9% |
| **SD** | 24% | 25% | 12% | 16% | 0% | 1% | 1% | 3% |
| | **9 Pre** | **9 Post** | **10 Pre** | **10 Post** | **11 Pre** | **11 Post** | **12 Pre** | **12 Post** |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **SA** | 12% | 16% | 4% | 5% | 17% | 21% | 22% | 29% |
| **A** | 37% | 39% | 21% | 19% | 72% | 68% | 60% | 46% |
| **D** | 41% | 39% | 48% | 49% | 9% | 8% | 13% | 18% |
| **SD** | 9% | 5% | 27% | 28% | 3% | 4% | 5% | 8% |

*Note*. (*N*=78 pre-treatment, *N*=80 post-treatment) (SA=Strongly Agree, A=Agree, D=Disagree, SD=Disagree).

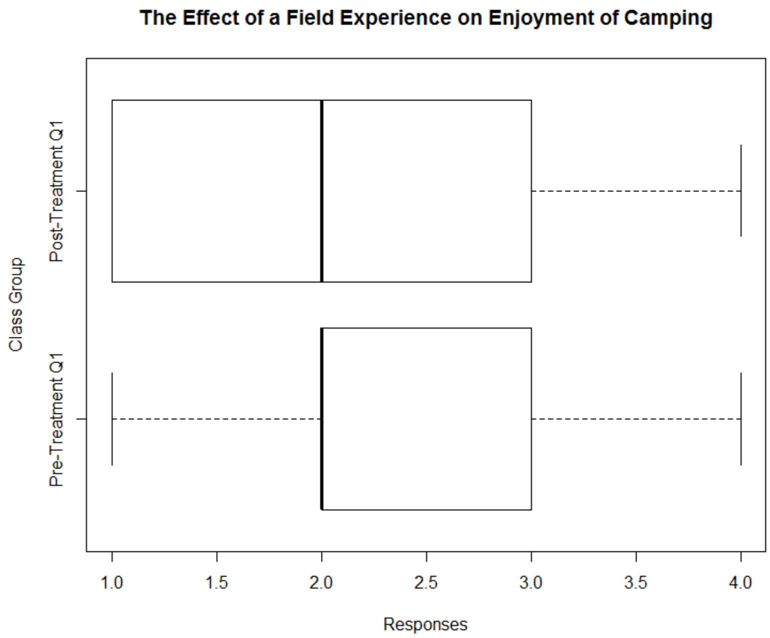


*Figure 3* Boxplot indicating consistency in medians pre- and post-treatment for question 1, the effect of a field experience on enjoyment of camping, (*N*=78 pre-treatment, *N*=80 post-treatment).

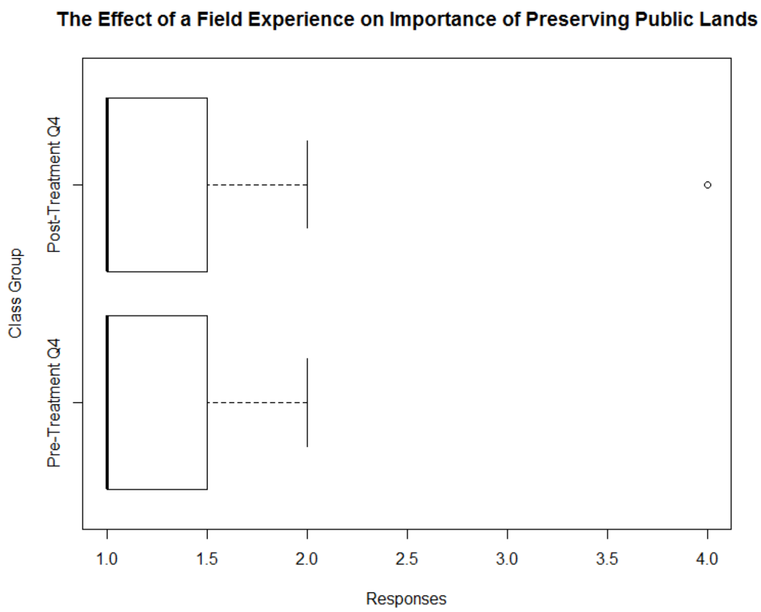


*Figure 4.* Boxplot indicating consistency in medians pre- and post-treatment for question 4, the effect of a field experience on student perception of the importance of preserving public lands, (*N*=78 pre-treatment, *N*=80 post-treatment).

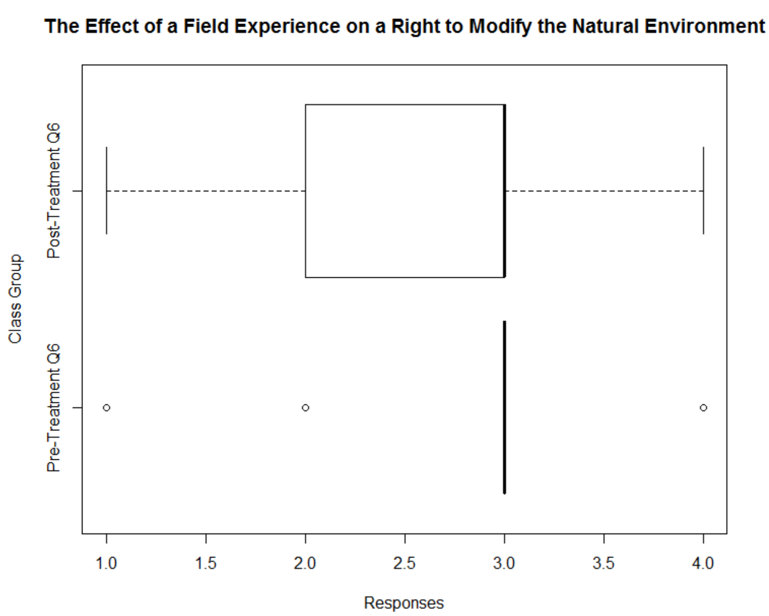


*Figure 5.* Boxplot indicating consistency in medians pre- and post-treatment for question 6, the effect of a field experience on a right to modify the natural environment (*N*=78 pre-treatment, *N*=80 post-treatment).

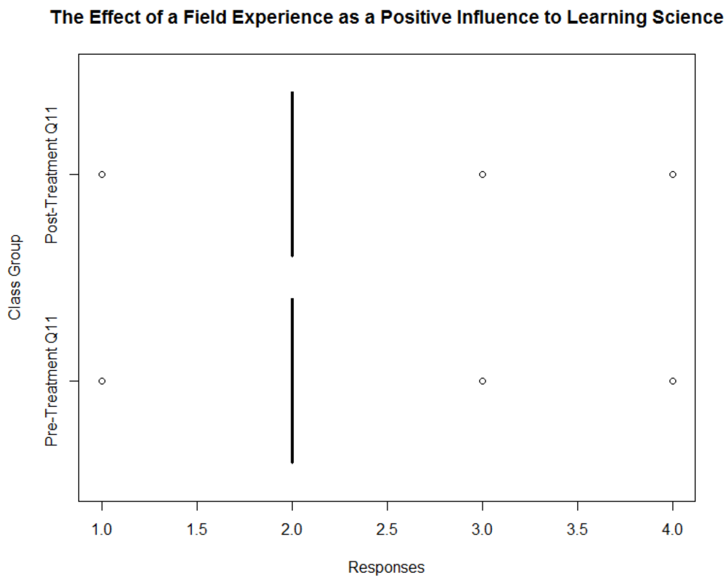


*Figure 6.* Boxplot indicating consistency in medians pre- and post-treatment for question 11, the effect of a field experience as a positive influence to learning science, (*N*=78 pre-treatment, *N*=80 post-treatment).

<u>Comparison Group Likert Responses</u>

Are there trends in science stewardship motivation and paleontology career motivation in a group of students who choose to continue their formative education in paleontology? A comparison group (*N*=17 pre-treatment, *N*=19 post-treatment) of freshman who applied to take a dedicated, sophomore year Honors Paleontology course as a continuation of their freshman biology experience was analyzed to determine any trends in survey responses as well as pre- and post-treatment short responses. Of the 19 total comparison group students, 8 (42%) were female-identifying and 11 (58%) were male-identifying. The same methods of analysis for descriptive and inferential statistics that were used for the comparison group were used for the treatment group (Table 6).

Table 6

*Descriptive and Inferential Statistics for Comparison Group*

| Question # | Paired t-test P-Value | Standard Deviation Pre-Treatment | Standard Deviation Post-Treatment | Median Pre-Treatment | Median Post-Treatment | Mean Pre-Treatment | Mean Post-Treatment |
|---|---|---|---|---|---|---|---|
| (1) Camping and outdoor activities bring me joy. | 0.172 | 0.90 | 0.69 | 2 | 2 | 2.06 | 1.84 |
| (2) The information we learn from field paleontology is worth the effort. | 0.431 | 0.51 | 0.51 | 2 | 1 | 1.53 | 1.47 |
| (3) Field paleontology is one of the reasons why I appreciate attending this school. | 0.104 | 0.59 | 0.51 | 2 | 1 | 1.71 | 1.47 |
| (4) Public lands such as national parks, national monuments, national forests, and other managed lands are important areas to preserve for future generations. | 0.332 | 0.44 | 0.32 | 1 | 1 | 1.24 | 1.11 |
| (5) Some protected natural areas that bear fossils must be disrupted, so that, for example, minerals can be mined or oil can be drilled. | 0.608 | 0.50 | 0.92 | 3 | 3 | 3.00 | 2.79 |
| (6) Humans have the right to modify the natural environment to suit their needs. | 0.455 | 0.66 | 0.95 | 3 | 3 | 2.76 | 2.68 |
| (7) When humans interfere with nature, it often produces negative consequences. | 0.104 | 0.66 | 0.65 | 2 | 2 | 1.94 | 1.74 |
| (8) Humans must live in harmony with nature in order to survive. | 0.055 | 0.59 | 0.58 | 2 | 1 | 1.71 | 1.32 |
| (9) Public lands belong to all Americans, and therefore their management should be the responsibility of the federal government – rather than individual states. | 0.718 | 0.70 | 0.76 | 2 | 3 | 2.35 | 2.37 |
| (10) I can see myself choosing a career in paleontology. | 0.013 | 0.99 | 0.79 | 3 | 2 | 2.71 | 2.21 |
| (11) Increasing appreciation of fossil resources is a good way to get people personally invested in science. | 0.382 | 0.64 | 0.48 | 2 | 2 | 1.82 | 1.68 |
| (12) Field paleontology makes me feel motivated to enjoy learning science. | 0.030 | 0.86 | 0.61 | 2 | 1 | 1.88 | 1.47 |

*Note:* *N*=78 pre-treatment, *N*=80 post-treatment

As in the treatment group, all questions had an increase in strongly agree percentages in the comparison group (Figure 7). Several questions in the comparison group tallied 0% for strongly disagree or disagree, including questions 2 and 4 pre- and post-treatment; or 0% for strongly disagree, including question 1 shifting from 6% to 0% strongly disagree; questions 7, 8, 9, and 11 exhibiting 0% strongly disagree; question 3 shifting from 6% to 0% disagree; question 12 shifting from 12% to 0% disagree; and question 12 shifting from 6% to 0% strongly disagree (Table 7).

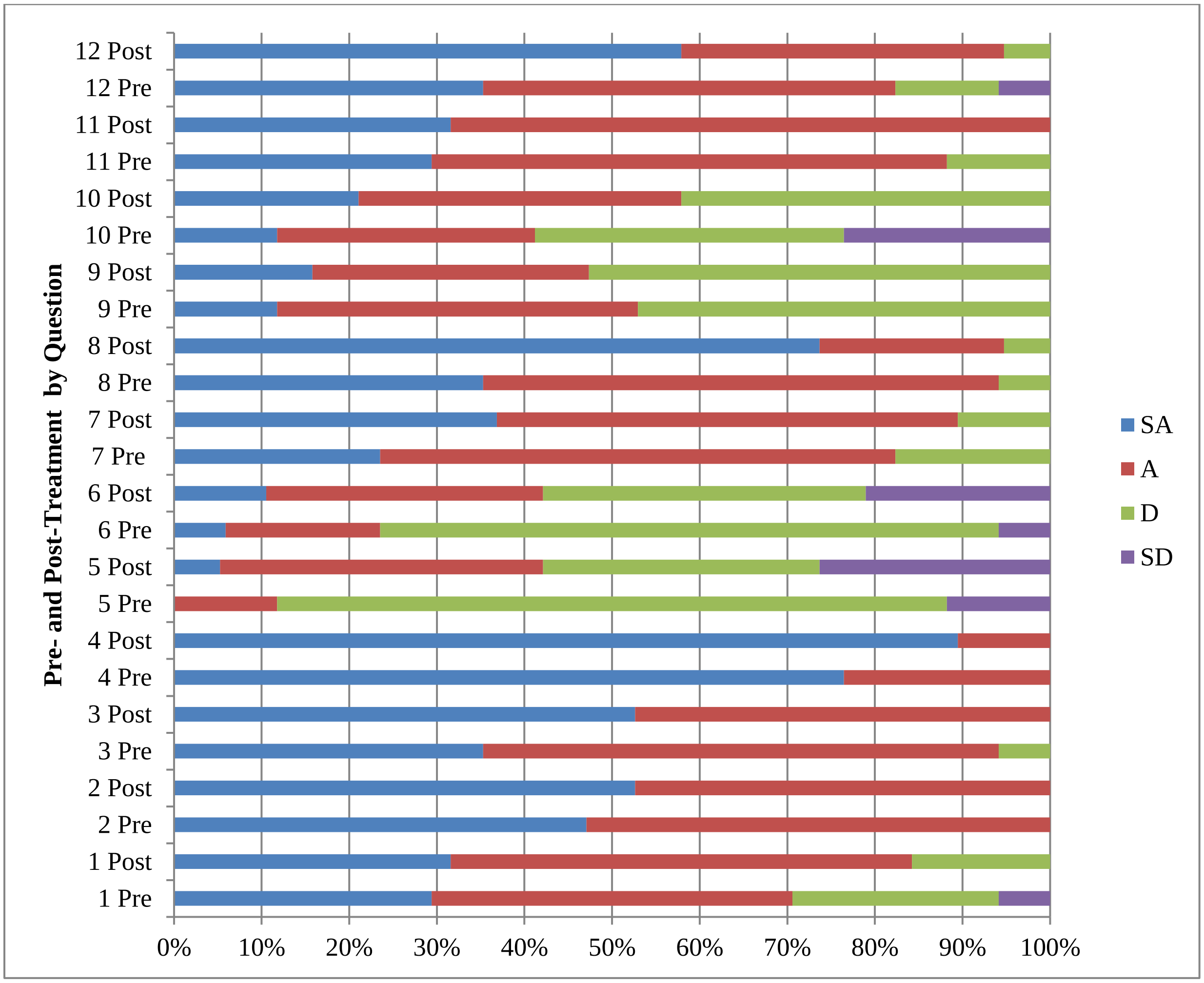


*Figure 7.* Pre- and post-treatment survey responses by question: comparison group, (*N*=17 pre-treatment, *N*=19 post-treatment).

Table 7

*Pre- and Post-Treatment Survey Response Percentages by Question: Comparison Group*

| | 1 Pre | 1 Post | 2 Pre | 2 Post | 3 Pre | 3 Post | 4 Pre | 4 Post |
|---|---|---|---|---|---|---|---|---|
| SA | 29% | 32% | 47% | 53% | 35% | 53% | 76% | 89% |
| A | 41% | 53% | 53% | 47% | 59% | 47% | 24% | 11% |
| D | 24% | 16% | 0% | 0% | 6% | 0% | 0% | 0% |
| SD | 6% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | 5 Pre | 5 Post | 6 Pre | 6 Post | 7 Pre | 7 Post | 8 Pre | 8 Post |
| SA | 0% | 5% | 6% | 11% | 24% | 37% | 35% | 74% |
| A | 12% | 37% | 18% | 32% | 59% | 53% | 59% | 21% |
| D | 76% | 32% | 71% | 37% | 18% | 11% | 6% | 5% |
| SD | 12% | 26% | 6% | 21% | 0% | 0% | 0% | 0% |
| | 9 Pre | 9 Post | 10 Pre | 10 Post | 11 Pre | 11 Post | 12 Pre | 12 Post |
| SA | 12% | 16% | 12% | 21% | 29% | 32% | 35% | 58% |
| A | 41% | 32% | 29% | 37% | 59% | 68% | 47% | 37% |
| D | 47% | 53% | 35% | 42% | 12% | 0% | 12% | 5% |
| SD | 0% | 0% | 24% | 0% | 0% | 0% | 6% | 0% |

*Note*. (*N*=17 pre-treatment, *N*=19 post-treatment) (SA=Strongly Agree, A=Agree, D=Disagree, SD=Strongly Disagree).

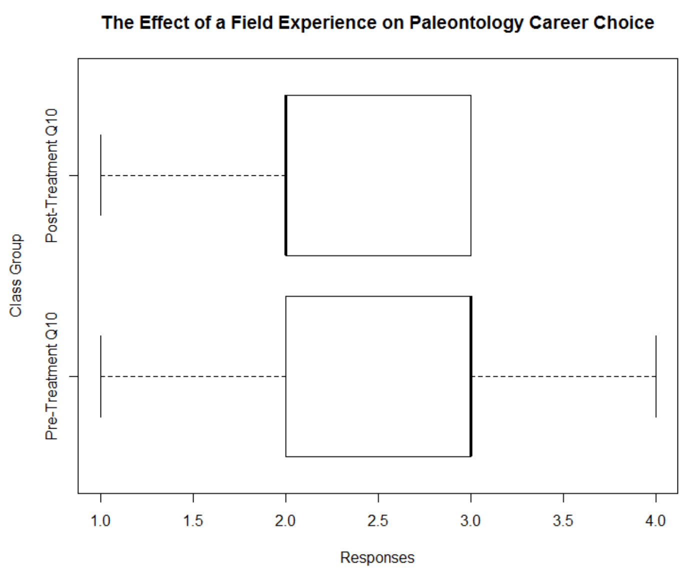


*Figure 8.* Boxplot indicating unequal medians pre- and post-treatment for question 10, the effect of a field experience on an interest in paleontology careers, (*N*=17 pre-treatment, *N*=19 post-treatment).

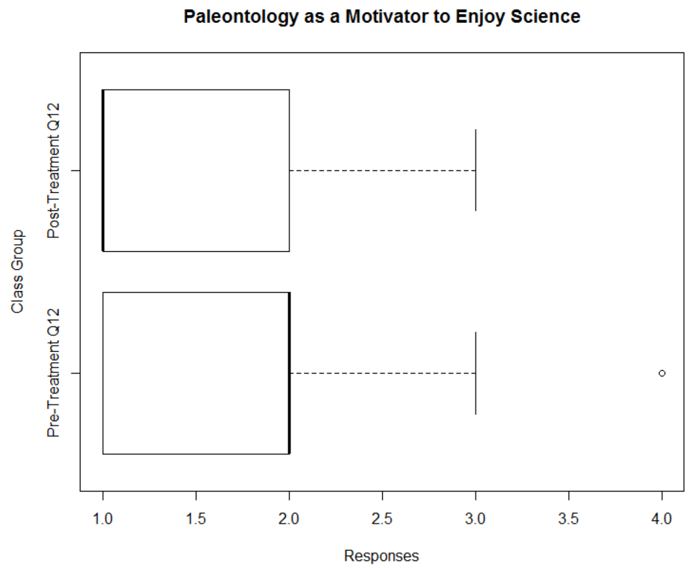


*Figure 9.* Boxplot indicating unequal medians pre- and post-treatment for question 12, the effect of a field experience on whether paleontology motivates the respondent to enjoy science, (*N*=17 pre-treatment, *N*=19 post-treatment).

<u>Paired t-test Comparison with Fisher's Exact Test</u>

Because paired t-tests show more reliable results when using interval data, a Fisher's Exact Test or Chi-square test can be preferable for Likert-style data or other styles of ordinal data (McCrum-Gardner, 2008). While parametric paired t-tests are robust to changes in their assumptions, non-parametric Fisher's Exact Tests are "typically less powerful and less flexible" than their parametric counterparts (McCrum-Gardner, 2008). In an effort to provide the clearest picture possible of the survey results, and to tease out any differences between the female-identifying and male-identifying survey groups, Fisher's Exact Test results were calculated (Table 8).

Table 8

*Fisher's Exact Test for Female-Identifying and Male-Identifying Groups, Total Survey Group, and Comparison Group*

| Question | Female-Identifying Group | Male-Identifying Group | Total Survey Group | Comparison Group |
|---|---|---|---|---|
| (1) Camping and outdoor activities bring me joy. | 0.892 | 0.329 | 0.426 | 0.817 |
| (2) The information we learn from field paleontology is worth the effort. | 0.098 | 0.543 | 0.151 | 1.000 |
| (3) Field paleontology is one of the reasons why I appreciate attending this school. | 0.072 | 0.363 | 0.154 | 0.402 |
| (4) Public lands such as national parks, national monuments, national forests, and other managed lands are important areas to preserve for future generations. | 0.713 | 1.000 | 0.409 | 0.391 |
| (5) Some protected natural areas that bear fossils must be disrupted, so that, for example, minerals can be mined or oil can be drilled. | 0.815 | 0.093 | 0.205 | 0.043 |
| (6) Humans have the right to modify the natural environment to suit their needs. | 0.390 | 0.023 | 0.040 | 0.265 |
| (7) When humans interfere with nature, it often produces negative consequences. | 0.703 | 0.895 | 0.644 | 0.720 |
| (8) Humans must live in harmony with nature in order to survive. | 0.641 | 0.931 | 0.791 | 0.057 |
| (9) Public lands belong to all Americans, and therefore their management should be the responsibility of the federal government – rather than individual states. | 0.862 | 0.952 | 0.677 | 0.903 |
| (10) I can see myself choosing a career in paleontology. | 0.315 | 0.950 | 0.993 | 0.191 |
| (11) Increasing appreciation of fossil resources is a good way to get people personally invested in science. | 0.862 | 0.746 | 0.864 | 0.420 |
| (12) Field paleontology makes me feel motivated to enjoy learning science. | 0.034 | 0.950 | 0.784 | 0.455 |

In order to compare the Fisher's Exact Test results with the paired t-test results for the male- and female-identifying groups, we must calculate paired t-tests for these subgroups (Tables 9 & 10). What then are the results of the female-identifying and male-identifying sub-groups using the paired t-test, and the corresponding descriptive statistics used for the treatment group as a whole?

Table 9

*Paired t-test for Female-Identifying Group*

| Question # | Paired t-test P-Value | Standard Deviation Pre-Treatment | Standard Deviation Post-Treatment | Median Pre-Treatment | Median Post-Treatment | Mean Pre-Treatment | Mean Post-Treatment |
|---|---|---|---|---|---|---|---|
| (1) Camping and outdoor activities bring me joy. | 0.745 | 0.63 | 0.71 | 2 | 2 | 2.47 | 2.37 |
| (2) The information we learn from field paleontology is worth the effort. | 0.059 | 0.63 | 0.67 | 2 | 2 | 1.87 | 2.11 |
| (3) Field paleontology is one of the reasons why I appreciate attending this school. | 0.013 | 0.73 | 0.77 | 2 | 3 | 2.13 | 2.61 |
| (4) Public lands such as national parks, national monuments, national forests, and other managed lands are important areas to preserve for future generations. | 0.326 | 0.43 | 0.71 | 1 | 1 | 1.23 | 1.35 |
| (5) Some protected natural areas that bear fossils must be disrupted, so that, for example, minerals can be mined or oil can be drilled. | 0.421 | 0.82 | 0.82 | 3 | 3 | 2.87 | 3.00 |
| (6) Humans have the right to modify the natural environment to suit their needs. | 0.663 | 0.65 | 0.80 | 3 | 3 | 2.83 | 2.93 |
| (7) When humans interfere with nature, it often produces negative consequences. | 0.477 | 0.67 | 0.83 | 2 | 2 | 2.03 | 2.07 |
| (8) Humans must live in harmony with nature in order to survive. | 0.523 | 0.57 | 0.75 | 2 | 1 | 1.53 | 1.59 |
| (9) Public lands belong to all Americans, and therefore their management should be the responsibility of the federal government – rather than individual states. | 0.394 | 0.96 | 0.89 | 2 | 2 | 2.20 | 2.28 |
| (10) I can see myself choosing a career in paleontology. | 0.523 | 0.74 | 0.71 | 3 | 3 | 3.07 | 3.24 |
| (11) Increasing appreciation of fossil resources is a good way to get people personally invested in science. | 0.232 | 0.49 | 0.63 | 2 | 2 | 1.97 | 2.09 |
| (12) Field paleontology makes me feel motivated to enjoy learning science. | 0.148 | 0.55 | 0.89 | 2 | 2 | 2.10 | 2.30 |

Table 10

*Paired t-test for Male-Identifying Group*

| Question # | Paired t-test P-Value | Standard Deviation Pre-Treatment | Standard Deviation Post-Treatment | Median Pre-Treatment | Median Post-Treatment | Mean Pre-Treatment | Mean Post-Treatment |
|---|---|---|---|---|---|---|---|
| (1) Camping and outdoor activities bring me joy. | 0.077 | 0.81 | 0.68 | 2 | 2 | 1.98 | 1.78 |
| (2) The information we learn from field paleontology is worth the effort. | 0.830 | 0.60 | 0.74 | 2 | 2 | 1.83 | 1.78 |
| (3) Field paleontology is one of the reasons why I appreciate attending this school. | 0.659 | 0.72 | 0.87 | 2 | 2 | 2.17 | 2.12 |
| (4) Public lands such as national parks, national monuments, national forests, and other managed lands are important areas to preserve for future generations. | 0.743 | 0.45 | 0.44 | 1 | 1 | 1.27 | 1.26 |
| (5) Some protected natural areas that bear fossils must be disrupted, so that, for example, minerals can be mined or oil can be drilled. | 0.052 | 0.70 | 0.93 | 3 | 3 | 3.02 | 2.72 |
| (6) Humans have the right to modify the natural environment to suit their needs. | 0.015 | 0.59 | 0.86 | 3 | 3 | 2.90 | 2.58 |
| (7) When humans interfere with nature, it often produces negative consequences. | 0.830 | 0.68 | 0.72 | 2 | 2 | 1.92 | 1.92 |
| (8) Humans must live in harmony with nature in order to survive. | 0.498 | 0.71 | 0.74 | 1.5 | 2 | 1.60 | 1.68 |
| (9) Public lands belong to all Americans, and therefore their management should be the responsibility of the federal government – rather than individual states. | 0.105 | 0.92 | 0.86 | 3 | 2 | 2.50 | 2.28 |
| (10) I can see myself choosing a career in paleontology. | 1.000 | 0.94 | 0.81 | 3 | 3 | 2.88 | 2.86 |
| (11) Increasing appreciation of fossil resources is a good way to get people personally invested in science. | 0.090 | 0.67 | 0.67 | 2 | 2 | 1.98 | 1.86 |
| (12) Field paleontology makes me feel motivated to enjoy learning science. | 0.595 | 0.85 | 0.82 | 2 | 2 | 1.96 | 1.88 |

<u>Qualitative Short-Responses</u>

One of the most valuable pieces of this research study was the use of qualitative short-responses, which helped illuminate the personal meaning and impact of a singular paleontological field experience on high school learners. While the survey responses showed consistency in pre- and post-treatment, comparison of pre- and post-treatment responses, as well as tabulation of themes in the post-treatment responses, were quite telling and at times truly touching. Qualitative responses took the form of optional brief, end-of-survey responses from both the female-identifying and male-identifying subgroups, for pre- and post-treatment surveys; in addition, the female-identifying subgroup was also given time to write more detailed post-treatment responses at the end of their field experience, while still in the field. Both the sub-group of longer free responses and the group of briefer pre- and post-responses for male-identifying and female-identifying students were tabulated via thematic analysis to determine emergent themes.

To address rigor in the thematic analysis, themes were deductive and mapped to the specific question of opinions of science on public lands. It should also be noted that differences in epistemological interpretation also play a role in how thematic analysis is conducted. For example, the following themes were selected using a constructivist perspective – meaning that students likely wrote their responses on the basis of their prior learning, social cues, what they were feeling at the time of writing, and so on, rather than inherent or essentialist drivers that connect meaning, experience, and language (Braun & Clarke, 2006). Using a deductive, latent (or, deep-meaning interpretive), and constructivist framework, the detailed, female-identifying post-treatment response group was categorized into six themes (Table 11), while the pre- and post-treatment brief responses of both male-identifying and female-identifying survey respondents were categorized into 17 themes (Table 12).

Table 11

*Thematic Analysis of Major Themes in Detailed Post-Treatment Female-Identifying Survey Respondents*

| Themes | Total | Percentage |
|---|---|---|
| Persistence | 28 | 29.5 |
| Failure | 8 | 8.4 |
| Learning in Nature | 27 | 28.4 |
| Conservation | 14 | 14.7 |
| Relaxation | 10 | 10.5 |
| Empathy and Collaboration | 8 | 8.4 |
| Total response items | 95 | |

Table 12

*Thematic Analysis of Major Themes in Brief Pre- and Post-Treatment Male-Identifying and Female-Identifying Survey Respondents*

| Themes | Totals | Percentage |
|---|---|---|
| Nature | 7 | 9.0 |
| Power | 1 | 1.3 |
| Destruction | 1 | 1.3 |
| Dislike | 4 | 5.1 |
| Learn | 3 | 3.8 |
| Enjoy | 11 | 14.1 |
| Fun | 10 | 12.8 |
| Protect | 5 | 6.4 |
| Peaceful | 1 | 1.3 |
| Interesting | 4 | 5.1 |
| Dependent | 1 | 1.3 |
| Wildlife | 1 | 1.3 |
| Respect | 2 | 2.6 |
| Public lands | 4 | 5.1 |
| Consequences | 1 | 1.3 |
| Preserve | 16 | 20.5 |
| Unique | 3 | 3.8 |
| Total Response Items | 78 | |

Detailed Short-Responses from Female-Identifying Group

Major themes that emerged in the detailed responses included "persistence" (29.5% *N*=95 response items), "learning in nature" (28.4%, *N*=95 response items), and "conservation" (14.7%, *N*=95 response items), the latter of which includes reflections on the importance of public lands (Table 11). Other themes in the more detailed responses written by female-identifying respondents included failure – namely, how to accept and cope with not finding fossils when you really wanted to; relaxation - or the moments spent de-stressing from the normal school routine and building friendships during the camping aspect of the field experience; and empathy and collaboration – which included teamwork, caring for those in need of a helping hand, and empathy for the natural environment itself, such as picking up trash or reflecting on care of the environment.

On the subject of failure, one student reflected,

> the Peccary Trip was a very influential experience. I learned that to succeed in life you [have] to keep trying over and over again and to never give up. […] Giving up can never be the answer to a problem, we all have to be passionate in the pursuit of completing our goals.

Another wrote,

> on this trip, I learned many valuable things, but the most important thing is learning from failure. When searching for fossils, it was difficult at first. However, I kept on trying and found some really cool rocks and [other] aspects. If I gave up, I probably would've never discovered the cool things, so, just keep trying and you will succeed.

One student shared the impact of the trip experience on her daily life:

> From the peccary trip I learned that in order to find fossils, we need to actively look for them, put ourselves under the sun for hours, fail several times, and experience the disappointment when realizing what we found were rocks. This could also apply to our daily lives. To reach a goal we need to work really hard.

From experience, and these reflections, it is a true lesson to spend time toiling in the hot sun with the faintest hope for the thrill of scientific discovery.

On the subject of conservation and public lands, students had several reflections that showed their depth of thought and the impact of the Peccary Trip experience. One young woman wrote,

> during the course of the Peccary Trip, I have learned various things about [many things from] fossils to friendships. However, one thing that stood out to me was the fact that we were camping and looking for fossils on federal land. This means that this is the government's land, and we are bound to protect it and respect it. […] This showed me that no matter what, we should always protect the land we ‘borrow’ like it's our home. Therefore we cleaned our campsite to the best of our ability. It is important to do this as we want to cause the least destruction. Overall, the Peccary Trip really emphasized my knowledge of various things. I had an immense amount of fun.

Yet another student wrote,

> over the course of today and yesterday, I've learned a significant amount of information on both fossils and nature. By staying on public lands, I realized the responsibilities that came with it. For example, we were told several times that we can't take bone fragments because [they] didn't belong to us but to the [entire] country. At times like these, it is crucial to follow the rules and show your integrity. If we all just took everything, our Earth would basically [be] dead because we didn't preserve it well enough. However, we can take some fossils for the museum [with permits] because [they are] used for scientific research.

These themes were repeated in the detailed written responses, with another student sharing,

> we shouldn't keep these fossils because we need to preserve them for future generations to look for. If everyone just took all the fossils they find then on the lands then we wouldn't be able to find any more bones years from now. It is important to remember that we must take the responsibility to preserve the fossils on the land for future generations.

The power of the place – Rainbow Basin Natural Area – and the fossils found within it really shone through in the student reflections on their responsibilities towards public lands and science stewardship.

Similar themes emerged on the subject of environmental conservation, and one student wrote,

> on our peccary trip, I learned a lot, but one of the most important things I learned is how crucial it is to preserve our ecosystem and surrounding environment. This preservation is what allows us to find fossils, because we haven't destroyed the land around them, or for example see the stars clearly because the sky isn't polluted.

Reflections such as these truly underscore the impact and importance of field paleontology experiences, even if the singular treatment of the field experience did not make a major change in survey responses. Six of the longer responses mentioned how amazing it was to go stargazing in a clear, unpolluted sky; two reflected on the sheer silence of the Mojave Desert; and four responses reflected on the importance of stepping away from civilization, preserving wild places, and conserving the land for future generations.

On the subject of persistence and hard work, one student reflected,

> during this Peccary Trip, I learned that field paleontology is very difficult. The sun is usually burning, and the hiking is arduous. Finding fossils is extremely difficult to do. It is usually unclear what is rock and what is [a] fossil. However, on the rare occasion that a real fossil is found, the feeling is unforgettable. The scientific findings that you make yourself [are] worth all the sun burns, heat exhaustion, and pain.

Another shared,

> I found the most interesting part is when we found fossil fragments. Fossils always seemed far away from me. I never expected to find a fossil by myself. We have seen what fossils look like. It was interesting to get to know how to find fossils. I used to think we had to dig up mud and rocks, but I was wrong. Also, it was fun to

> hang out with friends. We had time to forget about the stress and homework we usually have. I really loved the part we got to see the planets and the stars.

After reflecting on the challenges of finding fossils and stepping out of her comfort zone, another student concluded with, “mostly, this experience taught me to treasure what nature gave us.”

Stepping out of one’s comfort zone to explore field science and paleontology can be a big step for a learner of any age. One student shared,

> during this Peccary Trip, I expanded my knowledge in many areas. I learned that paleontologist[s] go through a lot of tedious work to become successful in the field. Although [our group] did not find any fossils, the experience made me appreciate the work of paleontology that much more. Along with learning about paleontology, I learned all about patience and sharing ONE bathroom with about 50 girls!” (emphasis is the student’s).

Another wrote,

> on this trip, I was able to put myself out there and try something new, [which] I wouldn't have normally done. We were unable to find any huge fossils (only snail shells) so I understand how hard it must be to sit out in the hot sun for hours with just water. It takes a lot of patience.

A majority of trip students live in urban or suburban environments, and for some, this was their first ever camping experience; students chose to reflect on the immense silence and power of the wilderness. For example, one student shared, “I didn't learn what true silence was until I came on the Peccary Trip.” The longer responses were overwhelmingly positive, with the biggest complaints involving the heat, the hard work, and the challenges of hiking.

<u>Brief Responses from Both Male- and Female-Identifying Groups</u>

Major themes in the male- and female-identifying mixed gender group included the idea of “preserving” the natural world and its beauty, including fossils (20.5%, $N$=78 response items); “enjoyment” (14.1%) or “fun” (12.8%); and some mention of “nature” (9.0%) (*N*=78 response items) (Table 12). Not all short responses coded positively; one female student wrote pre-treatment that the camping experience would be “too dirty”, while another wrote post-treatment, “I don't like going outside in general and much prefer to stay inside. I like science but choose the lab work over field work every time.” This same student reflected pre-treatment, “I don't go out much but when I do it's fun.” One student reflected post-treatment, “I like to have some interaction with the environment, but still I dislike the feeling of walking under sun for [two] or more hours without finding anything.” One male-identifying student shared pre-treatment that experiences on public lands are, “not enjoyable”, but post-treatment shared that public lands, “are very fun and bring me joy, they should be preserved to an extent.”

The shorter responses also provided opportunities to glimpse student opinions on conservation and stewardship on public lands. One student wrote, “interactions [such as this one] bring people awareness of conserving the environment and the danger [the environment] is facing.” One male-identifying student shared post-treatment, “there is a national forest next to my house and it has no effect on me. National Monuments, however, interest me greatly and I'm happy they are here.” The theme continued with another student reflecting, “in my experiences in interacting with public lands, they are always beautiful and positive experiences that are fun to explore.” A male-identifying student wrote pre-treatment, “When going to national parks, I had always been amazed by their scenery and sights. Governments should attempt to preserve them better because they will soon be our last glimpses of nature.” Post-treatment, the same student wrote, “I think interaction with public lands like national parks, forests, and managed lands from my experience with the Webb Freshman Peccary Trip that national parks are necessary to preserve for future generations."

Post-Treatment Interviews with Students

Interview Questions on Perceptions in Science

Three freshman students (two female-identifying and one male-identifying) were chosen at random for informal interviews on paleontology motivation and barriers to science; each student had also participated on the Peccary Trip. Students were asked to respond with the first thoughts that came to mind, and no time limit was imposed. While each student also had an alphanumeric survey code, the students were coded as Student 1, Student 2, and Student 3 for interview purposes. Five questions were asked in the following order:

1. What do you envision when you think of a scientist? Describe three terms that come to mind, and describe the person you envision.
2. Do you feel there are equal opportunities for people from all genders to enter science fields? Why, or why not?
3. Do you feel there are equal opportunities for people from all ethnic or socioeconomic backgrounds to enter science fields? Why, or why not?
4. What does "science stewardship" mean to you?
5. Do you have any other thoughts about field paleontology and science stewardship that you'd like to share?

Conception of a scientist

This exercise was an attempt to glimpse student preconceptions of scientists, which can impact their sense of mentorship or viewing themselves as scientists. Work by Symington & Spurling (1990) explored primary school students' views of what a scientist looks like through illustrations, which coded for stereotypical items such as lab goggles, a lab coat, and scientific equipment. Research by Newton & Newton (1998) in the U.K. determined that balding, bespectacled, lab coat wearing men were disproportionately represented in primary school student illustrations of a scientist. Native American youth comprise the smallest percentage of minority students entering STEM fields; a study conducted on the perception of a scientist by Navajo fourth to sixth grade students determined that 47% of students perceived scientists as male, and 66% of students perceived scientists as Caucasian (Monhardt, 2003). With these prior studies in mind, a brief look at high school reflections of a scientist – in words, rather than visually – was undertaken.

Student 1 responded with three words to describe a scientist: “smart”, “lab coat”, and “lab.” The person Student 1 envisioned was, “male, with glasses, not very tall, and white.” Student 2 described scientists with the words, “focused”, “microscope”, and “sci-fi”. Student 2 envisioned a scientist as, “a tall, young Asian man with glasses,” with “close-cropped hair, shirt and tie, and a lab coat.” Student 3 described scientists using three specific medical terms: “endocrine”, “surgery”, and “appendectomy”. The mental picture of a scientist for Student 3 included this detailed response: “When I envision a scientist, there are many kinds, but the first kind I envision is a surgeon or a person who studies the anatomy of the human body itself. There are paleontologists, archaeologists, medical scientists, but medical comes to mind first. I imagine someone tall, skinny, in a lab coat, with safety goggles. The first that comes to mind is a female, probably because I am female, but I do notice that there are more men represented in the science fields.”

<u>Equal opportunities for all genders</u>

When asked whether equal opportunities exist for all genders to enter science fields, students felt uniformly that gender roles were, in their perception, not a barrier to science. Student 1, female-identifying, responded, “yes, [equal opportunities do exist] because if a female or a male goes to the same college and has the same degree, they have the same chance of getting a job.” Student 2, male-identifying, said, “I do believe [so] because women are just as capable as men on anything. As much as society kind of makes gender roles for topics, there’s still room for adjustment in science and math.” Student 3, female-identifying, replied, “I do believe [so] because women are just as capable as men on anything. As much as society kind of makes gender roles for topics, there’s still room for adjustment in science and math.” This is intriguing given the recent surge of interest in promoting and maintaining the professional growth of women in science, technology, engineering, and math (STEM) fields, as evidenced by many “women in STEM” workshops and symposia at academic conferences in recent years.

While the number of women in science and engineering fields is growing in the United States, men continue to outnumber women at upper levels of these professions. While young women and men take science courses at roughly equal numbers in their K-12 careers, there are far fewer women majoring in science in college, especially in engineering. 29% of all male-identifying freshman compared to 15% of all female-identifying freshmen intended to major in a STEM field in 2006, for example. Interestingly, women in 2006 earned the majority of biology majors in the U.S. (Hill, Corbett, & St. Rose, 2010). Whether the student responses reflect a shift in student attitudes that runs counter to trends in national averages, or whether there is a sense of hopefulness and equity among the specific students interviewed is unclear, but nevertheless the spirit of their responses is encouraging.

Equal opportunities for race and socioeconomic backgrounds

Students were asked whether equal opportunities exist to enter science fields for people from differing racial or ethnic and socioeconomic backgrounds. Student 1, female-identifying, Caucasian-identifying, reflected, “ethnic, I would say yes, but socioeconomic I would say no, because in our debates [in other academic classes] people in lower socioeconomic classes, they don’t have as many opportunities to get a good education and have as many opportunities to join the science world.” Student 2, male-identifying, Caucasian-identifying, reflected, “for ethnic groups yes, I do believe there is equal opportunity because science isn’t based off of race. For socioeconomic backgrounds, it’s more the interest, if they didn’t have interests in school and never got into science, they might be less interested than those of higher income.” Student 3, female-identifying, Caucasian-identifying, shared, “I mean, I feel like in some cases they could be discriminated against, with ethnicity. Wealthier people have a better chance of getting a better education, unless you’re really really good [at science], so the wealthier people could have an advantage.

These reflections are interesting because they uniformly share that ethnicity is not a barrier, except for “some cases” of “discrimination”, yet all three students reflected that socioeconomic factors such as wealth and opportunities in education could have a substantial impact on a student’s ability to enter science fields. Work by Else-Quest et al.

(2013) analyzed over 300 urban high school students of various ethnic backgrounds and determined that Asian American males appear to be the highest achieving, mirroring the "model minority" effect that can plague some groups as stereotypical; while Latino and African American males appeared to be the lowest achieving, echoing the troubling trends seen in the American Psychological Association (APA) Presidential Task Force on Educational Disparities (2012). These student interviews reflect a very small sample size, as well as potential bias as interviewed students attend a relatively expensive private school. Future interviews could shed further light on student attitudes on this important topic. Without a dialogue on ethnic and socioeconomic disparities, and without a broad sense of education for our students who may not experience ethnic discrimination, even well-meaning young people may be blind to the disparity at hand.

<u>What is science stewardship?</u>

Even though students generally reflected in their written responses that taking care of or "preserving" natural resources on public lands was an important way to connect with the land, and students were advised prior to taking the surveys what stewardship was, the phrase "science stewardship" nevertheless caused some confusion. This is important to note since, while the idea of science stewardship makes sense to students in the context of wanting to preserve and conserve public lands, the word "stewardship" is not common to their vernacular. Student 1 responded with, "I don't know what that means. What does that mean?" Student 2 responded, "taking responsibility for something in science. Like, if you are doing an experiment with a lizard, take care of that lizard. Bioethics, like what we learned [in class]." Student 3 shared, "I don't know what stewardship is, collaboration? It can mean the caretaking of natural resources." A key recommendation would be to ensure future researchers work with teachers to ensure the definitions of science stewardship, managed lands, and even fossils themselves are clear or at least presented more than once to student respondents.

Regarding any final thoughts, two of the three students choose to share the following: Student 2 said, "I have an interest in field paleontology because I'm not much of a lab person, I like the field, and I want to be involved in paleontology possibly even as a career." Student 3 reflected, "Um, [field science] could be used in ways to better advance our field by using different methods to collaborate different sciences together, and we could discover something completely unexpected. The Peccary Trip did open me up to paleontology because I'd never really experienced it before."

<u>Interview Questions on the Impact of the Peccary Trip</u>

Five additional freshmen students, and three sophomore honors paleontology students from the current sophomore class, were selected at random to be interviewed on the question:

1. What is the most memorable about your experience on the freshman Peccary Trip?

The freshmen students correspond to coded identifiers VWS4, VWS45, VWS35, and VWS47 (all female-identifying), and WSC15 (male-identifying). Student VWS4 reported her most memorable experience in these words: "It was just like a really great experience overall. Just like being able to like, um, like research and like discover new things with like your fellow classmates. I just thought it was a cool experience." Student

VWS45 reported that she felt it would have been a better experience if she'd been able to personally keep the fossils she'd found, even though she understood the benefit of public lands and conserving fossils on those lands:

> I think it's good that we keep [public lands] nice and we should like [allow] other kids have the opportunity to look for the fossils and to see them … if you don't take care of [public lands], it would get like worse and worse. And then like basically […] your kids, kids like won't have this area to go to and like visually look as nice or like be as nice.

She also reported that the experience of cooking campfire food together was a great bonding experience.

Student VWS35 expressed that her most meaningful experience with the trip was, "it's just sort of really dirty. You can't wash your hands and I didn't like that. Um, but like I guess I got to know, I got to know a few more of my classmates, which was nice." When asked more specifically about the impact of the trip on public lands, and whether fossils should be preserved, she also shared,

> Well I mean, the fossils aren't really doing anything. They're just sitting there. So I don't think it's bad to be digging them up. And I also don't think it's bad to be like changing the landscape. I mean like everything changes. So it's okay if you sort of dig a smaller hole, it's fine.

Student VWS47 shared that her most meaningful experience of the fossil trip was,

> It was really exciting to see like one of my best friends finding a fossil and yeah, I was really happy for her. Yeah, it was really memorable seeing her, sharing the fossil around and yeah, show[ing] it to everyone. [What] would it look like? And it was really interesting to see that.

When asked to further elaborate on her feelings about looking for fossils on public lands, she related,

> Um, you know, working with fossils in a place that we all kind of take care of. I think it is a really important task for researchers. Students when they visited, they

> have to actually take responsibilities, but it's also a great opportunities for people to study the fossils in a public land, which means they have like better resources and assets to the, like the fossils they want to study and find. But also, it's really important for people to have preserve the land and take responsibilities.

Male-identifying student WSC15 shared that his most memorable experience from the trip was, "Oh, I think since like towards the beginning of the year, it was like a time when like, like friendships grew stronger. You actually got to go like go outside and like stay [with] your friends." He also shared that finding a fossil for the first time, and realizing it was a fossil and not a rock, "was like a really cool part in my paleontology journey". Finally, when asked to share more on his thoughts on paleontology on public lands, the student shared a misconception that all public lands are unregulated, so anyone could simply take what was on them. We had a discussion about the importance of paleontological permits and the permit that we used during the dig process. When asked how national parks, monuments, and other public lands make him feel, he shared, enthusiastically, "Happy! Just going into nature and like seeing stuff that could [be] dated back to a long time or if they're just recent, that' pretty cool."

Second-year sophomore students, who had already gone through one year of honors paleontology – the same course that the comparison group will take during the 2019-2020 school year – shared some interesting insights into the comparisons between the freshman field paleontology experience and their more dedicated, smaller honors paleontology field experience. Since these three students were not participants in the treatment or comparison groups, they are designated Sophomore 1, Sophomore 2, and Sophomore 3. Sophomores 1 and 2 were female-identifying, while Sophomore 3 was male-identifying. All three sophomores had received an additional year of paleontological training, equivalent to the course that the comparison group of freshmen will take during the 2019-2020 school year.

Sophomore 1 expressed that the honors paleontology trip was a more “intimate” experience with a greater ability to identify fossils that were found in the field, and a deeper appreciation for the fossils and public lands. She shared,

> I do prefer the honors paleontology peccary trip because I feel like with a smaller number of people and a more focused sort of goal within that, it really helps you to gain a better perspective. And especially as you go out on your own after you learned about all the different licensing and the different qualifications that you have to go through to research and collect fossils in that land, there's something very special about going there yourself and experiencing that.

Sophomore 2 also shared that the freshman peccary trip was a fun, but less personal experience. She recounted of the freshman trip,

> I remember just going around and finding rock after rock after rock. And like, it was a fun trip. I didn't really learn much because it was, it was, I just, I still didn't really know what a fossil looked like ‘cause it wasn't my own experience. Um, however, I think it's a good first step.

Sophomore 3, who was sketching a dinosaur during the interview, shared about his relationship with public lands,

> I sort of understand the extremely hard work that goes into [field work], um, as I see both professionals and people might like me [as a student] collecting specimens in the field and is, I'd be very sort of upset to see it sort of any further disrespected or undermined.

When asked to elaborate further on his feelings on public land boundaries being reduced, the student shared, “I think as a species, our power and intelligence sort of, um, deems us stewards of our own environment”, and when fossils aren’t accounted for during public lands boundary reductions, we lose “very valuable scientific information in that process”.

Post-Treatment Interviews with Teachers

One teacher was able to comment on his experiences with the freshman field paleontology trip, and he shared his thoughts on any perceived barriers to science motivation, as well as science motivation and stewardship.

Barriers to Science Motivation

The male-identifying teacher, in his first year of teaching this course and the field paleontology trip – but a veteran teacher with over 20 years of teaching experience – shared his thoughts on barriers to science motivation in general. A theme that emerged was the idea of science education as an entertainment piece, where students appear to struggle with science motivation unless they are entertained and excited by the material. This went hand-in-hand with retaining student attention, especially with increasingly rigorous scientific material. A third theme was the inability of some science curricula to bring meaningful application of scientific material to students' everyday lives. When students also face socioeconomic barriers, especially students of color, there can be a disturbing gap in resources available for those students to become motivated to learn science. In the end, serving all students and helping to shrink equity gaps in science education will benefit the entire educated population.

Rays of Hope for Science Motivation and Stewardship

Individualized attention, dedicated resources, and even specialized field experiences could help students who are underserved and all students who struggle with a sense of science motivation, the interviewee teacher shared. If greater efforts can be spent on applicability of science concepts, quantitative skills over independent skill sets that appear to exist in separate silos, and more support for students of color and young women in science, then perhaps there will be increased gains in student science motivation in the United States. As for science stewardship, particularly on public lands and especially on the school's very specific peccary trips, the teacher shared that it's hard to say whether the trip at our school is significantly different from trips elsewhere. Would a paleontology trip have the same impact on science motivation and science stewardship for all students, everywhere? Probably not, but it would be interesting to see whether students from public schools – especially urban public schools – would experience sharp contrasts in their answers from this private school population, due to the novelty of the field experience from everyday life.

## INTERPRETATION AND CONCLUSION

### Field Science Stewardship and Science Motivation

#### Total Survey Group Pre- and Post-Treatment

Of the twelve survey questions applied to the treatment and comparison groups, all showed consistency between the means pre-treatment and post-treatment. None of the pre- and post-treatment t-test comparisons elicited statistical significance and percentage changes in strongly agree responses did not increase or decrease by more or less than 10% pre- versus post-treatment. Questions that came close to 10% change include question 6 (8%) and question 12 (7%); only one question decreased in strongly agree percentages from 50% to 48% (question 8). This indicates that, overall, students largely did not change their minds about the questions asked pre-treatment versus post-treatment. The treatment group does not show statistical significance in stewardship survey questions; however, thematic analysis underscores the impact of public lands on a sense of science stewardship.

Medians pre- and post-treatment in the total treatment group remained unchanged, with the exception of a slight shift from strongly agree (numeric designation 1) to agree (numeric designation 2) in question 8 – “humans must live in harmony with nature in order to survive.” Utilizing means can be problematic in Likert-style surveys, because the data are ordinal; there is rarely a consistent, equal conceptual distance between “strongly agree” and “agree”, for example, for each individual respondent. While means should be analyzed under the umbrella of this caveat, the means pre- and post-treatment do not exhibit drastic shifts. Possible exceptions include a shift from 2.87 pre-treatment to 2.70 post-treatment for question 6, “humans have the right to modify the environment to suit their needs”, a potential signal that opinions shifted slightly toward agree (numerical indicator 2) from disagree (3). Another potential exception is a shift from 2.17 pre-treatment to 2.03 post-treatment for question 1, “camping and outdoor activities bring me joy,” a potential signal that opinions shifted slightly toward “agree”. Finally a small signal shift from 2.15 pre-treatment to 2.30 post-treatment in question 3, “field paleontology is one of the reasons I appreciate attending this school,” could indicate an opinion shift towards “disagree” (Table 4). Again, these interpretations are subject to the unreliability of using means alone as a source of significance. Overall, both means and medians have not changed drastically, which indicates few students significantly changed their opinions pre- and post-treatment.

Pre-treatment and post-treatment standard deviation are fairly consistent, however the standard deviations are closer to 1, which indicates more variation in the responses in both pre- and post-treatment. Interesting comparisons include question 4, “public lands such as national parks, national monuments, national forests, and other managed lands are important areas to preserve for future generations,” where the spread increased from 0.44 to 0.60 pre-versus post-treatment. This implies that opinions varied more greatly post-treatment (Table 4). The percent of survey respondents answering “strongly agree” increased in each case post-treatment, with the exception of question 8 (Figure 2, Table 5). Boxplot spreads allowed corroboration with the descriptive statistics; medians were unchanged in questions 1 (Figure 3), question 4 (Figure 4), question 6 (Figure 5), and question 11 (Figure 6).

<u>Comparison Group Pre- and Post-Treatment</u>

The same measures of descriptive and inferential statistics were used to determine any trends within the data for the comparison group (Table 6). The paired t-tests for questions 1 through 9 were not statistically significant at an alpha value of $p<0.05$; question 11 was also not statistically significant. However, question 10, “I can see myself choosing a career in paleontology”, displays a statistically significant p-value of 0.013. The median for question to shifts from 3 (disagree) to 2 (agree), and the spread narrowed with a standard deviation pre-treatment of 0.99 and post-treatment of 0.79. The mean, with the same caveat as in the treatment group, shifted from 2.71 pre-treatment to 2.21 post-treatment. Question 12, “field paleontology makes me feel motivated to enjoy learning science”, also displayed a statistically significant p-value of 0.030. Median responses shifted from 2 (agree) pre-treatment to 1 (strongly agree) post-treatment; spread narrowed with a standard deviation pre-treatment of 0.86, and post-treatment of 0.61. Means shifted slightly toward strongly agree, from 1.88 pre-treatment and 1.47 post-treatment (Table 6). There is also an increase in strongly agree responses in each of the 12 questions, and an increase of at least 10 percent pre- and post-treatment for questions 3 (13%), 4 (13%), 7 (13%), 8 (39%), and 12 (23%). Questions 8 (“humans must live in harmony with nature in order to survive”) and 12 (“field paleontology makes me feel motivated to enjoy learning science”) are particularly big jumps in strongly agree responses (Figure 7, Table 7). This appears to point out the increased likelihood of student interest in a career in paleontology post-field versus pre-field when that student is also interested in continuing her formal education in paleontology.

Fisher’s Exact Tests for Female- and Male-Identifying Groups

Utilizing Fisher’s Exact Test provides an interesting look at the significance per question between the female-identifying and male-identifying freshman groups. Question 12, “field paleontology makes me feel motivated to enjoy learning science”, reported a statistically significant p-value of 0.034 for the female-identifying group. Question 6, “humans have the right to modify the natural environment to suit their needs”, reported a statistically significant p-value of 0.023 in the male-identifying group. The total survey group also reported a Fisher’s Exact Test p-value of 0.040 for question 6 (Table 8). Within the paired t-test analysis, questions 10 and 12 returned statistically significant results for the comparison group; however, using Fisher’s Exact Test, only questions 5 and 11 appear to have statistical significance (Table 8), rejecting the null hypothesis that there is no change in the medians for these two questions.

Paired t-test for Female-Identifying and Male-Identifying Groups

Within the female-identifying group of students, the only statistically significant paired t-test result is question 3, “field paleontology is one of the reasons why I appreciate attending this school”. This question is specific to the unique program of the school and its paleontology field opportunities associated with the Alf Museum. Based on the medians pre- and post-treatment, there is a slight shift from agreeing with this question (a response of 2) to disagreeing with this question (a response of 3). In addition, the means pre- and post-treatment highlight this slight shift towards disagree, but still fall within the lukewarm “agree” territory of 2.61 post-treatment, compared to 2.13 pre-treatment (Table 9). As with the treatment group as a whole, the medians are remarkably consistent pre- and post-treatment, with the exception of question 3 discussed above; and question 8, “humans must live in harmony with nature in order to survive”, which signaled a shift from agree (a response of 2) to strongly agree (a response of 1). Spread narrowed in several questions post-treatment, including question 4, where standard deviation shifted from 0.43 to 0.71, and question 12 from 0.55 to 0.89; while it broadened in one question, question 9, from 0.96 to 0.89 (Table 9).

Within the male-identifying group of students, the only statistically significant paired t-test result is question 6, “humans have the right to modify the natural environment to suit their needs”. This is the only question where the paired t-test corroborates with the Fisher’s Exact Test for the male-identifying group. Medians remained consistent pre- and post-treatment, with the exception of question 8, "humans must live in harmony with nature in order to survive", which shifted slightly from 1.5 (towards strongly agree) to 2 (towards agree); and question 9, "public lands belong to all Americans, and therefore their management should be left to the federal government, rather than individual states" – which shifted slightly from 3 (disagree) to 2 (agree). Means pre- and post-treatment were fairly consistent, with a slightly more dramatic shift from 3.02 (a "disagree" signal) to 2.72 (a warmer "disagree" signal moving towards "agree") in question 5, "some protected natural areas that bear fossils must be disrupted, so that, for example, minerals can be mined or oil can be drilled" (Table 10). Standard deviation is also fairly consistent pre- and post-treatment, with narrowing of spread in questions 5 and 6; questions 1, 9, and 10 experienced slight broadening of spread.

Comparison of Paired t-test and Fisher's Exact Test

The total survey treatment group responses for question 6 returned a Fisher's Exact of 0.040, but a paired t-test of 0.103. These conflicting significances may call the validity of the significance into question; however, if we utilize the Fisher's Exact Test, then the treatment did have a significant impact on student views of whether humans have the right to modify the environment to suit their needs. The survey question in particular is not specific enough to determine what kind of modification students might be envisioning when they respond to this question. Perhaps some students would have liked a strip mall, but others may simply have wanted more accessible toilets! No other question, utilizing either Fisher's Exact Test or the paired t-test, returned a statistically significant result.

Within the comparison group, question 5 returned a Fisher's Exact Test result of 0.043 (Table 8), but a paired t-test of 0.608 (Table 6). This also muddies the interpretation of whether the results were truly statistically significant for the question on disrupting natural areas that bear fossils for economic gains. If we utilize the Fisher's Exact Test, then we can assume some statistical significance. This is an interesting result because it implies that there may be a slight shift in the median towards agreeing with disrupting areas that bear fossils for economic gains.

The results for the Fisher's Exact Test for the female-identifying group did not return significance on question 3, "field paleontology is one of the reasons why I enjoy attending this school", with a p-value of 0.072; however, it did return significance using the t-test, with a p-value of 0.013. If we utilize the Fisher's Exact Test, there is no statistical significance in the impact of a field experience on changing the median response for this question. The Fisher's Exact Test for question 12, with a p-value of 0.034 (Table 8), returned statistical significant, while the t-test was 0.148 (Table 9). If we again utilize the Fisher's Exact Test result, then field paleontology may have a significant impact on how female-identifying students feel motivated to learn science.

The male-identifying group returned statistical significance for both the Fisher's Exact Test, with a p-value of 0.023 (Table 8), and the paired t-test, with a p-value of 0.015 (Table 10), for question 6. This question again could have been more specific in its use of the term "modify", to allow more information to be gleaned from these significant responses in the male-identifying group and total survey groups. It is interesting to note that the female-identifying group did not return statistical significance in this question.

Field Science Experiences and Science Stewardship on Public Lands

This study ties in with previous work on experiential education, the ability of field work to inspire science motivation, and a history of concern for natural resources on public lands. Adding to the data available on science motivation and science stewardship on public lands, and the impact of field and outdoor experiences on learners, will help bring together a more cohesive picture of how field science experiences are influencing students. Student and teacher interviews reflected varying interest in field science, and allowed qualitative analysis of reactions to the field science experience.

Major themes that emerged in both the brief responses (both male- and female-identifying) and the longer, more detailed female-identifying student responses included persistence, learning in nature, conservation, accepting and coping with failure, relaxation, friendship, fun, empathy, and collaboration (Tables 11 & 12). The most important factors in these thematic analyses, and in the words of the student written and spoken responses, are the chances students get to reflect on their own learning while in the field. In addition, it's particularly touching to read or hear responses from students that express how meaningful, unique, or inspiring the field paleontology freshman experience was for them. Students who gained a small glimpse of the ability of natural spaces to change their worldview, from new understandings of science, to building friendships, to appreciation of the silence and beauty of the outdoors, will undoubtedly benefit in the long term – regardless of statistical results or the detail of the written or interview responses.

How does field paleontology impact student science motivation to be science stewards on public lands? There may be some small shifts in the way male-identifying students think about their right to modify the natural environment to suit their needs, and a sense of privilege that comes along with an increased agreement to modify the environment. And there may be a small shift in the overall group of respondents within the same question, towards “agree”. Perhaps it is a result of the “new”-ness of the environment, or perhaps students simply wanted more conveniences, or saw little to lose from disrupting land for personal comfort. There may also be a shift in female-identifying students’ desire to be more motivated to learn science, following a field paleontology experience, which if true, is particularly heartening in a world that truly needs more motivated and supported young women pursuing science careers worldwide.

Students who have a strong interest in paleontology are, unsurprisingly, perhaps more likely to pursue a career in field paleontology after a field science experience; while the same comparison group may also feel more motivated to enjoy science thanks to field science experiences. The number of student respondents who felt they strongly agreed with the necessity of humans living in harmony with nature in order to survive increased nearly 40% post-treatment, one of the largest percentage gains in the study. And questions 4, 7, and 9, which all pertained to science stewardship, may not have had a statistically significant signal in any group or treatment; yet, the written responses show strong signals of student interest in conservation, nature, and the importance of preserving public lands for future generations. Do field science experiences impact science motivation? Perhaps they do, even if that impact is not quantitatively tangible at a small scale with a singular treatment.

This study allows future work to take two important approaches: to ensure that sample sizes are large enough, and socioeconomically diverse enough, to gain a strong and unbiased signal of statistical significance in question responses – aiming for over 500 respondents would be ideal. And, to dig deeply into the thematic analysis of question responses, to allow themes to emerge that really get to the heart of these crucial issues of science stewardship and motivation. There is an aspect of human-based ennui in any survey; some students may have taken these surveys seriously, and others may not have. The consistency in their pre- and post-treatment responses, for the most part, brings up a third salient point in future study design: longer treatment, with more consistent and full immersion in paleontological (or, relevant field science) techniques. The responses of the honors paleontology sophomore students interviewed give some insight into this idea.

### Science Accessibility: Barriers and Solutions

The major focus of this study was not accessibility to science, and therefore the glimpses it can provide are a sliver of the work that needs to be done in this arena. Accessibility to science careers, especially by those who are traditionally underrepresented in science, such as people of color, first-generation students, immigrant or undocumented students, and LGBTQ individuals, is vital for a healthy and equitable scientific community. More than that, it's the responsibility of those who have had the life resources and abilities to forge a path in science to mentor, coach, teach, and simply to be visible to those who wish to pursue science as a career or interest. What can be done to address these issues? Bridging the gap may well start with bringing more students from underserved populations into experiences such as this fossil trip, or other outreach programs in paleontology globally. Future studies will allow this question to be given the detailed attention it needs and deserves.

## VALUE

### Impact on professional growth

Throughout the research process, this action research project has allowed me to reflect on how my students are learning while in the classroom and in the field. Particularly, the way in which I frame the field work that students conduct has shifted in my mind. The next time I teach these topics, it’s clear to me how students really should have a dedicated unit on science conservation and science stewardship; having the basics of the scientific method and the basics of paleontology and geologic time may not be enough of a scaffold for students. More than my curricular changes, I have learned from the written and interview responses that students truly are getting a valuable educational experience, even a life-changing experience, from the freshman field paleontology trip at Webb. Student reflections on friendship, teamwork, caring, and the power of wild places like public lands have made me stop and reflect on my own interactions with these places. The process of data collection and analysis has also helped hone my skills as a researcher, especially in the field of education research. I am truly grateful for this action research experience and for the Master of Science in Science Education program at Montana State for providing me with the tools, skills, and guidance I needed to complete this research project.

Next steps

One of the most interesting things that strikes me about this project is the relative dearth of educational research in K-12 paleontology education. This is a growing field, with more pieces of research appearing to bolster a conceptual framework in this specific area. Many exciting projects are presented each year as abstracts in regional and national meetings of paleontology and science education; it has been said before, but it would be wonderful to see more of these abstracts published as papers and action research "manuals" where individual projects can be replicated. It may be that similar projects have been presented at regional or national academic or educational conferences, but no digital record of an abstract exists. The more we can present research on the impact of paleontology on student motivations and aspirations, the richer our tapestry of understanding paleontology education will be.

Future work would, ideally, increase sample sizes of survey respondents, and lead in to the field experience with a deeper discussion of conservation and science stewardship. Longer periods of field work would also be interesting to explore; for example, would opinions change more or less drastically if students were in the field for 7 days rather than 2? Would activities other than prospecting, such as fossil excavation and jacketing, change the ways in which students think about their motivations in paleontology or as science stewards on public lands? Studying the effect size, or the statistical significance of the overall effect of a treatment rather than the change in medians, would also be useful to explore. Another aspect that is in need of further exploration is the differing impact on students of varying ethnic groups and socioeconomic backgrounds. While this study attempted to highlight some student thoughts on these important matters, ethnicity and socioeconomic questions were not a major focus, and much more work needs to be done. It is my hope that this study will spur future research in the impact of field paleontology on science stewardship, science motivation, and science accessibility, especially on the public lands that we share, conserve, and protect.

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# APPENDICES

# APPENDIX A

## INTERNAL REVIEW BOARD APPROVAL – MONTANA STATE UNIVERSITY

# INSTITUTIONAL REVIEW BOARD
**For the Protection of Human Subjects**
**FWA 00000165**

MONTANA STATE UNIVERSITY

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**MEMORANDUM**

**TO:** Taormina Lepore and Marcie Reuer

**FROM:** Mark Quinn, Chair *Mark Quinn CJ*

**DATE:** September 18, 2018

**RE:** *"Field Science Experiences in Paleontology: Shaping Science Stewardship in High School Learners" [TL091818-EX]*

The above research, described in your submission of September 17, 2018, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

_X_ (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

____ (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.

____ (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.

____ *(b) (4) Research involving* the collection or study of existing data, documents, records, pathological specimens, or *diagnostic specimens*, if these sources are publicly available, or if the information is recorded by the *investigator* in such a manner that the subjects cannot be identified, directly or through identifiers linked to *the subjects*.

____ *(b) (5)* Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.

____ *(b) (6)* Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

*Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.*

# APPENDIX B

## UNIT CONTENT STANDARDS AND SCIENCE PRACTICE STANDARDS

Unit 1 - What is a Scientist Content Standards

Content Standard 1.1 (NGSS HS-LS1-1) (AP Bio LO 4.1, 4.2, 4.3) - I can construct and revise an explanation based on evidence from a scientifically designed experiment or model. EXPLANATIONS

Content Standard 1.2 (AP Bio SP 2.1) - I can select and use appropriate measurement methods and techniques for gathering data, and systematically record and organize observations and measurements. MEASUREMENT

Unit 2 – Evidence for Evolution Content and Science Practice Standards

Content Standard 2.1 Evidence of Common Ancestry and Diversity - I can communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence and I am able to describe the reasons for revisions of scientific hypotheses of the origin of life on Earth. EVIDENCE OF COMMON ANCESTRY AND DIVERSITY

Content Standard 2.2 Natural Selection and Adaptation -

List of Science Practice Standards and Relevant Skills

Science Practice 1 (SP1) I can Ask Questions and Define Problems - Skills include:

- formulating, refining, and evaluating empirically testable questions or design problems
- reflecting upon lab work to propose meaningful follow-up questions and/or experiments
- generating a novel question that is appropriate in depth to match the time given for a project
- creating a research question that has enough specificity to lead to meaningful data collection
- generating and framing hypotheses based on conceptual knowledge and previous experiments

Science Practice 4 (SP4) I Can Use Technology to Explore, Learn, Analyze, and Communicate Information - Skills include:

- searching the internet for scientifically accurate resources
- correctly using Excel for graphical analysis & computations

- utilizing presentation software: PowerPoint, Prezi, etc. for oral presentations
- including and annotating sources in scientific writing
- including in-line citations and a bibliography when using the ideas or results of other scientists
- using proper lab report guidelines for presenting laboratory findings, including writing a proper scientific abstract
- labelled graphs support the analysis
- correct use of SI units, significant figures, uncertainty, and scientific notation
- writing with appropriate vocabulary and correct grammar

Science Practice 5 (SP5) I Can Engage in Argument from Evidence - Skills include:

- selecting and using data or research to support a claim
- working in the lab to justify or to challenge your existing conceptual understanding
- correctly interpreting qualitative and quantitative lab results
- understanding how uncertainty limits experimental results and conclusions
- explaining the effects of sources of error

Science Practice 6 (SP6) I Can Demonstrate Self-Analysis and Metacognition - Skills include:

- reflecting thoughtfully on what you do & don't know or understand
- understanding how you learn best & ensuring that you study that way
- exhibiting persistence, resilience, and humility
- assessing the progress and quality of your own work

Science Practice 7 (SP7) I Can Contribute to a Learning Community - Skills include:

- contributing positively to collaborative processes
- generously sharing your knowledge to move a group process forward
- using evidence to establish scientific consensus
- discovering, understanding, and evaluating previous research on a topic
- participating in the peer review process to assist others and to clarify your own work

- maintaining a safe and clean lab space
- working with honorable intent

Science Practice 8 (SP8) I can Connect Knowledge Across Various Scales and Disciplines - Skills include:

- connecting ideas from the disciplines of biology, chemistry & ethics
- connecting ideas from various scientific disciplines
- considering the macroscale & nanoscale reality in every situation
- utilizing the world "beyond the classroom" as you design solutions or make connections
- relating other classes or life experiences to your study of science

# APPENDIX C

## MODEL OF ATTITUDES OF PALEONTOLOGY ON PUBLIC LANDS (MAP-PL)

## SURVEY INSTRUMENT

Survey Instrument – Model of Attitudes of Paleontology on Public Lands (MAP-PL)

*Assigned Random Numeric Identifier*

(1) Camping and outdoor activities bring me joy.

Strongly Agree - Agree - Disagree - Strongly Disagree

(2) The information we learn from field paleontology is worth the effort.

Strongly Agree - Agree - Disagree - Strongly Disagree

(3) Field paleontology is one of the reasons why I appreciate attending this school.

Strongly Agree - Agree - Disagree - Strongly Disagree

(4) Public lands such as national parks, national monuments, national forests, and other managed lands are important areas to preserve for future generations.

Strongly Agree - Agree - Disagree - Strongly Disagree

(5) Some protected natural areas that bear fossils must be disrupted, so that, for example, minerals can be mined or oil can be drilled.

Strongly Agree - Agree - Disagree - Strongly Disagree

(6) Humans have the right to modify the natural environment to suit their needs.

Strongly Agree - Agree - Disagree - Strongly Disagree

(7) When humans interfere with nature, it often produces negative consequences.

Strongly Agree - Agree - Disagree - Strongly Disagree

(8) Humans must live in harmony with nature in order to survive.

Strongly Agree - Agree - Disagree - Strongly Disagree

(9) Public lands belong to all Americans, and therefore their management should be the responsibility of the federal government – rather than individual states.

Strongly Agree - Agree - Disagree - Strongly Disagree

(10) I can see myself choosing a career in paleontology.

Strongly Agree - Agree - Disagree - Strongly Disagree

(11) Increasing appreciation of fossil resources is a good way to get people personally invested in science.

Strongly Agree - Agree - Disagree - Strongly Disagree

(12) Field paleontology makes me feel motivated to enjoy learning science.

Strongly Agree - Agree - Disagree - Strongly Disagree

Open-Ended Question:

What are your thoughts or experiences in interacting with public lands such as national parks, national monuments, national forests, and other managed lands?

# APPENDIX D

## SAMPLE LESSON PLANS PRE-TREATMENT

Intro to the Museum and Paleontology - Standards Addressed: Standard 2.1

1. On whiteboards have students define “paleontology”

Discuss their ideas

Present formal definition: the study of ancient life

2. Why do we care about paleontology?

Answers pressing questions of present day:

How has Earth’s climate changed in the past, and what caused this?

What causes extinctions?

Gives us really important insight into evolution

Formal definition: descent with modification

Helps us understand how today’s life has changed through time

3. On whiteboards have students define “fossil”

Discuss their ideas

Present formal definition: remains or traces of ancient life

4. Bring students into museum for tour (bring notebooks!)

Sit in front of trackway slab at front of museum

Ask students what they see—how is this different from a dinosaur skeleton or a mammoth tusk?

Present definitions

Body fossil: actual part of the plant or animal

Trace fossil: something left behind by plant or animal Introduction (history, Ray Alf, Peccary fossil)

5. Return to classroom for slideshow and discussion of fossilization process

# APPENDIX E

# SAMPLE LESSON PLANS POST-TREATMENT

Evolutionary Biology Post-Field Trip Project

Use your research skills and some creativity to propose an expedition to discover a new transitional fossil. It is expected that you give a description of the animal, drawing of the animal, its habitat, the geologic time frame, distinct characteristics, adaptations, and the family tree (cladogram, with important anatomical features) of the organism. *Note that you are making something up that does not exist! You are not merely reporting on actual fossils that have been discovered.*

You will compose your information in a shared document in a word processor (Google Docs, Pages, whichever you choose).

A rubric will be used to grade your project that will be scored on a 1-4 grade, 4 being the best and 1 unacceptable. This covers Standards 2.1, 2.2, Science Practice 4, Science Practice 5, Science Practice 6, and Science Practice 7.

Your report should contain the following sections:

- Introduction: Research the known fossil record and evolutionary history of your group. What transitional fossils have already been found? Use this information to help you decided where your organism falls in relation to these other fossils, and what transitional adaptations it should have. Be sure to keep a list of your references!
- Expedition: You had to go on an expedition to find your fossil--tell us about it! You need to research the age of the rocks where you found your fossil, and the type of environment the rock should represent (think about: did your organism live in the ocean? on land?). Finally, figure out where on Earth that you can go today to find rocks of that age and from that environment.
- Describe your fossil: This part has four main sections.
    - A description of the transitional adaptations that characterize your fossil
    - A scientific name for your organism (you make up a new genus and species; the name should have two parts)
    - At least one drawing of your fossil, with adaptations labeled
    - A cladogram (family tree) of the group your organism belongs to, including your new organism

The list of transitional fossils follows:
Early Seahorse
Artiodactyl
Early Common Ancestor of Humans
Early Tetrapod
Early Amphibian
Early Synapsids (Precursor to mammals)
Pakicetidae (Early whale)
Early eunotosaurid (turtle precursor)
Early Snake
Cynodonts (mammal)
Early bird (bird)
Plesiadapids (early precursor to primates)
Primate
Early Bat
Early Carnivore
Early Diapsids
Sirenian (Early Manatee)
Pinniped  (Early Seal)
Proboscidean (Early Elephant)
Canidae (Early Dog)
Early Tyrannosaur (dinosaur)

Early angiosperm (flowering plant)
Early chordate (vertebrate ancestor)
Early parrot