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The impact of field experiences in paleontology on high school learners

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ABSTRACT

Field experiences are an important element of paleontological knowledge building. However, there is little information about the effects field experiences have on science stewardship and personal growth in high school learners. This pilot study analyzed the reflections of a group of female and male 9th grade U.S. high school students ($N=72$) on their first field paleontology experience at Rainbow Basin Natural Area, California. We investigate the attitudinal impact of this experience within a human dimensions research framework using mixed methods. Likert-style surveys indicate relative consistency in pre- and post-treatment total group responses student-to-student. Qualitative responses highlight themes such as the power of science stewardship and a personal sense of connection to public lands. An increase in reflections of stewardship across coded segments occurred, from 18.4% to 29.4% pretreatment versus post-treatment. Qualitative responses and the human dimensions research framework are highly recommended as tools for paleontology education researchers to more effectively document attitudinal changes during field experiences and to better understand field paleontology narratives. In combination, these methods can highlight the intersection of science stewardship, personal growth through experiential education, and the importance of field paleontology. Future studies can make use of human dimensions research to illuminate the impact of field paleontology on pre-college students, and document the influence of field science on future generations of policy-makers, educators, and scientists.

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Introduction

The impact of field paleontology

Outdoor experiences have the potential to impact people in profound ways. This type of experience is relevant for science learners, and for scientists who spend their careers conducting work outdoors, or 'in the field'. Many professional and avocational geoscientists and paleontologists will often share stories of their memorable experiences in the field in conversation, while additional scholarly resources have underscored the ongoing inequities of field experiences (Atchison et al., 2019; Atchison & Libarkin, 2016; Carabajal et al., 2017; Carabajal & Atchison, 2020; Núñez et al., 2020; Stokes et al., 2019). What is the impact of these paleontology-based outdoor experiences, and how can we record that impact on learners, especially in a pre-college setting?

There is a body of literature on the impact of paleontology-based science teacher training (e.g. Marlow et al., 2003; Rischbieter et al., 1993), as well as a growing body of work on student experiences during geoscience fieldwork or field trips (Boyd & Lazar, 2022). Much of the current published work in general paleontology education places a heavy emphasis on undergraduate case studies in the classroom (Beerbower, 1963; Clapham, 2018; Cohen et al., 2018; Domack, 2000; Lockwood et al., 2018; Mendelson, 1991; Montgomery & Donaldson, 2014; Pestana, 1977; Yacobucci & Lockwood, 2012). Additional work has focused on paleontology education in the context of the K-12 classroom (Grant et al., 2016; Gunckel, 1994; Ziegler et al., 2020), but there is less known about the combination of these factors: attitudinal impacts of paleontology field work experiences for K-12 learners.

Among the leaders in published paleontology K-12 education field research are museums and science learning centers, including several national park and monument visitor centers (Benton, 2003; Butler et al., 2020; Santucci et al., 2016), universities (Sheffield & Bauer, 2017), and centers for outreach such as the Paleontological Research Institute and Museum (PRI) (Harnik & Ross, 2003, 2004). Hancock Field Station, associated with the Oregon Museum of Science and Industry (OMSI), and John Day Fossil Beds National Monument also provide opportunities for field-based paleontology education for elementary school students (Gunckel, 1994). Dig programs for families at museum venues such as the Museums of Western Colorado: Dinosaur Journey and for teachers via programs such as the Discoveries in Geoscience (DIG) Field School of the Burke Museum at the

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University of Washington are among numerous opportunities for outreach and education at field paleontology sites, where educational research could occur.

While these programs have provided excellent opportunities for classroom or outdoor learning, or for teacher professional development, to our knowledge there is no current research connecting the work of paleontology field programs to their attitudinal impact on high school students. Since paleontology field experiences often connect students with stewardship-centered experiences on public lands, and have the potential to be quite memorable, we're curious about how students discuss a sense of science stewardship and personal growth in relation to these experiences. This pilot study identifies this area of discourse, and provides baseline data on the attitudinal impacts of field paleontology on high school students.

Paleontology is a scientific subject that draws the interest of many young learners (Moran et al., 2015), and has the potential to motivate students to consider the vast expanse of Earth's geologic history, as well as concepts of land conservation and science stewardship while they participate in fossil-based field activities on conserved, public lands. Fossils hold relevance to many people for innumerable scientific, cultural, educational, and interpersonal reasons (Santucci et al., 2016) - because they fascinate people, and connect us to our planet's past. Outdoor experiences can shape the ways in which we view land and fossil conservation.

Through understanding student reflections of outdoor paleontological experiences, we build a more cohesive case for fossil conservation policy and the importance of fossils writ large. To begin to assess this potential, we explore the impact of field paleontology on United States high school students' sense of science stewardship on public lands. Following the definition of the term 'stewardship' as it was taught to the high school student participants, we define this term in a Eurocentric conservation science setting, though we recognize a broad literature of Indigenous conservation stewardship (Leonard et al., 2020). In addition to the impact on sense of stewardship, we explore how students reflect aspects of personal growth and general outdoor enthusiasm following their paleontology field experience.

Research questions

We ask the following research questions:

1. How does field paleontology impact a sense of student science stewardship on public lands?
2. How does field paleontology impact student reflections of personal growth and outdoor enthusiasm?

We hypothesize that short-term participation in field paleontology experiences will increase student self-reported sense of science stewardship and personal growth. Here, short-term refers to a two-day, overnight field paleontology camping experience. Through analysis of student paleontological experiences on public lands, we can gain a more cogent understanding of the impact of field science education experiences on broader themes, such as student compassion for the natural world and its resources, student personal growth, interest in science, and conceptualization of lifelong science stewardship.

Conceptual framework

To explore the impact and relevance of field science education experiences such as field paleontology, we set our conceptual framework within the larger background of waning science enthusiasm in the United States' education system. Impactful field experiences may change this landscape. Because the intersection of science enthusiasm, field paleontology, science stewardship, and human impact is relatively unexplored, we provide a short review of relevant literature and connect these concepts in the human dimensions framework. We define the core concepts of field science education and experiential education, which are applied in this study and other studies in the relevant framework literature. Science stewardship and connection to public lands is introduced as another potential salve to waning science enthusiasm. Finally, we connect science stewardship to human dimensions research, which is the key theoretical framework for our study (Figure 1). Through better understanding human-environment interactions in natural settings, we can assess and improve fossil and public lands conservation efforts.

Science knowledge and enthusiasm: What happens to the spark?

Young children have an innate sense of curiosity and wonder, yet a sustained interest in and enthusiasm for science and areas of natural beauty rests on many factors. These factors are numerous, and include individual student gravitation toward one topic over another and a positive attitude toward science (Buccheri et al., 2011; Gardner, 1975; Stake & Mares, 2001; Talton & Simpson, 1986); exposure to engaging science content, natural areas, and dedicated science programs (Heck et al., 2012; Markowitz, 2004; Shahali et al., 2016; Stake & Mares, 2001) and parental, familial, and educational support for science interests (George, 2000; George & Kaplan, 1998; Scibeci & Riley, 1986; Stake & Mares, 2001).

Also relevant are the science interests of peers (George, 2000); socioeconomic factors (Yilmaz-Tüzün & Topçu, 2009) that allow for the prioritization of academic interests along with basic needs of security; cultural and traditional science knowledge contextualization and integration with hegemonic Eurocentric science (Apple et al., 2014; Jackson et al., 2016; Zidny et al., 2020); the availability of academic resources for adequate teacher preparation (Bizimana & Orodho, 2014); and, potentially, a broader, societal appreciation for the importance of science and nature. While it is not within the scope of this paper to address all of the various ways in which science interest and enthusiasm can be cultivated, we emphasize the myriad paths through which science and nature can be championed or discarded and point out

Figure 1. Why human dimensions research? Here we highlight key strands of research to which human dimensions research can be applied in the context of paleontology field experiences. Figure modified from Biorender.com (2022).

that there are personal, institutional, and social factors simultaneously at play.

So then, why is science interest, knowledge, and enthusiasm important? Specific knowledge in a science, including intense curiosity about fossils, can aid in the development of structured knowledge and higher order thinking skills. Gobbo and Chi (1986) connected intense bouts of interest in science in young learners with the strengthening of cohesive analogical knowledge - that is, the ability to directly compare two items or features of an item - which forms part of the basis of deeper analytical skill building. Glaser (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 can help students connect in-school learning with out-of-school interests and experience (Bryson, 1994; Clapham, 2018; Katz et al., 2014; Pugh, 2011).

Yet as children grow older, some of this innate curiosity, the 'spark' of science curiosity, appears to wane. Strong interests in specific content, or conceptual domains, appear to decline as school begins for preschool aged students (Alexander et al., 2008). A trend toward declining interest or motivation in science and technology is well-documented as students progress from early grades to high school or secondary school age (Galton, 2009; Krapp & Prenzel, 2011; Osborne et al., 2003; Potvin & Hasni, 2014). Can field science and field paleontology education recover some of this innate science curiosity? Connecting field science with positive experiences of stewardship and personal growth may help students and educators to do this.

Field science education

Field science education, the practice of engaging in the generation of questions and collection of scientific data either outside the classroom in a natural setting (Levitt, 2016) or through a virtual substitute (Mistler-Jackson & Songer, 2000; Rahman et al., 2012; Tapanila, 2007; U.S. Department of Education, 2010), can be an engagement tool for students and likely serves as a modest science interest motivator for middle school students in the U.S. (Levitt, 2016). In U.S. high school earth and life science classrooms, field study is recommended alongside required lab-based activities (National Research Council, 2012). Investing time, accessibility, and resources for field study in the high school setting can be a challenge for tightened U.S. school district budgets and for busy educators operating within an inequitable education system, but the benefits of field science experiences are clear.

These experiences can allow the learner to recall childhood memories of outdoor play (Vadala et al., 2007), while nature-based trips can provide learners with experiential connections to fundamental principles of scientific exploration, science motivation, and curiosity in a dynamic and often unpredictable natural environment (Behrendt & Franklin, 2014; Driscoll, 2004; Driscoll & Lownds, 2007; Ting & Siew, 2014). The value and importance of field geoscience experiences has been underscored in studies that focus on the emotional and values-based impact, or the affective domain, of such experiences (Boyle et al., 2007; Jolley et al., 2018). Place-based geoscience field education has the potential to link student sense of place and motivations about a field experience with learning and valuing science content (Semken et al., 2017; van der Hoeven Kraft et al., 2011); mini-essays and other short responses provide a useful format for these place-based geoscience value reflections (Clary & Wandersee, 2006, 2008). Student affect in place-based geoscience settings can further motivate learning (van der Hoeven Kraft et al., 2011). In a field-based setting, teaching and learning—and the acquisition of knowledge based on hands-on experiences—fits within the framework of *experiential education*, whereas a more personal human connection to outdoor spaces, including stewardship and personal growth through outdoor experiences, fits within the framework of *human dimensions research*. Therefore, we differentiate between the two frameworks here, and emphasize human dimensions research as our grounding.

Experiential education

Experiential education emphasizes life-long learning and a deep connection between social responsibility, independent inquiry, and the integration of new learning into preconceived notions (Caulfield & Woods, 2013). Dewey (1938) outlined the need for a theory of experiential education, describing how hands-on experiences inspire curiosity in the learner, while asserting that bringing the educational experience outside of the classroom walls would galvanize societal change. Pugh (2011) connects Dewey's concepts to the idea of transformative experience, defined as a learning experience or episode in which a student acts on learned subject matter by using it in an everyday experience, thereby more fully perceiving an aspect of the world and consequently finding meaning. While we focus here on specific attitudinal changes, rather than learning changes as a result of outdoor experiences, student learning itself is impacted by interacting with the natural environment. As a result of experiential interaction with the natural environment, increasingly complex learning phenomena can be realized (Emo et al., 2015; Ormrod, 2011).

What is science stewardship?

We define science stewardship as the responsible use and conservation of scientifically important natural resources (Worrell & Appleby, 2000), and within that umbrella, we focus specifically on fossil stewardship on public lands. We recognize that the phrase 'scientifically important' centers the scientific value often placed on fossils, and acknowledge multiple ways of knowing and perceiving fossil importance. 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. Science stewardship of these public lands may also encompass the caretaking of ecosystems, of organisms and their migrations, archaeological artifacts, and geologic formations, as well as the use of traditional Indigenous knowledge in the stewardship process. Paleontological examples of science stewardship relevant to this study include the care, conservation, and study of fossils within U.S. national monuments and other public lands.

Eurocentric science stewardship has a history of being studied in a field-based, environmental and citizen science context (Bogner, 1998; Bogner & Wilhelm, 1996; Dopico & Garcia-Vazquez, 2011; Glasson, 2011; Merenlender et al., 2016; Toomey & Domroese, 2013; Wals et al., 2014), yet we are only beginning to move toward an understanding of *field paleontology* as a vehicle for conservation and science stewardship. Indigenous stewardship has been a part of global Indigenous societies since time immemorial, and has been championed as necessary for biodiversity conservation and environmental management (Domínguez & Luoma, 2020; Leonard et al., 2020; Schuster et al., 2019; Thompson et al., 2020; Tran et al., 2020). At present, Indigenous stewardship is relatively decoupled from Eurocentric stewardship in environmental conservation at large (Thompson et al., 2020). More work must be done to decolonize paleontology (Cisneros et al., 2022; Monarrez et al., 2021; Raja et al., 2022), and to recognize and respectfully integrate Indigenous stewardship within paleontology. A theoretical framework that holds a great deal of promise for analyzing a multitude of stewardship connections to paleontology is human dimensions research, which has been proposed as increasingly important not only to field-based environmental and conservation science, but to public lands paleontology conservation as well (Santucci et al., 2016).

Science stewardship and human dimensions research

To get a better sense of how human beings think about and relate to science, public lands, areas of natural beauty, and natural resources such as fossils, we can use the framework of human dimensions research. This is a multidisciplinary research field grounded in social science research methodology - that is, using a mixture of textual, interview, or survey-based data - to better understand human-environment interactions to broaden and enhance natural resource management (Bauer et al., 2010), ultimately to improve conservation efforts (Bennett et al., 2017). As a result of the growing concerns of global climate change, human dimensions research initiatives sprang up in the 1990s to 2010s, including the International Human Dimensions Programme (IHDP), which strived to integrate social science survey research with pressing global climate and conservation concerns. The goals of the IHDP were effectively subsumed into the 2014 Human Developments Reports of the United Nations Development Programme.

There are specific connections between human behaviors and attitudes about natural spaces or natural resources, and the actions we take to conserve them. Pro-environmental behavior appears to be motivated by individual sense of connection to nature (Mayer & Frantz, 2004; Whitburn et al., 2020). Without an understanding of these connections, societies may end up neglecting or damaging natural spaces and resources through resource exploitation and unsustainable human modification of the environment.

What is the current status of human dimensions research? Numerous U.S. colleges and universities currently offer coursework and research programs in human dimensions, especially in departments of fisheries and wildlife or in environmental science policy. Various public agencies such as the U.S. Forest Service and the Human Dimensions Resource Management program of the U.S. Geological Survey spearhead human dimensions research initiatives. These initiatives have deepened the research community's understanding of human-environment interactions, and have increased support for resource management, in fields such as ecology (Bauer et al., 2010), fisheries management (Heck et al., 2015), and protected areas (Ferraro & Pressey, 2015).

Specific to paleontology and the geosciences, human-environment interactions have tangible benefits for fossil conservation. Geoscience thinking imparts a so-called long view of time; a view of deep time that connects past trends with present ones, and may lead to "more farseeing and environmentally responsible decision making" (Kastens et al., 2009, p. 265). This responsible decision making may be influenced by a person's internalized sense of science stewardship. Collaborative research that uses survey analysis to detect attitudinal changes brought on by paleontology field experiences would help test this assertion and record crucial paleontology field narratives. Social science research, including qualitative or mixed methods survey analysis, is applied sporadically within paleontology resource conservation (Hockett, 2008; Ward & Roggenbuck, 2003; Widner & Roggenbuck, 2000); we affirm the need expressed by Santucci et al. (2016) to expand this type of analysis within paleontology, by using human dimensions research as a key theoretical concept. As a paleontological research community we have a responsibility to build a culture that is conducive to ongoing social science research in order to highlight the benefits of science stewardship, multiple ways of knowing, and the ongoing conservation of natural resources such as fossils on public lands. By doing so, we can continue to build the necessary research framework that defends irreplaceable fossils on public lands and the unique learning, cultural, and personal growth experiences that occur on these lands.

Study population and setting

School setting

This study was undertaken at an independent, non-parochial boarding school located in southern California, with enrollment averages of 35% day and 65% boarding students for the 2018–2019 school year, and 21% of students reported from countries other than the United States. Students in the 2018–2019 academic year came from 12 U.S. states and 14 countries, and the school emphasizes its 100% college acceptance rate, with a college-focused curriculum and highly motivated student body. The associated museum of paleontology on the school's campus 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 et al., 2019). The study group was composed of 9th grade students, ages 13-15, with female ($N = 26$) and male ($N = 46$) Likert survey respondents. Demographic data were limited to the researchers, but the study group included a mixture of international and domestic U.S. students. All students were enrolled in the required 9th grade evolutionary biology course at the study school, which includes in its first semester unit a mandatory trip to conduct paleontological field prospecting and fossil identification at Rainbow Basin Natural Area (Bureau of Land Management), near Barstow, California.

Curricular timing

The female student trip occurred on September 22 and 23, 2018, and the male student trip occurred on September 29 and 30, 2018. 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. Following the paleontological field experience, all students completed a project in which they designed their own imaginative 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.

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. The students met at the school museum on the first day 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 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 museum staff and school 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. Day 2 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' trip, detailed post-reflections were conducted in the field on the night of their first field day. For the boys' trip, post-reflections were conducted solely via written prompt at the end of the Likert post-treatment surveys. The annual trips provide an excellent opportunity for students to interact directly with fossils in the field, and gain an understanding of the challenges and rewards of paleontological field work.

Methods

Here we describe our overall process and proceed to outline specific aspects of qualitative and quantitative analysis. We collected data in the form of identical pre-post surveys during a two-day trip (pre-survey) and four months following the trip (post-survey), to assess the impact of the field paleontology experience. Pre-post surveys included one open-ended and 12 Likert-scale questions. Potential participant and expert focus groups were also implemented during the survey instrument creation process. We then edited any unclear or confusing wording accordingly. Quantitative data from numerically-designated responses to Likert-style survey questions were analyzed using Excel and R Studio (2020) core package.

Written responses were coded in parallel by two researchers in a bottom-up, data driven fashion that was largely inductive, but shifted to deductive as codes were structured into themes. We used convergent parallel mixed methods (Creswell & Creswell, 2017; Demir & Pismek, 2018), which entail the collection of both quantitative (fixed response) and qualitative (written response) data elements concurrently, analyzing the data independently, and then interpreting the data convergence and divergence (Creswell & Plano Clark, 2011). We chose this methodology to compare quantitative statistics and qualitative codebook thematic analysis (Saldaña, 2015). While we utilize mixed methods here and assess percentage qualitative responses and our hypotheses in a more positivist manner, we approach our analysis of consensus coding in a more post-positivist fashion, critical of pure positivism, and underpinned by the author team's qualitative methodological values. We approach our qualitative analysis within an experiential orientation and a social constructionist framework centered in critical realism (Clarke & Braun, 2013), recognizing that students were reflecting their lived experience on the public lands, and that students may build new understandings and values based on these social experiences.

The first author analyzed qualitative data in MaxQDA and developed a corresponding codebook using attitudinal codebook thematic analysis (Saldaña, 2015), then the second author recoded 10% of the data, a reasonable percentage for the amount of data collected in this study (O'Connor & Joffe, 2020). The first two authors then discussed to consensus when disagreement between coded themes arose (Sandelowski & Barroso, 2007). As an action-based research study undertaken in a Master's program, we engaged in an ongoing evaluation of trustworthiness and dependability throughout the process of data collection and analysis, through more than a year of bi-weekly peer consulation and reflexive auditing - or, describing researcher involvement in the research process (Stahl & King, 2020).

Quantitative: Likert survey development and methodology

We analyzed Likert-style survey data using paired t-tests ($p = 0.05$). Wilcoxon ranked sum tests were also performed, however no change in significance was found using this test compared to the paired t-tests, so we focus here on the latter. Pretreatment surveys were given in fall 2018, while post-treatment surveys were given in spring 2019. A minimum of one month's span between pre- and post-treatment survey application is recommended to minimize short-term effect (Bogner & Wiseman, 2004); in this study four months lapsed between pretreatment and post-treatment surveys.

A total of 72 students were surveyed both pre- and post-treatment ($N = 26$ female, 36%; $N = 46$ male, 64%), and students were assigned a randomly generated numeric code that allowed researchers to pair pre-post data without identifying students. Student names were also protected using assigned pseudonyms. Gender identity was regretfully not assessed through self-identification, and was assumed in the female-male binary based solely on school designation into the coordinate female-only and male-only class structure. We encourage deliberately addressing a variety of gender identities, with participant and parent permission. Respondents were given parent-student Internal Review Board (IRB)-approved waiver forms under Montana State University IRB TL-091818; 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 surveys and written self-reflection was not required. To minimize perception of teacher-student bias, and because one of the study authors was also one of the teachers of record, surveys were distributed whenever possible by a teacher not responsible for direct instruction of the students being surveyed.

The pilot survey instrument, titled the Model of Attitudes of Paleontology on Public Lands (MAP-PL), contains 12 questions in the Strongly Agree—Strongly Disagree format, without Neutral or No Response options in an attempt to elicit polarity. Although no prior validated survey instrument pertaining to field paleontology and public lands attitudes existed for us to utilize, we were inspired by the work of F.X. Bogner and coauthors on outdoor education and K-12 students' environmental attitudes and beliefs. One question pertaining to modifying the natural environment (question 6) was identical to an item from Bogner and Wiseman (2002, 2004) 2-factor Model of Environmental Values (2-MEV), "Humans have the right to modify the natural environment to suit their needs". This question was relevant to the field paleontology experience and the conservation context of the survey. Bogner and Wiseman (2002, 2004) set this question within a 'human over nature' primary factor. A second question pertaining to protection of natural areas (question 5) was inspired by an item from Bogner and Wilhelm (1996) environmental perspectives of pupils survey. This item was within Bogner and Wilhelm (1996) exploitation of nature scale, originally worded, "In order to feed human beings, nature must be cleared, so that, for example, grain can be grown". For our survey instrument, the question is worded, "Some protected natural areas that bear fossils must be disrupted, so that, for example, minerals can be mined or oil can be drilled." This shift was made to capture respondent attitudes on human-nature interactions in a fossil conservation context. These two questions were reverse coded for descriptive statistics.

The remaining questions were developed by two of the current study's authors with qualitative research expertise. The current study authors are comprised of two professional vertebrate paleontologists and a professional researcher in learning science with experience analyzing the attitudes of paleontological communities. One of the paleontologist authors has led or co-led five field paleontology experiences in the western United States, and was also the science education action researcher and teacher-researcher responsible in part for direct classroom instruction at the study institution. The second paleontologist author has eight years experience leading paleontology summer field courses in the Late Cretaceous Hell Creek and Two Medicine formations of Montana.

For informant review, draft surveys were given to an expert writer with over a decade of experience in the psychology of language. In addition, a small cohort of vertebrate paleontologists with expertise in science education on public lands reviewed the survey for content validity, question wording, and flow; these vertebrate paleontologists were members of an online paleontology education working group and/or employed at the study institution. Survey text was distributed to a small number of students not involved with the survey courses for focus group feedback. Informants were asked to identify any areas of confusion or question indecision. Following review, small verbiage edits were made for clarity. Combined, the informant review group and author group has over three decades of experience in vertebrate paleontology field research and over a decade of science education research.

Likert questions 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. By grouping questions categorically, 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 were selected as separate categories 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 study school. Finally, science stewardship questions attempt to shed light on responsibility and motivation for caretaking and conservation of scientific resources in natural areas.

Qualitative: written self-reflections

Qualitative data were collected in the form of written self-reflections before and after the field paleontology experience. Space for these written reflections was provided at the end of the Likert-style survey instrument. We conducted codebook thematic analysis and determined themes with affective method process coding (Saldaña, 2015), as students reflected on their paleontology field experiences on a personal level. We developed our themes iteratively, using open coding, and developed and refined our research questions based on the experiences reflected in the respondent text (Creswell & Poth, 2016). Themes were united around a central organizing concept. The question posed to all students at the end of the survey instrument was: *What are your thoughts or experiences in interacting with public lands such as national parks, national monuments, national forests, and other managed lands?*

While only 26 female students were able to complete both pre- and post-treatment Likert surveys due to the busy nature of high school classrooms throughout the school year, the entire female class of paleontology trip participants ($N = 47$) was given the opportunity to complete longer written responses immediately post-treatment, while still in the field. The reason for this is that one of the authors was present on this trip and able to better guide and encourage the post-treatment reflection process. The female sub-group free-write response question was *What was the most important thing you learned during your experience in the field, in the last 24 hours?* Within the male student group, 46 students completed both pre- and post-treatment Likert surveys, many of which also included the brief written reflections. Because of the different question prompt and the more detailed nature of the longer, *in situ* responses, the female sub-group of longer free responses was coded independently, and the total group of briefer pre- and post-responses for male and female students was coded separately from those more detailed responses.

Results

Participant responses to the model of attitudes of paleontology on public lands (MAP-PL)

Descriptive statistics assessed how participants felt the field experience impacted their appreciation of nature, paleontology motivation, science stewardship, and science motivation. Likert items were converted to ordinal, numeric values, with Strongly Agree equaling 1 and Strongly Disagree equaling 4. For the two reverse-coded questions, questions 5 and 6, the same Strongly Agree - Strongly Disagree numeric scale was used and the questions assessed accordingly in reverse for descriptive statistics, because we did not conduct internal reliability assessment of Likert questions. For the Total Group ($N = 72$), there was no statistical significance pre- and post-treatment for any question or question category (Table 1). Using the mixed methods approach, we were motivated to explore whether an in-depth analysis of the written responses clarified these results.

Brief responses from the total group, pre- and post-treatment combined

The top six major themes from the Total Group, pre- and post-treatment combined across four documents ($N = 183$ segments) were beauty of nature, fun, stewardship, public lands, learning, and hard work (Table 2). Three additional themes reported smaller percentages: neutral or no effect ($N = 4$, 2.2%), friendship ($N = 1$; 0.5%), and persistence (not reported). Comparing selected student quotations pre- and post-treatment holistically allowed us to investigate student perspectives on these kinds of field experiences, including their reported sense of nature appreciation, feelings surrounding public lands preservation, and general attitudes toward areas of natural beauty.

Table 1. Descriptive statistics: total group (N = 72).

Question #	Category	Total Mean Pretreatment	Total Mean Post-Treatment	Total SD Pretreatment	Total SD Post-Treatment	*p*
(1) Camping and outdoor activities bring me joy.	Nature Appreciation	2.17	2.04	0.80	0.78	0.151
(2) The information we learn from field paleontology is worth the effort.	Paleontology Motivation	1.85	1.93	0.62	0.76	0.358
(3) Field paleontology is one of the reasons why I appreciate attending this school.	Paleontology Motivation	2.17	2.31	0.73	0.88	0.150
(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	1.26	1.31	0.44	0.62	0.605
(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	2.04	2.17	0.74	0.90	0.321
(6) Humans have the right to modify the natural environment to suit their needs.	Human-Nature Connection	2.15	2.32	0.60	0.84	0.103
(7) When humans interfere with nature, it often produces negative consequences.	Human-Nature Connection	2.00	1.96	0.67	0.78	0.625
(8) Humans must live in harmony with nature in order to survive.	Human-Nature Connection	1.58	1.67	0.67	0.77	0.418
(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	2.46	2.33	0.84	0.84	0.236
(10) I can see myself choosing a career in paleontology.	Paleontology Motivation	2.97	2.97	0.80	0.84	1.000
(11) Increasing appreciation of fossil resources is a good way to get people personally invested in science.	Science Motivation	1.99	1.94	0.62	0.67	0.605
(12) Field paleontology makes me feel motivated to enjoy learning science.	Science Motivation	1.99	2.10	0.76	0.89	0.261

Table 2. Example responses for most frequent themes (pre- and post-treatment combined).

Selected Theme	% of Coded Segments (*N* = 183)	Definition	Example
Beauty of Nature (*N* = 48)	26.2%	Student description of an appreciation of the beauty of nature, and aspects of nature such as the authentic landscape, and the sounds, sights, smells, and feelings it invokes. Examples include silence and peace, privilege and uniqueness of the experience, an aspect of the beauty of the natural environment, or treasuring / valuing nature.	They are beautiful lands that should not be destroyed. (VWS26 Pre)
Stewardship (*N* = 43)	23.5%	Student description of stewardship which includes conservation, thinking about future generations, adapting to the world around us, or appreciation of nature and natural resources.	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 it didn't belong to us but to the 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. (VWS32 Post)
Fun (*N* = 32)	19.8%	Any mention of fun, happiness, relaxation, an unforgettable experience, or enjoyment in the context of their experiences in nature, before, during, or after the field experience. Includes a simple lexical search for the word "fun".	It was fun to hang out with friends. We had time to forget about the stress and homework we usually have. (VWS27 Post)
Public Lands (*N* = 27)	14.8%	A direct mention of interaction with public lands, including national and state parks and national forests, before, during, or after the field experience.	Interacting with public lands allow us student[s] to learn with [outdoor] experience. (WSC30 Pre)
Learning (*N* = 14)	7.7%	What did students express that they were learning? Includes a simple lexical search for the words "learn" and "learning". Examples include learning about fossils, learning about evolution or deep time, learning about compassion, learning to support one another.	I realized what fossils REALLY looked like when you are in the field. I was expecting a very white, clear, easy to see bone, but they actually look more like deep colored wood. (VWS14 Post)
Hard Work (*N* = 14)	7.7%	Any mention of hard work, such as expressing that fossils are hard to find, either by students themselves, or that scientists work hard to find fossils. Also includes stepping out of a comfort zone, being careful, or doing something the student wouldn't normally do.	I learned that paleontologists go through a lot of tedious work to become successful in the field. Although we [in our group] did not find any fossils, the experience made me appreciate the work of paleontology that much more. (VWS29 Post)

Note. Alphanumeric codes in parentheses represent anonymized student responses.

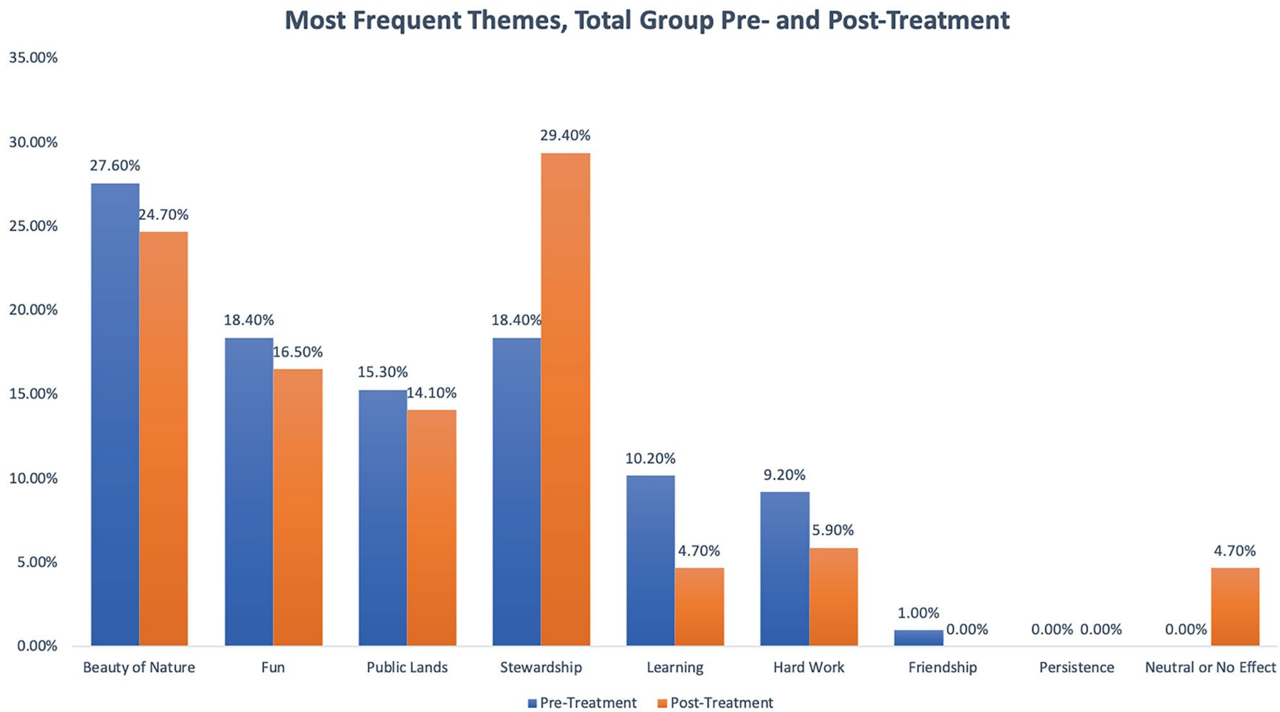

Figure 2. Most frequent themes, total group pretreatment (segments N = 98) and total group post-treatment (segments N = 85).

In doing so we can inspect how individual student opinions of a field experience change. In addition to total theme percentages pre- and post-treatment combined (Table 2), total theme percentages pretreatment versus post-treatment were separated for comparison (Figure 2).

Beauty of nature

Approximately 26% of all coded student responses reflected expressions of the beauty of nature. For example, Aisha wrote post-treatment, "I always appreciate humans not interfering with nature because it is more enjoyable and beautiful to be around." Jalil reflected post-treatment, "I love the outdoors. No man-made thing can replicate what nature created." Additionally, Marie shared post-treatment that natural areas, "give people a new perspective for people to learn more about nature and science to grow to love it." Dak 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 Jake reflecting pretreatment, "in my experiences in interacting with public lands, they are always beautiful and positive experiences that are fun to explore." Tobias wrote pretreatment, "When going to national parks, I had always been amazed by their scenery and sights." These reflections capture the powerful experiences young people can have while interacting with the beauty and solitude of natural places.

Stewardship

Nearly twenty-four percent of coded responses reflected some aspect of stewardship, including responses about conservation, appreciation of natural resources, and respecting nature for the benefit of future generations. Aldrea wrote post-treatment, "interactions [such as this one] bring people awareness of conserving the environment and the danger [the environment] is facing." Kathy shared pretreatment, "I believe that we shouldn't disrupt natural environments, so it is important for us to create national parks, monuments, and forests." Barbara wrote post-treatment, "I think it's important to interact with public lands but also keep them clean, safe, and untouched." Giacomo reflected pretreatment, "When these resources are used, we instantly waste millions of years of aged beauty, which then takes millions of years to regenerate." Tobias shared pretreatment, "Governments should attempt to preserve [natural areas] better because they will soon be our last glimpses of nature," and post-treatment wrote, "I think interaction with public lands like national parks, forests, and managed lands from my experience with the [field trip] that national parks are necessary to preserve for future generations." The reflection of stewardship and natural conservation across responses highlights some students' preconceptions of these concepts, and captures reflections after a field experience on these lands.

Fun

Around 18% of coded responses reflected the broad category of "fun", including happiness, relaxation, an unforgettable experience, or enjoyment in the context of their experiences in nature. This theme also included a direct lexical search for the word "fun". Winston shared pretreatment, "I feel excited while interacting with natural places and doing discoveries in the nature (*sic*)." Loren wrote post-treatment, "I have a great time interacting with nature." Hobbs reflected, "I enjoy spending time in undisturbed nature, and like to preserve it." These responses were particularly compelling

Table 3. Example responses for most frequent themes (female sub-group post-treatment longer short-responses).

Selected Theme	% of Coded Segments ($N = 170$)	Example
Learning ($N = 57$)	33.5%	On our 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. (VWS28 Post)
Hard Work ($N = 38$)	22.4%	The most important thing I have learned through this experience is how hard it is to find a fossil. I used to think that it is probably easy to find, since museums were always filled with them. When I was looking through, trying to find something, I end up only find fragments or pieces, not a full fossil. (VWS6 Post)
Persistence ($N = 23$)	13.5%	When searching for fossils, it was difficult at first. However, I kept on trying and found some really cool rocks and aspects. If I gave up, I probably would've never discovered the cool things, so, just keep trying and you will succeed. (VWS2 Post)
Fun ($N = 17$)	10.0%	I had an immense amount of fun. (VWS4 Post)
Beauty of Nature ($N = 11$)	6.5%	I learned that nature is wild, beautiful, and new, but I also learned that I need to appreciate my surroundings. (VWS36 Post)
Friendship ($N = 10$)	5.9%	You have the chance to deepen friendships in a free and fun environment. (VWS40 Post)
Stewardship ($N = 7$)	4.1%	I learned about conserving our environment. It was a fun trip! (VWS18 Post)

when compared to responses from the survey in which students either did not respond positively to field experiences or felt so similarly pre- and post-treatment that no significant differences were evident in the Likert questions. Capturing responses that convey the emotions students express while engaging with field experiences is particularly powerful, and indicates that students can feel excited and encouraged by new field experiences.

Public lands

Approximately 15% of coded responses discussed or directly mentioned public lands. Elliott shared post-treatment, "Public lands are a key component to influence future generations." Stunt shared that he had recently visited a national park, writing, "It changed my life. I won't ever forget it." And Marlene wrote post-treatment, "It is important that public lands be left undisturbed unless in the cases in which they benefit from the interaction." While related to the stewardship theme, reflections pertaining to public lands were coded as moments where students considered the *place* in which the *action* of stewardship can occur.

Learning

Approximately eight percent of students shared reflections around learning. Loren wrote pretreatment, "I'm enjoying expanding my knowledge", while Autumn reflected post-treatment, "I did not expect to enjoy the [field trip] as much as I did. I learned a lot and gained a deeper understanding/respect for paleontology." Jalil reflected pretreatment, "I enjoy outdoors and national parks, monuments, etc. They are fun and interesting. Learn *(sic)* a lot." Interestingly, 10.2% of students reflected on learning pretreatment, while only 4.7% of students did so post-treatment (Figure 2). Student reflections centered around learning capture how students perceive their learning process while in the classroom, on public lands, and their learning process while engaging in paleontology education activities.

Hard work

Approximately eight percent of students reflected a preconception or post-trip reflection that field science is hard work or in some way outside their comfort zone. Rachel predicted pretreatment that the camping experience would be "too dirty," while Cassie shared pretreatment, "I don't go out much but when I do it's fun." Cassie then 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." Melissa 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." Marco shared pretreatment that experiences on public lands are, "not enjoyable", but post-treatment shared, under the Stewardship theme, that public lands "are very fun and bring me joy, they should be preserved to an extent." These responses underscore some of the challenges of field work and stepping out of a comfort zone to go camping or hiking, both of which are integral components of field work.

Percentages of most frequent themes pre- and post-treatment indicate an increase in the Stewardship theme post-treatment, (pre = 18.4%, post = 29.4%, Figure 2). These theme quotes highlight what students report thinking and feeling before, during, and after field science experiences, which can be far more illuminating than quantitative measures of attitudinal or opinion change, which may not shift greatly or accurately capture the nuance of a trip's impact on stewardship and personal growth following a single field experience.

On-site female student reflections: field paleontology's impact

In addition to analyzing responses from all students, we also examined female students' detailed reflections with the separate prompt, which they wrote the first night in the field. The coded segments from this rich sample ($N = 170$) were so abundant, they nearly matched the number of coded segments for the brief responses of the entire pre- and post-treatment male and female group ($N = 183$). Major themes that were crafted in the student responses regardless of binary sex were also present in this sample (e.g. learning, hard work, persistence) (Table 3). In their on-site reflections, girls rarely talked about public lands ($N = 7$, 4.1%) and never included responses that could be coded as neutral or no effect. However, two additional themes were crafted from analyzing these data: friendship (any mention of friendship or friends), and persistence (pushing through an experience that may require patience; continuing despite difficulties and challenges; failure; and being out of one's comfort zone).

Consistent with the question prompt, the greatest percentage of reflections in code segments (33.5%) captured student feelings under the Learning theme, emphasizing direct interaction with fossils in the field. For example, Toby wrote, "I learned about teamwork and about different fossils, overall this trip was a giant learning experience and I'm happy I was given the opportunity to enjoy nature." Twenty-two percent of students reflected that their experience, or the experience of field paleontology, was a lot of hard work, while 13.5% shared that field paleontology took persistence. Under the Hard Work theme, Sapphire shared, "Fossils are much harder to find than it seems. You have to be very vigilant and know what things you need to keep an eye out for. You need to know the right areas to look and the right type of rocks." Amber wrote, "Fossils always seemed far away from me. I have 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." Ten percent of students shared that they had fun, including a simple lexical search for the word "fun".

Within the Beauty of Nature theme, 6.5% of the student group chose to reflect on the immense power and beauty of the wilderness. Edriss shared, "I didn't learn what true silence was until I came on the [field trip]." From a reflection on a birthday celebrated in the field, to deepening friendships, 5.9% of reflections discussed the importance of friends. 4.1% of reflections also specifically championed Stewardship; Marlene reflected, "This [trip] showed me that no matter what, we should always protect the land we 'borrow' like it's our home."

While exact demographic housing and prior outdoor experience data were not collected, the trip students live in a suburban boarding environment for much of the school year, and for some, this was their first camping experience. Exemplar reflections from the girls' longer responses showed that the process of writing responses to questions while in the field allowed students to reflect on their experiences more fully than the limited space on the survey instrument allowed, and with greater nuance than their post-survey Likert responses showed (Table 3). These written reflections capture reflections of meaningful post-treatment impact from the students themselves. The written comments unpack the hard work and challenge of the experience while conversely reflecting the many positive experiences of the field trip. For example, Eva shared, "I feel like this trip was more fun than I had anticiated (*sic*). Although I'm left with bumps and scratches and bruises, I feel special in that no other school will provide such an opportunity for its students."

Discussion

Does field paleontology impact student sense of stewardship? (Research question 1)

Hands-on, outdoor science experiences are impactful. They have the potential to inspire curiosity in learners, and can bring the educational experience outward to inspire societal change (Dewey, 1938). Student learning in field settings can have a lasting impact on higher order thinking skills (Emo et al., 2015), while transformative experiences, as proposed by Pugh (2011), can come about as students act on learned subject material by applying it to their everyday, lived experiences in a way that brings them personal meaning. Through learning a particular science concept, a student can develop a deeper sense of value for the world at large, a concept referred to as experiential value (Pugh, 2011).

The valuable, initial attitudinal aspects of science experiences should be recorded, and can be framed within human dimensions research in paleontology (Santucci et al., 2016) and other environmental or geological fields. Likewise, the associated long-term attitudinal changes in learners as a result of these experiences (Ormrod, 2011) cannot be analyzed if we fail to record their initial impact. The field of science stewardship at large will benefit from a stronger social science understanding of field experiences as a method of boosting conservation awareness in new generations of science learners. Paleontology provides a specific field experience that is aligned with the nascent interests of many young children, but field paleontology is an experience that relatively few have access to, and which is fraught with inequities. Assessing the benefits of field paleontology can help break down barriers and broadcast its importance, along with that of general geoscience education, in primary and secondary education.

Our findings demonstrate that, when given the opportunity to reflect on a field paleontology experience on public lands, students share thoughts on the beauty of nature, a sense of stewardship, and discuss public lands. These top three most frequent themes from the total student group underscored the unique experiences of interacting with natural areas and fossil resources, and the effort it takes to protect them. The shift in percentage responses reflecting the stewardship theme increased from 18.4% pretreatment to 29.4% post-treatment, the only theme that increased post-treatment. This indicates that the act of taking students out to have field experiences, discussing conservation, and inviting their reflections can boost the number of students actively considering ideals of stewardship compared to before the field trip.

Does field paleontology impact student sense of personal growth or outdoor enthusiasm? (Research question 2)

Previous research has shown that many students experience a decline in interest or motivation in science and technology as they progress through school (e.g., Potvin & Hasni, 2014). Field study has been explored as a way to augment this lack of interest and motivation, and can function as a modest science interest motivator (Levitt, 2016). We found that in their written responses, students reflected on how this field study experience introduced them to the hardships of fieldwork, and how to persevere and overcome those hardships, as well as how it impacted their sense of personal growth through friendship and persistence. There is a dearth of literature that explores the impact of field paleontology on high school students, and most programs focus on younger children (Gunckel, 1994; Harnik & Ross, 2004), educators, or college students (e.g., Yacobucci & Lockwood, 2012); additionally there is little research on how declining science interest or motivation can be alleviated in later grades. Our findings relate to the larger body of literature in that they provide a perspective on a subset of field science experiences and how these experiences impact students' sense of the beauty of nature, as well as their personal growth through hardship and social connections such as friendships, which may have long-lasting impact on the students themselves.

Convergence and divergence of data sets

Our quantitative data for the total survey group did not identify statistically significant changes pre- and post-treatment, and we emphasize the pilot nature of this survey instrument. Qualitative comments for the on-site responses provided the most insight beyond the survey instrument, where twenty-two percent of students reflected that paleontology was very hard work, and 13.5% shared comments reflecting persistence. These top two themes in the on-site female responses and the sense of appreciation are worth a pause to consider the balance between challenging outdoor experiences, and inspiring ones. The students were required to attend the trip, and future work on self-selected paleontology trip attendees from a variety of backgrounds and outdoor experience levels would make an interesting comparison.

On-site reflections also underscored positive aspects of the trip, such as the beauty of nature, learning, stewardship, and fun. At least one of the female students felt their school provided an unmatched experience. There was no significant shift in related questions that probed fossil appreciation and personal investment in science (question 11), or in our three paleontology motivation questions. Work by Stevenson et al. (2021) has demonstrated increased science knowledge and grades in groups of girls participating in outdoor science work; while we did not assess science knowledge, outdoor learning experiences like paleontology field trips may have multi-pronged benefits for boosting science learning and science attitudes. Future work would benefit from using open-ended questions which ask students to reflect on the uniqueness of their particular educational experience, and on the connection between their field experience and science enjoyment. Additional Likert scale attitudinal questions that assess these questions that can be analyzed for internal item consistency would likely also clarify these discrepancies.

Limitations

Ranked data and demographics

Student grades and test scores (ranked data) were not analyzed due to permissions from the school administration but are recommended when performing studies that incorporate student surveys, to provide a baseline of ranked data for participant comparison. The students attend a private, suburban non-parochial school that attracts high-achieving students, which limits the broad transferability of their responses to a wider high school audience. Student demographic data was very limited to the researchers; these data would have allowed additional analysis beyond binary sex designation. We emphasize the importance of recording demographics, including cultural background and gender identity, but recognize it can be challenging to acquire proper permissions for minor populations. Students who are less familiar with outdoor experiences such as camping or field paleontology, outside of the study context, are likely to respond differently than those with more extensive experience. We recommend collecting baseline data on prior experience camping, such as, "how many times have you camped or experienced an overnight outdoor trip?" along with data on whether camping or outdoor experiences elicit different feelings.

Survey wording and definitions

Students may not have had a thorough understanding or prior scaffolding on the definitions of public lands, "modifying the land", "managed" lands, stewardship, and conservation. 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 taught briefly about stewardship prior to taking the surveys, the phrase "science stewardship" nevertheless caused some confusion as evidenced by exit interviews and informal discussion. 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. In addition, question 6 would benefit from a specific example of what "modifying the land to suit" human needs would look like.

Methodological notes

This study was undertaken as part of a Master of Science action research capstone project by one of the authors who was also the high school teacher of a portion of the girls' class on this field trip. All written reflections were analyzed as anonymized data, but some written reflections may have been somewhat identifiable through unavoidable knowledge of student writing patterns or the content of the written responses. Interpretation of student written reflections is also biased by the lead author's past experiences in field paleontology, both positive and negative, as well as a desire for students to have a good experience as their lead educator. The study was also centered within Eurocentric definitions of stewardship rather than a holistic or integrative Indigenous stewardship definition; however as non-Indigenous authors, we would defer to Indigenous cultural and scientific expertise rather than attempt to reproduce Indigenous stewardship values and education ourselves, in isolation.

Student mood and length of treatment

There is an aspect of survey taker bias in any survey; some students may have taken these surveys seriously, and others may not have. The consistency in their pre- and post-treatment total group responses, for the most part, brings up a last salient point in study design: longer treatment, with more consistent and full immersion in paleontological (or, relevant field science) techniques, is recommended. Researchers should work with teachers and students if possible to ensure the definitions of science stewardship, managed lands, and fossils are clear and presented more than once to student respondents.

A note on limitations

We conducted a mixed methods study underpinned by experiential ontology, social constructivism, and qualitative sensibilities. While we describe limitations here, we also recognize that limitations of generalizability are to be expected in a qualitative framework. It is not expected that the same outcome can be replicated as we report here, even in similar settings. In a post-positive sense, we are emphasizing that what our student respondents *say* about their affects and attitudes is more salient, and that the discrepancies between the quantitative and qualitative findings highlights the usefulness of qualitative data rather than negating them in favor of positivist fixed response agreement.

Conclusions and future work

We surveyed high school students before and after a field paleontology experience using the MAP-PL, a pilot-tested survey instrument which provided participants opportunities for detailed written reflections. If these field paleontology experiences are positive for high school learners, students may come to appreciate the importance of science stewardship and the caretaking of natural resources on public lands, especially fossil resources, and may be empowered to champion natural resource conservation throughout their lives. Outdoor experiences bring a set of new challenges to which students may respond to in a variety of ways, from expression of hard work, to a sense of beauty of nature and camaraderie. Depending on fixed-response survey wording and respondent opinions, there may be very little to no quantitative change. Selecting a method of thematic analysis and theoretical underpinnings to craft themes from written responses will allow us to record reflections and narratives of these outdoor experiences, as well as changes in a sense of stewardship and personal growth, and an increased engagement with the concept of stewardship, as a result of field paleontology.

We strongly recommend utilizing social science research methodologies such these, in the human dimensions framework, to better understand student responses to field paleontology experiences. The human dimensions of paleontological experiences, including how we relate to fossils and fieldwork, are key components of our scientific fields that deserve attention. We advocate for an understanding of why paleontology matters, and how we bring our whole and authentic selves to paleontology work. Additional frameworks for future work include place-based education, field science learning, and experiential learning assessment. Outdoor field science experiences have the potential to benefit student personal growth and science stewardship in unexpected ways longitudinally, the impact of which is lost if we don't record their baseline reflections.

Further studies on the impact of paleontology field experiences on K-12 learners globally, with self-identified gender diverse audiences, through a range of cultural and socioeconomic lenses, and in collaboration with a variety of underrepresented groups in STEM, will allow us to assess the benefits of field science on learner personal growth and conservation attitudes, and help scientists and educators take actionable steps toward not only conservation of public lands, but toward a more inclusive and equitable scientific community at large. The geoscience community at large is an unsafe and systemically harmful space for historically excluded minorities, with limited outdoor experiences for many minoritized groups (Baber et al., 2010; Levine et al., 2007; Stokes et al., 2015). Much more work needs to be done to champion fossil conservation and to create and maintain a safe, welcoming, and productive environment for STEM learners of all ages, and human dimensions research within the field of paleontology is an excellent vehicle for collaboratively building these efforts.

The more we can share social science research on the impact of paleontology education and field experiences on students at large, the richer our tapestry of understanding the importance of paleontology and public lands will be. Because one of the study authors conducted this work while employed as a high school teacher, we emphatically recognize the limited time educators may have to conduct such analyses. We encourage teachers and education researchers to utilize these results to inform their own classroom and field discussions on the potential impact of paleontology on public lands. It is our hope that this study will spur future research in the impact of field paleontology on science stewardship, personal growth, and science accessibility, especially on the public lands that we share, conserve, and revere.

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References

Alexander, J. M., Johnson, K. E., Leibham, M. E., & Kelley, K. (2008). The development of conceptual interests in young children. *Cognitive Development*, *23*(2), 324–334.

Apple, J., Lemus, J., & Semken, S. (2014). Teaching geoscience in the context of culture and place. *Journal of Geoscience Education*, *62*(1), 1–4. https://doi.org/10.5408/1089-9995-62.1.1

Atchison, C. L., & Libarkin, J. C. (2016). Professionally held perceptions about the accessibility of the geosciences. *Geosphere*, *12*(4), 1154–1165.

Atchison, C. L., Marshall, A. M., & Collins, T. D. (2019). A multiple case study of inclusive learning communities enabling active participation in geoscience field courses for students with physical disabilities. *Journal of Geoscience Education*, *67*(4), 472–486.

Baber, L. D., Pifer, M. J., Colbeck, C., & Furman, T. (2010). Increasing diversity in the geosciences: Recruitment programs and student self-efficacy. *Journal of Geoscience Education*, *58*(1), 32–42.

Bauer, M., Hoagland, P., Leschine, T. M., Blount, B. G., Pomeroy, C. M., Lampl, L. L., Scherer, C. W., Ayres, D. L., Tester, P. A., Sengco, M. R., Sellner, K. G., & Schumacker, J. (2010). The importance of human dimensions research in managing harmful algal blooms. *Frontiers in Ecology and the Environment*, *8*, 75–83. https://doi.org/10.1890/070181

Beerbower, J. R. (1963). New perspectives in paleontology. *Journal of Geological Education*, *11*(3), 95–97. https://doi.org/10.5408/0022-1368-11.3.95

Behrendt, M., & Franklin, T. (2014). A review of research on school field trips and their value in education. *International Journal of Environmental and Science Education*, *9*(3), 235–245.

Bennett, N. J., Roth, R., Klain, S. C., Chan, K. M. A., Clark, D. A., Cullman, G., Epstein, G., Nelson, M. P., Stedman, R., Teel, T. L., Thomas, R. E. W., Wyborn, C., Curran, D., Greenberg, A., Sandlos, J., & Veríssimo, D. (2017). Mainstreaming the social sciences in conservation. *Conservation Biology : The Journal of the Society for Conservation Biology*, *31*(1), 56–66. https://doi.org/10.1111/cobi.12788

Benton, R. (2003). The big pig dig: Integrating paleontological research and visitor education at Badlands National Park, South Dakota. *Journal of Geoscience Education*, *51*(3), 313–316. https://doi.org/10.5408/1089-9995-51.3.313

Biorender.com. (2022). Figure 1 adapted from "water cycle template". *BioRender.com*. https://app.biorender.com/biorender-templates

Bizimana, D., & Orodho, J. A. (2014). Teaching and learning resource availability and teachers' effective classroom management and content delivery in secondary schools in Huye District, Rwanda. *Journal of Education and Practice*, *5*(9), 111–122. https://ssrn.com/abstract=3178220

Bogner, F. X. (1998). The influence of short-term outdoor ecology education on long-term variables of environmental perspective. *The Journal of Environmental Education*, *29*(4), 17–29.

Bogner, F. X., & Wilhelm, M. (1996). Environmental perspectives of pupils: Development of an attitude and behaviour scale. *The Environmentalist*, *16*, 95–110.

Bogner, F. X., & Wiseman, M. (2002). Environmental perception: Factor profiles of extreme groups. *European Psychologist*, *7*(3), 225–237. https://doi.org/10.1027/1016-9040.7.3.225

Bogner, F. X., & Wiseman, M. (2004). Outdoor ecology education and pupils' environmental perception in preservation and utilization. *Science Education International*, *15*(1), 27–48.

Boyd, E. A., & Lazar, K. B. (2022). "It's not just a picture": The effects of an international two-week field experience on student geoscience involvement and persistence. *Journal of Geoscience Education*, *70*(3), 399–411. https://doi.org/10.1080/10899995.2022.2036045

Boyle, A., Maguire, S., Martin, A., Milsom, C., Nash, R., Rawlinson, S., Turner, A., Wurthmann, S., & Conchie, S. (2007). Fieldwork is good: The student perception and the affective domain. *Journal of Geography in Higher Education*, *31*(2), 299–317.

Bryson, E. (1994). *Will a project approach to learning provide children opportunities to do purposeful reading and writing, as well as provide opportunities for authentic learning in other curriculum areas?* Education Resources Information Center, U.S. Department of Education. https://files.eric.ed.gov/fulltext/ED392513.pdf

Buccheri, G., Gürber, N. A., & Brühwiler, C. (2011). The impact of gender on interest in science topics and the choice of scientific and technical vocations. *International Journal of Science Education*, *33*(1), 159–178.

Butler, D. K., Esker, D. A., Juntunen, K. L., & Lawver, D. R. (2020). An analysis of fossil identification guides to improve data reporting in citizen science programs. *Palaeontologia Electronica*, *23*(1), a19. https://doi.org/10.26879/901palaeo-electronica.org/content/2020/3010-analysis-of-fossil-id-guides

Carabajal, I. G., & Atchison, C. L. (2020). An investigation of accessible and inclusive instructional field practices in US geoscience departments. *Advances in Geosciences*, *53*, 53–63.

Carabajal, I. G., Marshall, A. M., & Atchison, C. L. (2017). A synthesis of instructional strategies in geoscience education literature that address barriers to inclusion for students with disabilities. *Journal of Geoscience Education*, *65*(4), 531–541.

Caulfield, J., & Woods, T. (2013). Experiential learning: Exploring its long-term impact on socially responsible behavior. *Journal of the Scholarship of Teaching and Learning*, *13*(2), 31–48.

Cisneros, J. C., Ghilardi, A. M., Raja, N. B., & Stewens, P. P. (2022). The moral and legal imperative to return illegally exported fossils. *Nature Ecology & Evolution*, *6*(1), 2–3. https://doi.org/10.1038/s41559-021-01588-9

Clapham, M. (2018). *Flipping the paleontology classroom: Benefits, challenges, and strategies (elements of paleontology)*. Cambridge University Press. https://doi.org/10.1017/9781108681421

Clarke, V., & Braun, V. (2013). *Successful qualitative research*. SAGE Publications.

Clary, R. M., & Wandersee, J. H. (2006). A writing template for probing students' geological sense of place. *Science Education Review*, *5*(2), 51–59.

Clary, R. M., & Wandersee, J. H. (2008). Earth science teachers' perceptions of an autonomous fieldwork assignment in a nationwide online paleontology course. *Journal of Geoscience Education*, *56*(2), 149–155.

Cohen, P. A., Lockwood, R., & Peters, S. (2018). *Integrating Macrostrat and Rockd into undergraduate earth science teaching*. Cambridge University Press.

Creswell, J. W., & Creswell, J. D. (2017). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.

Creswell, J. W., & Plano Clark, V. L. (2011). *Designing and conducting mixed methods research* (2nd ed.). Sage Publications.

Creswell, J. W., & Poth, C. N. (2016). *Qualitative inquiry and research design: Choosing among five approaches*. Sage Publications.

Demir, S. B., & Pismek, N. (2018). A convergent parallel mixed-methods study of controversial issues in social studies classes: A clash of ideologies. *Educational Sciences: Theory & Practice*, *18*, 119–149. https://doi.org/10.12738/estp.2018.1.0298

Dewey, J. (1938). *Experience and education*. Macmillan.

Domack, C. W. (2000). A service-learning component in a paleontology course as a model for community outreach by geology students. *Journal of Geoscience Education*, *48*(5), 658–661. https://doi.org/10.5408/1089-9995-48.5.658

Domínguez, L., & Luoma, C. (2020). Decolonising conservation policy: How colonial land and conservation ideologies persist and perpetuate indigenous injustices at the expense of the environment. *Land*, *9*(3), 65. https://doi.org/10.3390/land9030065

Dopico, E., & Garcia-Vazquez, E. (2011). Leaving the classroom: A didactic framework for education in environmental sciences. *Cultural Studies of Science Education*, *6*, 311–326. https://doi.org/10.1007/s11422-010-9271-9

Driscoll, E. A. (2004). *Fostering wonder and curiosity: Immersion field trips in the Michigan 4-H children's garden*. Michigan State University.

Driscoll, E. A., & Lownds, N. K. (2007). The garden wonder wall: Fostering wonder and curiosity on multi-day garden field trips. *Applied Environmental Education and Communication*, *6*(1), 105–112.

Emo, K., Emo, W., Kimn, J., & Gent, S. (2015). The complex experience of learning to do research. *Journal of Experiential Education*, *38*(4), 339–353. https://doi.org/10.1177/1053825915578913

Ferraro, P. J., & Pressey, R. L. (2015). Measuring the difference made by conservation initiatives: Protected areas and their environmental and social impacts. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *370*, 20140270. https://doi.org/10.1098/rstb.2014.0270

Galton, M. (2009). Moving to secondary school: Initial encounters and their effects. *Perspectives on Education*, *2*, 5–21.

Gardner, P. L. (1975). Attitudes to science: A review. *Studies in Science Education*, *2*(1), 1–41. https://doi.org/10.1080/03057267508559818

George, R. (2000). Measuring change in students' attitudes toward science over time: An application of latent variable growth modeling. *Journal of Science Education and Technology*, *9*(3), 213–225.

George, R., & Kaplan, D. (1998). A structural model of parent and teacher influences on science attitudes of eighth graders: Evidence from NELS: 88. *Science Education*, *82*(1), 93–109.

Glaser, R. (1984). Education and thinking: The role of knowledge. *American Psychologist*, *39*(2), 93.

Glasson, G. (2011). Global environmental crisis: Is there a connection with place-based, ecosociocultural education in rural Spain? *Cultural Studies of Science Education*, *6*, 327–335. https://doi.org/10.1007/s11422-011-9321-y

Gobbo, C., & Chi, M. (1986). How knowledge is structured and used by expert and novice children. *Cognitive Development*, *1*(3), 221–237.

Grant, C. A., MacFadden, B. J., Antonenko, P., & Perez, V. J. (2016). 3-D Fossils for k–12 education: A case example using the giant extinct Sharkcarcharocles Megalodon. *The Paleontological Society Papers*, *22*, 197–209.

Gunckel, K. /L. (1994). Research-based geology and paleontology education for elementary- and secondary-school students. *Journal of Geological Education*, *42*(5), 420–423. https://doi.org/10.5408/0022-1368-42.5.420

Harnik, P. G., & Ross, R. M. (2003). Assessing data accuracy when involving students in authentic paleontological research. *Journal of Geoscience Education*, *51*(1), 76–84. https://doi.org/10.5408/1089-9995-51.1.76

Harnik, P. G., & Ross, R. M. (2004). Models of inquiry-based science outreach to urban schools. *Journal of Geoscience Education*, *52*(5), 420–428. https://doi.org/10.5408/1089-9995-52.5.420

Heck, K. E., Carlos, R. M., Barnett, C. C., & Smith, M. H. (2012). 4-H participation and science interest in youth. *Journal of Extension*, *50*(2), 2FEA5.

Heck, N., Stedman, R. C., & Gaden, M. (2015). The integration of social science information into Great Lakes fishery management: Opportunities and challenges. *Fisheries Research*, *167*, 30–37.

Hockett, K. S. (2008). *Influence of interpretation on visitors' knowledge gain and respect for fossil resources in a national monument* [Doctoral dissertation, Virginia Tech].

Jackson, M. C., Galvez, G., Landa, I., Buonora, P., & Thoman, D. B. (2016). Science that matters: The importance of a cultural connection in underrepresented students' science pursuit. *CBE Life Sciences Education*, *15*(3), ar42. https://doi.org/10.1187/cbe.16-01-0067

Jolley, A., Kennedy, B. M., Brogt, E., Hampton, S. J., & Fraser, L. (2018). Are we there yet? Sense of place and the student experience on roadside and situated geology field trips. *Geosphere*, *14*(2), 651–667.

Kastens, K. A., Manduca, C. A., Cervato, C., Frodeman, R., Goodwin, C., Liben, L. S., Mogk, D. W., Spangler, T. C., Stillings, N. A., & Titus, S. (2009). How geoscientists think and learn. *Eos Trans. AGU*, *90*(31), 265–266. https://doi.org/10.1029/2009EO310001

Katz, L. G., Chard, S. C., & Kogan, Y. (2014). *Engaging children's minds: The project approach.* (3rd ed.). Praeger.

Krapp, A., & Prenzel, M. (2011). Research on interest in science: Theories, methods, and findings. *International Journal of Science Education*, *33*(1), 27–50.

Leonard, K., Aldern, J. D., Christianson, A., Ranco, D., Thornbrugh, C., Loring, P. A., Coughlan, M. R., Jones, P., Mancini, J., May, D., & Moola, F. (2020). Indigenous conservation practices are not a monolith: Western cultural biases and a lack of engagement with Indigenous experts undermine studies of land stewardship. *ecoevorxiv.org*. https://doi.org/10.32942/osf.io/jmvqy

Levine, R., González, R., Cole, S., Fuhrman, M., & Le Floch, K. C. (2007). The geoscience pipeline: A conceptual framework. *Journal of Geoscience Education*, *55*(6), 458–468.

Levitt, J. (2016). *Field research and motivation: Experiential learning in the parker river estuary* [Unpublished Master's Professional Paper]. Montana State University. https://scholarworks.montana.edu/xmlui/handle/1/10069

Lockwood, R., Cohen, P., Uhen, M., & Ryker, K. (2018). *Utilizing the paleobiology database to provide educational opportunities for undergraduates (elements of paleontology).* Cambridge University Press. https://doi.org/10.1017/9781108681667

Lofgren, D., Liu, J., & Williams, E. B. (2019). *Moment of time: the life of Raymond Alf and the history of the peccary society*. Independent Publication.

Markowitz, D. G. (2004). Evaluation of the long-term impact of a university high school summer science program on students' interest and perceived abilities in science. *Journal of Science Education and Technology*, *13*(3), 395–407.

Marlow, M. P., Wright, J. L., & Hand, J. D. (2003). A paleontology network inquiry consortium: Impact on teacher practice. *Journal of Geoscience Education*, *51*(3), 317–321. https://doi.org/10.5408/Marlow_v51n3

Mayer, F. S., & Frantz, C. M. (2004). The connectedness to nature scale: A measure of individuals' feeling in community with nature. *Journal of Environmental Psychology*, *24*(4), 503–515.

Mendelson, C. V. (1991). Constructional morphology and exaptation as perspectives for a term project in paleontology. *Journal of Geological Education*, *39*(3), 213–216. https://doi.org/10.5408/0022-1368-39.3.213

Merenlender, A. M., Crall, A. W., Drill, S., Prysby, M., & Ballard, H. (2016). Evaluating environmental education, citizen science, and stewardship through naturalist programs. *Conservation Biology : The Journal of the Society for Conservation Biology*, *30*(6), 1255–1265. https://doi.org/10.1111/cobi.12737

Mistler-Jackson, M., & Songer, N. B. (2000). Student motivation and Internet technology: Are students empowered to learn science? *Journal of Research in Science Teaching*, *37*(5), 459–479.

Monarrez, P. M., Zimmt, J. B., Clement, A. M., Gearty, W., Jacisin, J. J., Jenkins, K. M., Kusnerik, K. M., Poust, A. W., Robson, S. V., Sclafani, J. A., & Stilson, K. T. (2021). Our past creates our present: A brief overview of racism and colonialism in Western paleontology. *Paleobiology*, *48*(2), 173–185. https://doi.org/10.1017/pab.2021.28

Montgomery, H., & Donaldson, K. (2014). Using problem-based learning to deliver a more authentic experience in paleontology. *Journal of Geoscience Education*, *62*(4), 714–724. https://doi.org/10.5408/13-085.1

Moran, S., McLaughlin, C., MacFadden, B., Jacobbe, E., & Poole, M. (2015). Fossil explorers: Third-grade students examine ancient organisms in modern times. *Science and Children*, *53*(4), 62–67.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. National Academies Press.

Núñez, A. M., Rivera, J., & Hallmark, T. (2020). Applying an intersectionality lens to expand equity in the geosciences. *Journal of Geoscience Education*, *68*(2), 97–114.

O'Connor, C., & Joffe, H. (2020). Intercoder reliability in qualitative research: Debates and practical guidelines. *International Journal of Qualitative Methods*, *19*. https://doi.org/10.1177/1609406919899220

Ormrod, J. E. (2011). *Educational psychology: Developing learners* (7th ed.). Pearson.

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education*, *25*(9), 1049–1079.

Pestana, H. R. (1977). Paleontology for non-science majors: An introductory course emphasizing the uses of fossils. *Journal of Geological Education*, *25*(2), 50–52. https://doi.org/10.5408/0022-1368-25.2.50

Potvin, P., & Hasni, A. (2014). Analysis of the decline in interest towards school science and technology from grades 5 through 11. *Journal of Science Education and Technology*, *23*(6), 784–802.

Pugh, K. J. (2011). Transformative experience: An integrative construct in the spirit of Deweyan pragmatism. *Educational Psychologist*, *46*(2), 107–121. https://doi.org/10.1080/00461520.2011.558817

R Studio. (2020). RStudio: Integrated development for R. *RStudio, PBC*. http://www.rstudio.com/

Rahman, I. A., Adcock, K., & Garwood, R. J. (2012). Virtual fossils: A new resource for science communication in paleontology. *Evolution: Education and Outreach*, *5*(4), 635–641.

Raja, N. B., Dunne, E. M., Matiwane, A., Khan, T. M., Nätscher, P. S., Ghilardi, A. M., & Chattopadhyay, D. (2022). Colonial history and global economics distort our understanding of deep-time biodiversity. *Nature Ecology & Evolution*, *6*, 145–154. https://doi.org/10.1038/s41559-021-01608-8

Rischbieter, M. O., Ryan, J. M., & Carpenter, J. R. (1993). Use of microethnographic strategies to analyze some affective aspects of learning-cycle-based minicourses in paleontology for teachers. *Journal of Geological Education*, *41*(3), 208–218. https://doi.org/10.5408/0022-1368-41.3.208

Saldaña, J. (2015). *The coding manual for qualitative researchers*. Sage.

Sandelowski, M., & Barroso, J. (2007). *Handbook for synthesizing qualitative research*. Springer.

Santucci, V., Newman, P., & Taff, D. (2016). Toward a conceptual framework for assessing the human dimensions of paleontological resources. *New Mexico Museum of Natural History and Science Bulletin*, *74*, 239–248.

Schuster, R., Germain, R. R., Bennett, J. R., Reo, N. J., & Arcese, P. (2019). Vertebrate biodiversity on indigenous-managed lands in Australia, Brazil, and Canada equals that in protected areas. *Environmental Science & Policy*, *101*, 1–6.

Scibeci, R. A., & Riley, J. P. (1986). Influence of students' background and perceptions on science attitudes and achievements. *Journal of Research in Science Teaching*, *23*(3), 177–187.

Semken, S., Ward, E. G., Moosavi, S., & Chinn, P. W. (2017). Place-based education in geoscience: Theory, research, practice, and assessment. *Journal of Geoscience Education*, *65*(4), 542–562.

Shahali, E. H. M., Halim, L., Rasul, M. S., Osman, K., & Zulkifeli, M. A. (2016). STEM learning through engineering design: Impact on middle secondary students' interest towards STEM. *EURASIA Journal of Mathematics, Science and Technology Education*, *13*(5), 1189–1211.

Sheffield, S. L., & Bauer, J. E. (2017). Darwin Day in deep time: Promoting evolutionary science through paleontology. *Evolution: Education and Outreach*, *10*, art. 10. https://doi.org/10.1186/s12052-017-0073-3

Stahl, N. A., & King, J. R. (2020). Expanding approaches for research: Understanding and using trustworthiness in qualitative research. *Journal of Developmental Education*, *44*(1), 26–28.

Stake, J. E., & Mares, K. R. (2001). Science enrichment programs for gifted high school girls and boys: Predictors of program impact on science confidence and motivation. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *38*(10), 1065–1088.

Stevenson, K. T., Szczytko, R. E., Carrier, S. J., & Peterson, M. N. (2021). How outdoor science education can help girls stay engaged with science. *International Journal of Science Education*, *43*(7), 1090–1111.

Stokes, A., Feig, A. D., Atchison, C. L., & Gilley, B. (2019). Making geoscience fieldwork inclusive and accessible for students with disabilities. *Geosphere*, *15*(6), 1809–1825.

Stokes, P. J., Levine, R., & Flessa, K. W. (2015). Choosing the geoscience major: Important factors, race/ethnicity, and gender. *Journal of Geoscience Education*, *63*(3), 250–263.

Talton, E. L., & Simpson, R. D. (1986). Relationships of attitudes toward self, family, and school with attitude toward science among adolescents. *Science Education*, *70*(4), 365–374.

Tapanila, L. (2007). FossilPlot, an Excel-based computer application for teaching stratigraphic paleontology using the Sepkoski compendium of fossil marine genera. *Journal of Geoscience Education*, *55*(2), 133–137. https://doi.org/10.5408/1089-9995-55.2.133

Thompson, K. L., Lantz, T., & Ban, N. (2020). A review of Indigenous knowledge and participation in environmental monitoring. *Ecology and Society*, *25*(2), 10. https://doi.org/10.5751/ES-11503-250210

Ting, K. L., & Siew, N. M. (2014). Effects of outdoor school ground lessons on students' science process skills and scientific curiosity. *Journal of Education and Learning*, *3*(4), 96–107. https://doi.org/10.5539/jel.v3n4p96

Toomey, A. H., & Domroese, M. C. (2013). Can citizen science lead to positive conservation attitudes and behaviors? *Human Ecology Review*, 50–62.

Tran, T. C., Ban, N. C., & Bhattacharyya, J. (2020). A review of successes, challenges, and lessons from Indigenous protected and conserved areas. *Biological Conservation*, *241*, 108271. https://doi.org/10.1016/j.biocon.2019.108271

U.S. Department of Education. (2010). *Classification of instructional programs (CIP)*. National Center for Educational Statistics. https://nces.ed.gov/ipeds/cipcode/CIPDetail.aspx?y=55&cipid=89204

Vadala, C. E., Bixler, R. D., & James, J. J. (2007). Childhood play and environmental interests: Panacea or snake oil? *The Journal of Environmental Education*, *39*(1), 3–18. https://doi.org/10.3200/JOEE.39.1.3-18

van der Hoeven Kraft, K. J., Srogi, L., Husman, J., Semken, S., & Fuhrman, M. (2011). Engaging students to learn through the affective domain: A new framework for teaching in the geosciences. *Journal of Geoscience Education*, *59*(2), 71–84. https://doi.org/10.5408/1.3543934a

Wals, A. E., Brody, M., Dillon, J., & Stevenson, R. B. (2014). Convergence between science and environmental education. *Science (New York, N.Y.)*, *344*(6184), 583–584. https://doi.org/10.1126/science.1250515

Ward, C. W., & Roggenbuck, J. (2003). Understanding park visitors' response to interventions to reduce petrified wood theft. *Journal of Interpretation Research*, *8*(1), 67–82. https://doi.org/10.1177/109258720300800106

Whitburn, J., Linklater, W., & Abrahamse, W. (2020). Meta-analysis of human connection to nature and proenvironmental behavior. *Conservation Biology : The Journal of the Society for Conservation Biology*, *34*(1), 180–193. https://doi.org/10.1111/cobi.13381

Widner, C. J., & Roggenbuck, J. (2000). Reducing theft of petrified wood at Petrified Forest National Park. *Journal of Interpretation Research*, *5*(1), 1–18. https://doi.org/10.1177/109258720000500101

Worrell, R., & Appleby, M. C. (2000). Stewardship of natural resources: Definition, ethical and practical aspects. *Journal of Agricultural and Environmental Ethics*, *12*(3), 263–277. https://doi.org/10.1023/A:1009534214698

Yacobucci, M. M. & Lockwood, R. (Eds.). (2012). Teaching paleontology in the 21st century. In *Geological Society of America abstracts with program* (Vol. 12). The Paleontological Society Special Publication.

Yilmaz-Tüzün, Ö., & Topçu, M. S. (2009). Elementary students' metacognition and epistemological beliefs considering science achievement, gender and socioeconomic status. *Elementary Education Online*, *8*(3), 676–693.

Zidny, R., Sjöström, J., & Eilks, I. (2020). A multi-perspective reflection on how indigenous knowledge and related ideas can improve science education for sustainability. *Science & Education*, *29*(1), 145–185. https://doi.org/10.1007/s11191-019-00100-x

Ziegler, M. J., Perez, V. J., Pirlo, J., Narducci, R. E., Moran, S. M., Selba, M. C., Hastings, A. K., Vargas-Vergara, C., Antonenko, P. D., & MacFadden, B. J. (2020). Applications of 3D paleontological data at the Florida Museum of Natural History. *Frontiers in Earth Science*, 570.