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# THE ORGANIZATION OF LEARNING IN GEOSCIENCE FIELDWORK AND IMPLICATIONS FOR INCLUSION

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*Geoscience is one of the least diverse STEM fields in terms of gender, race, and disability. Geoscience outdoor field activities, known as fieldwork, offer significant opportunities for socialization into the discipline, but they can also pose barriers to participation for scholars from different backgrounds. This multiple-case ethnographic study examined the organization of learning in geoscience fieldwork with implications for inclusion and exclusion of diverse learners. The research involved 275 hours of observations and 32 interviews of participants at two separate undergraduate and graduate fieldwork courses in the western United States. The results indicate that conducting fieldwork affords significant opportunities for cognitive growth by encouraging scholars to grapple with complex problems that they are unlikely to encounter in a classroom or lab. Yet, the physical challenges of fieldwork also present significant barriers to equivalent participation in collecting data and group work, particularly for students with different physical abilities. The findings also indicate that, consistent with sociocultural perspectives on learning, managing social interactions constitutes a central part of fieldwork in group instruction. Furthermore, the quality of social interactions can vary according to different abilities and identities like disability and gender, which can affect the potential for learning and cognitive growth in fieldwork among students from different backgrounds. Based on these findings, we conclude with recommendations to design future research and practice geared toward inclusivity in geoscience fieldwork and equity in geoscience.*

**KEY WORDS:** *equity, science, STEM, Earth Science, diversity, ethnography, disability, gender, higher education, organizational culture*

## 1. INTRODUCTION

Geoscience involves the study of the earth's surface, interior, atmosphere, oceans and other bodies of water, ice formations, and soils (American Geosciences Institute [AGI], n.d.). It is one of the least diverse STEM fields with respect to racial/ethnic and gender representation. The current share of women bachelor's degree recipients is 40% (Wilson, 2018), which lags behind the 55% share of women across STEM (National Center for Science and Engineering Statistics [NCSES], 2017). In 2017, people with disabilities represented just 9% of workers in the geosciences, less than their 11% share of undergraduates, and a 12.6% share of the U.S. population (NCSES, 2017). During the past 40 years, 85% of PhD recipients in the field have come from White, non-Hispanic backgrounds, compared with just 7% who identify as African American, Hispanic/Latino, and/or Native American (Bernard and Cooperdock, 2018).

Against this demographic backdrop, field-based geoscience courses have the potential to heighten the engagement of students from historically underserved groups (e.g., Hammersley et al., 2012; Levine et al., 2007; Miller et al., 2007; Serpa et al., 2007; Williams and Semken, 2011; Wolfe and Riggs, 2017). Fieldwork conducted in natural settings, where students apply lab- and classroom-based knowledge to understand how natural landscapes have evolved over millions of years, constitutes a central component of geoscience education and a key site of socialization in the discipline (Goodwin, 2018; Mogk and Goodwin, 2012; Streule and Craig, 2016). Learning in outdoor settings enables students to develop specific professional sensibilities and skills to make sense of these landscapes (Feig, 2010; Goodwin, 2018; Kastens et al., 2009; Mogk and Goodwin, 2012; Ryker et al., 2018; Streule and Craig, 2016). Likewise, field-based instruction can inspire learners to commit to and pursue geoscience through experiences like supportive teamwork or enjoyment of outdoor activities (Levine et al., 2007; Stokes and Boyle, 2009).

However, a sizeable body of work has found fieldwork to be a site of significant exclusion for historically underserved groups. For example, conventional geoscience fieldwork places a premium on being physically able and fit (e.g., Carabajal et al., 2017; Mogk and Goodwin, 2012; Núñez et al., 2020; Posselt, 2020), which limits students with disabilities from full participation (Atchison and Libarkin, 2016; Atchison et al., 2019; Feig et al., 2019; Gilley et al., 2015). Because they may have less exposure to outdoor activities at an earlier age, people of color and those from low-income backgrounds can find participation in fieldwork more challenging (O'Connell and Holmes, 2011; Stokes et al., 2015). Gendered bullying and sexual harassment in the field are not uncommon and have adverse consequences for women's participation in particular (Clancy et al., 2017; Mattheis et al., 2019; Nelson et al., 2017). Finally, expenses required for fieldwork (e.g., for hiking gear, tools, accommodations, and travel) can be prohibitive for low-income students (Ham and Flood, 2009; Kelleher, 2017).

Despite these barriers, little research has examined how the organization of learning in fieldwork can contribute to patterns of inclusion or exclusion (Mattheis et al., 2019; Núñez et al., 2020; Streule and Craig, 2016), although there have been some exceptions (Atchison et al., 2019; Feig et al., 2019). Recently, *A Community Framework for Geoscience Education Research* (St. John, 2018), organized by the National Association of Geoscience Teachers, called for more research on how social identities and learning contexts shape participation in geoscience (Riggs et al., 2018). Such an emphasis requires more attention to the lived experiences of fieldwork, which qualitative methods, particularly ethnographic methods, are especially well positioned to explain (Atchison et al., 2019; Feig, 2010; Feig et al., 2019; Goodwin, 2018; Mattheis et al., 2019; Mogk and Goodwin, 2012; Riggs et al., 2018; Streule and Craig, 2016).

This multiple ethnographic case study (Eisenhardt and Graebner, 2007) is based on extended engagement in two university field-based courses. Our purpose was to examine the organization of learning in geoscience fieldwork, with attention to implications for diverse learners. The paper is part of a larger project designed to identify exclusionary dynamics of field-based geoscience and equip leaders with knowledge and skills that enable more inclusive design of field experiences (Núñez et al., 2020; Posselt et al., 2019). The research presented here addresses two questions: How do undergraduate and graduate students experience the organization of learning in fieldwork? What implications does the organization of learning in fieldwork have for diverse students' inclusion or exclusion? Following Streule and Craig's (2016) call to examine sociocultural dynamics of learning in fieldwork—and guided by Hurtado et al.'s (2012) multicontextual model of diverse learning environments—we focused on students' experiences with course pedagogy and curriculum, their social interactions with one another and with their instructors, and the associated implications for inclusion and exclusion in fieldwork.

## 2. LITERATURE REVIEW

Fieldwork is a key site for socialization into geoscience (e.g., Feig, 2010; Goodwin, 2018; Mogk and Goodwin, 2012; Streule and Craig, 2016). Field-based geoscience courses often involve group work and extended trips away from campus to geologically significant landscapes, where students and instructors together practice skills, dispositions, and habits of mind that are much harder, if not impossible, to develop in the classroom or lab (Feig, 2010; Goodwin, 2018; Kastens and Manduca, 2012; Kortz et al., 2020; Mogk and Goodwin, 2012; Streule and Craig, 2016). Streule and Craig (2016) compared fieldwork to residency for medical students, while Goodwin (2018) characterized it as experts and apprentices "touching the world together" (p. 348). Both illustrate fieldwork's uniquely communal character (Goodwin, 2018; Kastens and Manduca, 2012; Kortz et al., 2020; Mogk and Goodwin, 2012; Posselt, 2020; Streule and Craig, 2016).

Fieldwork is prevalent in geoscience curricula, with one study finding that the majority of geoscience graduates report participating in at least one field-based course (Wilson, 2016). It is often a capstone experience in a degree program, as fieldwork ideally enhances multiple domains of growth: (a) cognitive growth (e.g., integrating prior course material to learn new skills); (b) metacognitive growth (e.g., learning how to organize thinking and work patterns to reach learning goals); (c) affective growth (e.g., strengthening a commitment to pursue geoscience); (d) exposure to nature and full engagement of the senses to understand the composition and history of the earth's landscapes; and (e) acquiring critical skills in the discipline itself, including identification of rock types, mapping, and taking observations and measurements in the outdoors (Mogk and Goodwin, 2012). Scholars in the field must relate theoretical or incomplete datasets with real-world scientific processes. This demands data acquisition and problem-solving skills, a willingness and ability to realize and challenge their own physical and intellectual limits, and development of social and teamwork skills (Feig, 2010; Kastens and Manduca, 2012; Mogk and Goodwin, 2012; Petcovic et al., 2014; Streule and Craig, 2016; Stokes and Boyle, 2009).

## 2.1 Barriers to Equitable Participation in Fieldwork

Below we review extant research on barriers to participation in geoscience fieldwork, with a focus on identity categories of race, disability, and gender. Although class and LGBTQ+* status likely also affect geoscience fieldwork experiences, there is relatively little literature about them specifically (Mattheis et al., 2019); disability and gender as factors in fieldwork are most predominant in the literature at this time. Given concerns about limitations in racial/ethnic representation (Bernard and Cooperdock, 2018), we begin with the role of race and ethnicity in fieldwork and continue with a focus on disability and gender.

Research points to patterns through which minoritized groups' shared histories may affect their disposition toward the geoscience field. People of color and those from low-income backgrounds report having fewer informal outdoor experiences while growing up, which can make participating in fieldwork less familiar and comfortable for them and deter their pursuit of a geoscience degree (O'Connell and Holmes, 2011; Stokes et al., 2015). People of color, especially Indigenous groups, may also carry negative associations with the role of fieldwork in the U.S. history of military expansion and natural resource extraction (Winchester, 2001; Turner, 1893; Yusoff, 2018). For African Americans, the U.S. wilderness has historically been a site of violence, where chattel slavery and Jim Crow laws were enforced for centuries (Finney, 2014).

Research has also identified a variety of barriers to inclusion in fieldwork for students with disabilities. For example, faculty leading geoscience field experiences may hold negative assumptions about the talents and skills of students with disabilities (Atchison and Libarkin, 2016). Instructors, even those with disabilities, can disagree about how disabilities should be defined and accommodated (Feig et al., 2019). These views are related to the "boot camp" mentality that has developed in fieldwork, which emphasizes the physical fitness required to navigate difficult terrain, hike for long hours, and carry heavy gear (Mogk and Goodwin, 2012). Prevalence of this mindset impedes inclusion of students with disabilities (Atchison et al., 2019; Carabajal et al., 2017; Núñez et al., 2020; Stokes et al., 2012).

Improved norms for interactions are also needed with respect to gender. The prevalence of gendered bullying and sexual harassment in the field (Clancy et al., 2017; Mattheis et al., 2019; Nelson et al., 2017) has recently drawn national attention (National Academies of Sciences, Engineering, and Medicine, 2018; Wadman, 2019). One study indicated that women who participated in fieldwork experiences without clear guidelines for appropriate behavior were more likely to feel a lack of safety or be harmed in ways that could adversely affect their career trajectories, including leaving graduate programs (Nelson et al., 2017). Women of color and those with lower role status reported even higher rates of negative experiences (Clancy et al., 2017), which is significant,

* We use the term *LGBTQ+ status* to recognize the fluidity of this identity and to include populations not limited to lesbian, gay, bisexual, transgender, queer, and questioning (Mattheis et al., 2019; Pitcher et al., 2018).

given that women and people of color in geoscience are concentrated in lower seniority roles (Glass, 2015; NCSES, 2017, 2019).

A recent comprehensive review of 165 articles published between 2008 and 2018 in eight key science and geoscience education journals reached a conclusion that is consonant with our own: Most studies about diversity in the geosciences have focused on individual student-level factors rather than organizational or system forces (Mattheis et al., 2019). Considering that most geoscience fieldwork is sponsored by organizations whose policies and practices define the work, this inhibits opportunities to institutionalize and sustain practices that would increase diversity and equity in the discipline (Karsten, 2019; Mattheis et al., 2019; Núñez et al., 2020; Posselt, 2020).

There are two exceptions to the general oversight of organizational barriers. First, and perhaps ironically, promotional materials for fieldwork may impede engagement and participation of diverse learners through the messages they send about “who belongs.” These materials tend to emphasize outdoor fieldwork and narrowly portray geoscientists as White, able-bodied men; women, people of color, and people with disabilities are hardly represented (Hall et al., 2004; Mattox et al., 2008; Sexton et al., 2014). And, when promotional materials do not communicate available financial supports, they can hinder low-income students’ perceptions that they can participate because, as mentioned earlier, costs of travel and gear can be prohibitive (Ham and Flood, 2009; Kelleher, 2017). Additionally, a lack of organizational representation and role models (in printed materials and in reality) may inhibit students from historically underrepresented backgrounds from identifying as geoscientists (Callahan et al., 2018; O’Connell and Holmes, 2011).

## 2.2 Prior Ethnographic Studies of Geoscience Fieldwork

To advance the understanding of social and organizational factors in broadening participation in the geosciences, researchers have emphasized the importance of using qualitative methods, including ethnographic studies of fieldwork (Goodwin, 2018; Mattheis et al., 2019; Mogk and Goodwin, 2012; Williams and Semken, 2011). There is a tradition of ethnographies within science and technology studies, often at multiple sites or over several years (e.g., Latour and Woolgar, 1979; Traweek, 1988; Knorr-Cetina, 1999; Vertesi, 2014). These studies have largely focused on lab and team science rather than geoscience fieldwork, but we identified three studies that primarily used ethnographic methods to examine student experiences in field-based courses (Feig, 2010; Goodwin, 2018; Williams and Semken, 2011).

Feig (2010) examined students’ learning and skill development in a geosciences field camp. He observed that students tended to focus on precision in measurements and observations rather than on accurately making sense of data to assemble a plausible explanation. He interpreted these patterns as inhibiting development of spatial skills and holistic understanding of earth processes. Williams and Semken (2011) employed ethnographic observations and interviews to examine in-service teachers’ experiences with a place-based geoscience curriculum in local school districts in Arizona. The activities led students to feel an increased sense of connection to, engagement with, and understanding of their local natural environment; their teachers—one third of whom were Latinx, Native American, and/or Asian (with the rest White)—felt this enhanced their capability to teach and engage the students.

Finally, through extended observations of social interactions in earth science courses, Goodwin (2018) found that field-based learning afforded significant opportunities for undergraduates to act as apprentices and for faculty to transmit critical disciplinary knowledge. He observed faculty and students jointly drawing on multiple senses to identify rocks, interpret and make maps, communicate about key concepts, and explain landscape formation. He suggested that geoscience fieldwork offers opportunities for instructors and students to build upon one another's language and actions to construct a shared set of enduring symbols and terms and to transmit a critical body of knowledge to the next generation.

For various reasons, it is not possible to know from these studies how social identities or abilities might influence inclusion and exclusion in fieldwork. Williams and Semken (2011) reported demographic characteristics of their sample, but it consisted of in-service K–12 teachers and therefore does not generalize to higher education faculty or students in geoscience. Further, they focused on teachers' self-reported experiences and individual behaviors and did not address group dynamics with implications for inclusion and exclusion. Feig (2010) and Goodwin (2018) studied group dynamics through patterns of communication and knowledge transmission, but neither reported the demographic composition of their samples. With these limits of prior research in mind, along with calls from scholars to attend to social and cultural factors in fieldwork, there is a clear need to examine the organization of learning and consequences for inclusion and exclusion on the basis of abilities and social identities.

## 3. CONCEPTUAL FRAMEWORK

To develop understanding required for broadening participation in geoscience, Riggs and colleagues (2018) recommended that scholars apply lenses from the higher education learning and development literature. Thus we examined the organization of learning in relation to diversity and inclusion by employing two models from higher education scholarship: Hurtado and colleagues' (2012) multicontextual model of diverse learning environments (the DLE model) and King and Kitchener's (1994) reflective judgment model (RJM).

### 3.1 Multicontextual Model of Diverse Learning Environments

The DLE model links student identities and learning outcomes with the contexts in which learning occurs. It stipulates that micro-, meso-, and macrolevel contexts interactively construct learning environments that shape experiences and outcomes for learners with diverse social identities. This model predates Wolfe and Riggs's (2017) framework from geoscience education research, which also defines macro-, meso-, and microlevel factors affecting equity. The DLE model also specifies educational, organizational, and institutional practices as well as participant experiences within these levels.

The DLE model identifies five interrelated dimensions of the learning environment: (a) the social identities of those in different roles (e.g., instructors, students, staff); (b) participants' perceptions of and behaviors in the environment; (c) curricular processes of pedagogy and course content; (d) cocurricular processes of practice and programming; and (e) how these entities are situated in behavioral, psychological, compositional, organizational, and historical contexts (Hurtado et al., 2012). These components are collectively contextualized by a particular institution (and its mission), state and federal policies regarding higher education, and the corresponding sociohistorical context (Hurtado et al., 2012).

According to the DLE model, educational, organizational, and institutional practices within learning environments may be associated with differential experiences and participation among actors with different social identities (Hurtado et al., 2012). For example, in one empirical application in broad-access colleges (with a high proportion of students of color), Hurtado and colleagues (2012) found that validation from faculty and staff mediated negative impacts of discrimination. As the model's attention to micro-, meso-, and macrocontexts implies, these relationships may be context dependent. As a key site for learning and integrating essential disciplinary knowledge (Goodwin, 2018; Feig, 2010; Mogk and Goodwin, 2012), fieldwork offers a compelling setting for studying diversity's role in the organization of learning in geoscience.

## 3.2 Reflective Judgment Model

The DLE provided a framework for foregrounding abilities, identities, perceptions, and behaviors of students as well as curriculum, pedagogy, and context as sensitizing concepts (e.g., Bowen, 2006). However, it did not provide substance to anticipate specific habits of mind and cognitive development that would be central to our fieldwork sites. We found King and Kitchener's (1994) RJM to be well suited to making sense of the specific demands of learning in fieldwork and the intellectual shifts that students had to make to succeed in their field courses.

The RJM focuses on people's assumptions about how knowledge is developed and how people reason and make decisions about dilemmas and complex issues. Development is conceived of as a transformation where lower-level dispositions and skills are integrated into new approaches and applications of skills to address more complex cognitive problems and tasks (King, 2009). A key developmental transition is from prereflective to reflective judgment, where a student begins to understand multiple knowledge perspectives, to evaluate and (where necessary) integrate these different perspectives, and to commit to particular approaches to address cognitive complexity, based on empirical evidence (King and Kitchener, 1994).

According to the RJM, a central way to facilitate this kind of development is by engaging students in addressing *ill-structured problems* that lack straightforward solutions. King and Kitchener (1994) noted that one way learners come to understand and integrate multiple perspectives to address ill-structured problems is by *perspective taking*, or imagining approaches to solve a problem and comparing them to determine which are appropriate to select or integrate based on the evidence. One way to foster perspective taking to address ill-structured problems in the classroom is to engage diverse learners who might have different backgrounds and approaches (King and Kitchener, 1994).

The application of the DLE model and RJM together allowed us to identify the organization of learning in the field and the implications of current practice for inclusion and exclusion. Moreover, it enabled us to explore the nature of and relationship between critical cognitive, affective, physical, and social dimensions of fieldwork learning (Atchison et al., 2019; Feig et al., 2019; Kortz et al., 2020; Mogk and Goodwin, 2012; Streule and Craig, 2016). The DLE model's focus on multiple dimensions of diversity and the RJM's focus on cognitive growth in relation to grappling with ill-structured problems and perspective taking offered helpful lenses for understanding the dynamics of participation in fieldwork, with implications for socializing diverse undergraduate and graduate students into geoscience.

## 4. METHODS

This paper is part of a larger project funded by the National Science Foundation (NSF) examining how design and leadership of fieldwork can be improved for diversity in the geosciences. The current research occurred in the first stage of the project and was designed to capture processes behind the barriers that impede participation for marginalized groups in the discipline. The naturalistic approach of ethnographic research, which we employed here, can reveal "epistemological blind spots"[†] (Scheurich and Young, 1997) in which even the most equity-minded field-course instructors might not be fully aware of how standard practice affects students' engagement and learning. This paper is based on extended engagement in two different fieldwork sites that enrolled students at two distinct stages of postsecondary education: undergraduate and graduate. The study is among the first to examine how cultural norms and practices in the field carry risks for inclusion and exclusion at different stages of geoscience education (Posselt and Núñez, 2018).

We employed a constructivist grounded theory approach (Charmaz, 2014; Jones et al., 2014), which integrates a constructivist paradigm that draws on prior socially constructed understandings (i.e., from research, theory, and experience) with the development of grounded theory about a particular topic (Charmaz, 2014, 2017). Grounded theory initially emerged as a qualitative methodology designed to generate theory based purely on interview and observational data—that is, theory grounded in the data (Glaser and Strauss, 1967). It has evolved to encompass multiple degrees of "grounding," ranging from the initial conception (collecting and analyzing data without prior assumptions) to the more recent tendency to design data collection and analysis processes by

† While attractive as a concept for its intuitiveness, the notion of "blind spots" has been described as ableist in connoting blindness with areas of oversight or lack of attention.

integrating past literature (Charmaz, 2017). Here we tend toward the latter, beginning with inductive analysis, then applying the two conceptual frameworks described above to deepen understanding and inform interventions.

## 4.1 Sites and Participants

Two of the authors collected data as participant-observers in separate postsecondary field-based summer learning experiences—an undergraduate course in the Rocky Mountains and a graduate course on the West Coast. The undergraduate course closely resembled that of a typical field camp (Feig, 2010; Mogk and Goodwin, 2012; Oleson, 2013) and took place where many undergraduate field courses are conducted every summer. Offered by a large, predominantly White public flagship university, the six-week course enrolled 23 students from three public institutions who resided in a university dormitory near the fieldwork sites. Students learned basic skills, such as identifying rocks, analyzing rock strata formation, and mapping key geological features. For most, this was the first outdoor fieldwork trip to exceed a day in length.

The six-week, graduate-level course was offered by a private research university on the West Coast and involved a competitive application process and students from multiple universities. It was designed to provide students the opportunity to learn advanced field-based research techniques and apply them to interdisciplinary research questions. All but two of the 17 students had prior field experience. Consistent with other graduate-level geoscience courses, it was not uncommon for students to present or publish their research together and to continue collaborations long beyond course completion. Three weeks of the course were held in field at stations in the Sierra Nevada mountains and along the Pacific Ocean.

Table 1 shows the participant sample of each field course, including students, instructors (professors and teaching assistants [Tas]), and staff members. Each participant was assigned a pseudonym. About one-third (34.5%) of the undergraduate student participants and nearly half (47.1%) of graduate student participants were women.

**TABLE 1:** Participant sample

| Course level | Location | Instructors | Students | % Women students | % Underrepresented students* |
|---|---|---|---|---|---|
| Undergraduate | Rocky Mountains | 2 faculty; 4 TAs | 23 | 34.5% | 17.3% |
| Graduate | Sierra Nevada; Island field station | 3 faculty; 5 TAs | 17 | 47.1% | 6.0% |

*In congruence with the NSF's definition, we define underrepresented students as U.S. students of Black/African American, Hispanic/Latinx, and/or Native American heritage.

The underrepresentation of people of color within geology is reflected in our sample. Only 17.3% of the undergraduate students (five of 23) came from Black/African American, Hispanic/Latinx, or Native American racial/ethnic groups—the groups considered underrepresented by the NSF. In the graduate class, just one of 17 students (6%) was from these underrepresented groups. This prevented us from exploring in depth the role of racial/ethnic identities in field-course experiences.

Further, in following guidelines to let students self-identify their own salient identities (Mattheis et al., 2019; Núñez et al., 2020), too few participants self-identified as low-income or LGBTQ+ for us to examine how these identities were associated with fieldwork participation. As is typical in any postsecondary course, disability status was kept confidential from all but the instructors. We only learned about disabilities when students disclosed them, so the total number of students with disabilities in the study is not known. Accordingly, our findings focus on identities related to gender and diverse abilities as they were revealed.

### 4.2 Data Collection

The constructivist paradigm frames the nature of reality during data collection as coconstructed between researchers and participants. In this ontological perspective, the focus of data collection is on uncovering social processes as understood and experienced by community insiders (Charmaz, 2014). To this end, we collected a combination of observational, documentary, and interview data that provide distinctive yet complementary perspectives on how the organization of learning in fieldwork is associated with various physical abilities and social identities and the implications of how learning is organized for inclusion or exclusion in fieldwork activities.

Across the two sites, we conducted approximately 275 hours of observations and interviews with as many of the 40 undergraduate students, nine graduate student teaching assistants, and five instructors as time permitted. In total, we conducted 32 semistructured interviews with these participants. The two authors who collected data resided in dormitories or apartments along with students, teaching assistants, and instructors. We began data collection at the beginning of each course, when most students and faculty participants were learning course guidelines and either meeting for the first time or getting to know one another better as a group. We interacted with the classes through participation in day trips to fieldwork sites and during meals, class meetings, and work sessions.

Participant observation involved taking extensive field notes about group interactions, instructors' approaches to managing student learning, moments where social identities became salient, and the role of the physical environment, as well as personal reflections about moments that proved important within each class (Emerson et al., 2011). We also analyzed documents including syllabi, assignments, and related course content (Hodder, 2000). Finally, semistructured interviews with a subset of participants centered on their experiences in the field, past and present (see Appendix A). The protocols included questions relevant to both field sites and subsets of questions specific to the undergraduate and graduate settings (Charmaz, 2014).

### 4.3 Data Analysis

Data analysis in constructivist grounded theory involves making comparisons within and across data types to locate themes that inform conceptualizations of the empirical topic (Charmaz, 2014, 2017). However, existing theory and literature informed the development of the interview protocol, which directly affected the content of interview data and provided us with sensitizing concepts (Bowen, 2006) for early interpretations of the observational and interview data. As noted, the protocol and sensitizing concepts drew from a conceptual model about inclusion in higher education (the DLE model) and extant literature on geoscience fieldwork.

At the analysis stage, the research team included the two participant-observers and three doctoral student research assistants selected for their knowledge about equity and inclusion in higher education. We inductively analyzed the data to make sense of field-based learning as participants themselves experienced it (Charmaz, 2017). We analyzed field notes and interview transcripts following the constant comparative method of generating initial and focused codes (Charmaz, 2014), while noting patterns of convergence and divergence across the two courses (Charmaz, 2014; Emerson et al., 2011). Line-by-line initial coding allowed patterns to emerge from the interview and field note data. For example, the protocol did not include questions directly about learning, but participants repeatedly volunteered how they were learning and growing in their field experiences (Saldaña, 2015), so initial codes were created about learning and growing. Our complete set of focused codes is depicted in Table 2.

**TABLE 2:** Themes identified through focused coding

| Code | Definition |
|---|---|
| Learning | Development or integration of knowledge, about science and/or self |
| Abilities | Physical, mental, emotional, or academic abilities that affect success in fieldwork |
| Interactions according to identities | People's interactions within or across social identities or academic roles |
| Conditions in field | Natural environments (e.g., physical conditions and elements experienced in the field trip or site) and/or built environments (e.g., dorms, condos, dining hall, bars) |
| Barriers and resources for entry | How individuals acquire access to educational, scientific, or field-based opportunities |
| Transit to field | how one physically gets to a field site (e.g., hiking, van, boat) |
| Experience of time in the field | Experience and tracking of time through availability of daylight and demand of tasks, especially that which is unlike what is experienced on campus |

As is common in multicase ethnographic studies, collecting data at two different sites with different participants yielded both convergence and variation in student experiences. Therefore our process of relating codes involved more aggregation and abstraction than if we had a single case study. The focused coding process involved looking across initial codes to see how they related to one another and considering whether it would be more effective to combine or split them. For instance, we linked codes about natural conditions in the field and the built environment outside of it (e.g., residence halls) to a focused code related to fieldwork conditions (Saldaña, 2015). Next we followed theoretical coding (Charmaz, 2014) to examine relationships among the first four focused codes in Table 2 (learning, abilities, interactions according to identities, and conditions in field), from which we generated themes about the organization of learning in geoscience fieldwork and implications for exclusion or inclusion.

### 4.4 Trustworthiness

Several components of the research design contributed to its trustworthiness and, by extension, the trustworthiness of the findings. First, our research team included varied gender and ethnic perspectives. As such, the analysis benefited from a rich set of perspectives (Saldaña, 2015). In this collaborative analysis, at least two researchers independently coded transcripts and field notes before comparing memos and collaboratively refining themes (Saldaña, 2015). Additionally, multiple data sources from multiple sites, coupled with immersion in field sites over entire cycles of activity, facilitated triangulation of multiple perspectives and interpretations (Lincoln and Guba, 1985; Saldaña, 2015).

To enhance trustworthiness and credibility (Guba and Lincoln, 1989), we obtained feedback on the resonance of preliminary themes from three groups: (a) 32 field geoscientists who had come together for a three-day institute to explore ways of improving the field-based learning experience; (b) 50 geoscientists attending a major disciplinary society meeting; and (c) 40 geoscientists attending a major research university colloquium. These experts expressed that the findings resonated with their own experiences of fieldwork. None challenged our interpretations and analyses, although in some cases they suggested that the organization of learning in fieldwork was context specific depending on the geoscience subdiscipline (e.g., atmospheric science, ecology, oceanography). In sum, expert checking corroborated our findings and their trustworthiness, suggesting that participant observation did not significantly alter the learning and social dynamics in either course.

### 4.5 Positionality

The two authors responsible for participant observation are social scientists whose goal was to understand the culture of learning in the field in order to advance more inclusive geoscience fieldwork practices. As newcomers to geoscience, they were cultural outsiders relative to the field-course participants. Both were women and both were physically capable of handling each course’s demanding schedule, work conditions, and terrain, which allowed them full access to field sites. The larger analysis team was diverse along gender, race/ethnicity, and class backgrounds, and the doctoral students' own varied experiences and identities attuned them to the potential roles of multiple identities in influencing fieldwork experiences.

## 5. FINDINGS

Despite expected differences across sites associated with participants' relative exposure to fieldwork and the goals of their courses, we found three central cultural processes related to field-based learning that were associated with or carried clear consequences for the learning experiences of students with different social identities or abilities: (a) extending prior knowledge in the unstructured field; (b) learning through the physical challenges of the field; and (c) managing social interactions under increased salience of identity. We present evidence for each theme and then resituate them in the DLE and RJM frameworks.

### 5.1 Extending Prior Knowledge in the Unstructured Field

For both graduate and undergraduate students, fieldwork settings lacked the structure, control, and organization that characterized lecture or lab environments in which their prior learning had been primarily situated. The complex landscapes of the natural world did not lend themselves to the precise, straightforward interpretations that textbooks and theories imply; learning here required different disciplinary content and skills. Despite different levels of background knowledge and exposure to field-based techniques, students experienced cognitive growth as they were challenged to construct interpretations of their data and observations in ways that extended prior knowledge.

Students were challenged to assemble observations and measurements into explanations of earth history. Leann, a graduate student, noted that the value of fieldwork is that "It makes sense for geologists [to look at] where their samples come from in a more intimate way. You just get to know your study environment so that you avoid biases." She highlighted how fieldwork affords knowledge of a research site that pushes one to test assumptions, identify biases, and arrive at more evidence-based conclusions. Another graduate student, Hannah, explained:

> *You're looking at this rock and this rock, and you are identifying them bit by bit, layer by layer. And then you get to the points where they are finally taking it apart, where you can see the structure. And you can start seeing the faults in the folds and everything. And you're just going, 'What? Like, how can it be folding this way and that way?'…But you start being able to put it together [until it] feels like you are manipulating it yourself.*

Hannah illustrated how examining the natural world can present many data points that do not necessarily align. The student must interpret—often in story form—how they fit together.

The graduate course instructors sometimes presented students with a two-part challenge at the start of the day: First, define a research question using little more than the observable aspects of a given field site; then, answer it by collecting relevant data and bringing it to the field station for analysis. Students had to impose established scholarly structure—clear questions, trustworthy data, and valid answers—on an environment whose boundaries might literally go as far as their eyes could see. They struggled to achieve consensus with peers about what answerable yet interesting questions a landscape might present and what data would answer those questions. Extending prior knowledge in this way, participants learned about their underlying assumptions about the research process, about field-based knowledge and observations, and about themselves as learners and constructors of knowledge. They came to grips with imprecision in measurement as the tradeoff for the contextualization that field-based observations presented. As such, the process encouraged deep learning.

The undergraduate students were typically learning for the first time how to measure phenomena they had learned about in classes and to develop stories based on those measurements. For them, this was the intellectual challenge of the field. Two vignettes illustrate their cognitive struggles.

One day, after two hours of weaving up hills, the undergraduate students crowded in clusters, gazing into the distance. Standing closest to a ridge that rose in the distance, an instructor, Leo, asked, "Can any of you propose a story about how the rocks came to be this way?" Gary stepped forward, explaining, "I thought this was the Dinwoody [rock layer]. I think there was faulting going on to cause folding and wacky combinations of the K1 layer next to the Blackleaf layer." Leo nodded and asked the remaining students, "Can you all evaluate Gary's story?" Jim offered, "I think the Blackleaf layer goes further than what Gary says"; Mary added, "I feel like the Phosphoria [layer] is doing a thrust fault and has a really big fold."

The instructors and students continued to volley back and forth hypotheses for how the rocks got to be that way, with instructors pushing students to explain their reasoning. Then Zoe, an instructor, held her arm out, tracing the ridges in the distance with her fingers to show the layers and pointing to possible locations of thrusting that might cause rocks to fold. In the foreground, a student, Mark, said, "It's kind of funny how you ask one question, and you get another question." His friend Ben shook his head and muttered, "Pandora's box." Indeed, this scene illustrates how instructors and undergraduate students worked together to address the "Pandora's box" of naturalistic inquiry.

Writing up their assignments back at the dormitories also presented undergraduates with cognitive challenges in the form of articulating shared interpretations. Many of their assignments involved group work to collect observations and write up explanations to questions posed by the instructors. Completing their first assignment, two groups of women started asking questions of one another and comparing maps each had developed based on observations in the field. They explored several possibilities but came to no resolution. Finally, Ines stood up and said to both groups, "What we are trying to get at is an interpretation, rather than a clear-cut answer." She paused, adding, "The answers are subjective." Wendy looked up from her paper and shrugged her shoulders, saying dryly in a monotone voice, “So, none of it matters.” The students laughed together, as they began to commit to an explanation of the landscape’s history.

In this exchange, Ines recognized that the goal was not to provide an unequivocally right answer. Wendy’s sarcastic response that “none of it matters” can be understood as a need to grow out of the binary thinking of what King and Kitchener (1994) called prereflective judgment. The students’ laughter indicated recognition of the tension between finding the *right* answer (or, in the absence of a right answer, having none of their observations matter) and having to settle down and figure out what actually *did* matter. Identifying the most plausible answer called them to exercise judgment, as they compared multiple potential explanations before choosing the one supported by the most evidence from their field observations.

In both courses, our data add to the evidence that fieldwork pushes the boundaries of students’ cognitive development through the ill-structured problems the field presents, sometimes for the first time in their academic careers. In the words of an undergraduate field camp instructor, doing fieldwork means “you’ve actually done science, rather than [just] been in a science class.”

## 5.2 Learning through the Physical Challenges of the Field

The physical challenges inherent in learning in the field differentially affected students’ opportunities to engage. We found the field especially presented barriers to students with different abilities, which ranged from lifelong disabilities to temporary situations, such as virus or a first-time panic attack. In both courses, when students struggled to navigate the terrain, it affected the extent to which they could gather observations or maintain engagement with their group. Those with permanent or temporary physical conditions that compromised their capacity to physically keep up faced particular struggles.

To complete assignments and research tasks, students at both sites were required to hike 8 hours a day, carrying 20+-pound backpacks, at over 5,000 feet above sea level on terrain that included sharp hills, slippery rocks, and cacti whose needles could find their way into shoes and skin. Rattlesnakes that approached several participants’ ankles at the undergraduate site and an unprecedented heat wave at the graduate site were just two physical risks participants experienced. While challenging even for students who appeared fit and nimble, these demands created an especially difficult learning environment for students who were less able-bodied, who struggled with anxiety, or who had little prior exposure to wilderness activities.

A graduate course instructor, Rose, described the importance of physical activity in the field: “You gotta have your shit together, ‘cause if you don’t, you’re slowing down the whole rest of the group.” When reflecting on her own group’s dynamics, Hannah, a graduate student, felt that slower students hampered the group’s work: “There’s also some frustration, right? Like, we want to keep moving.” These comments indicate that group pace could affect how a student related to others in the learning environment.

Peter, who was from an impoverished Appalachian area, was the only graduate student without either hiking or fieldwork experience. He struggled daily to maintain the group's pace and to keep his footing on the uneven ground where his group mapped outcroppings. He did not participate in optional activities, like night swimming, that bonded the group. One day, above a steep ravine that his peers had all carefully climbed down for their next tasks, Peter froze. He had a panic attack, the dramatic landscape activating a fear of heights he had never experienced. A male TA carefully took him by the arm and walked him several feet, step by precarious step, before Peter decided he could not proceed. The two ultimately walked back to the van so Peter could recover. He felt embarrassed by the incident and admitted in an interview that it led him to withdraw further from the group.

Similar issues arose in the undergraduate field camp. When trying to load the last person on the van at the end of one day, an instructor shouted to a student far behind, "Jim! Get your ass over here!" Throughout the course, Jim carried the tail end of whatever group he worked in. He disclosed a congenital heart condition in an interview, adding that field camp was "physically difficult, not so much mentally difficult," and added, "it's not the material that I dislike, it's the exercise.…Gonna take me a while, I'm gonna be out of breath, 180 beats per minute, just miserable." Jim explained that he struggled to participate equally with others in group work because he could not traverse as much terrain and collect as many measurements.

In the undergraduate course, a hike up the highest peak in the area was described as optional. Every year, however, the ritual of taking the class picture occurred at the top of this hike, so those who did not make it up did not appear in a photo that was supposed to represent the whole group. Kim, one student who had contracted bronchitis during the trip, expressed great difficulty keeping up on this hike; she nearly stopped but pushed herself to make it up the mountain. While doing so afforded her more information about the landscape to complete her assignment, two days later she went to the hospital, taking a day away from fieldwork and compromising her participation in the learning, which made coordinating group work with her partner difficult.

The field thus made disparities in permanent or temporary abilities more salient—which also made it more difficult for some students to participate in learning itself. In select cases it even pressured students to overexert themselves in ways that threatened their basic safety. Faster physical pacing in covering natural terrain put certain students at a disadvantage and rationalized not fully involving some students—for example, those with health conditions, like Jim. This pacing was emphasized as an advantage in fieldwork and reflected the same boot camp mentality found in previous research (Mogk and Goodwin, 2012). The dynamic differentially affected students' opportunities to gather data, to be part of the group interpretation processes described earlier, and to simply feel they belonged.

### 5.3 Managing Social Interactions under Increased Salience of Identity

Finally, our data suggest that social interactions may intersect with social identities in ways that can hinder sense of belonging in the learning environment as well as impede critical learning outcomes, like retention in the major. In the undergraduate course, for example, after noting her instructor said some people decide not to become geologists after field camp, one undergraduate described fieldwork as “50% social interaction, 50% fieldwork.” Reflecting on why students might leave geology, she added, “Maybe [those students] just had a bad time. And it’s not the geology part’s fault, it could’ve been something else.…Maybe they did like the fieldwork, but they were picked on the whole time or something.” If interactions are typically negative and students feel they have no recourse, self-selection out of the work becomes logical.

Sometimes exclusionary interactions were more nuanced. Jim, the undergraduate with the heart condition introduced earlier, described how groupmates did not involve him in generating explanations about the earth’s formation that were central to the assignment; rather, he was asked only to edit the final writeup. He expressed hope that his teammates would not call him a “slacker” for not being more substantively involved because, in his words, “they did not ask me to do anything else.”

Likewise, graduate students and instructors stressed the centrality of social interactions to fieldwork, with several linking this to personality traits of introversion and extroversion. Caleb described how the graduate students were mostly introverts, but the course involved 16 hours a day of group activity, which could be particularly “exhausting to people, more than having to think about things for 12 hours a day.” Thus, sustained social activity, perhaps as much as physical and cognitive activities, shaped opportunities to learn in the field.

Observations and interviews with women in both classes indicated how they coordinated supportive interactions and group involvement in learning. Kim, the undergraduate with bronchitis (described in the last section) and her partner developed strategies to work together on observation and measurement during their last day in the field, after she visited the hospital. For example, her partner scaled a hill and walked along a ridge about 1,000 feet away while she followed on roughly parallel road cuts. They yelled observations to each other as they went, recording them in their notebooks. Meanwhile, graduate student Kayla, referencing an experience in which her group collected water samples from a boat, spoke of how setting up a “system” for group interactions in data collection and analysis fostered a positive learning environment: “It was just sort of this really fun dynamic sort of thing.” Women in both groups interacted responsively with one another, reducing the risk of isolation or marginalization.

## 6. DISCUSSION

In our multiple-case study, undergraduates and graduate students were at different stages of learning. As might be expected, graduate students were learning advanced field-based techniques and addressing independent research questions, while the majority of undergraduates were learning basic techniques for the first time. Nevertheless, three key themes characterized the organization of learning across sites: extending prior knowledge in the field, learning through physical challenges, and managing social interactions under increased salience of identity.

Regarding the first theme, students at both sites encountered cognitive challenges, as the field experience forced an extension of previously developed knowledge or skills. King and Kitchener's (1994) concept of ill-structured problems offers a template for capturing the nature of these challenges and the related potential for growth. We found fieldwork provided a central socialization experience into geoscience, especially with regard to cognitive growth (Feig, 2010; Goodwin, 2018; Mogk and Goodwin, 2012; Streule and Craig, 2016) and to equipping students with the habits of mind and skills to address uncertainties in the discipline (Bond et al., 2011).

Regarding the second theme, students encountered physical challenges to varying degrees according to abilities and health, which clearly affected their engagement in the rich intellectual experiences the courses offered. Group work is integral to field-based learning and socialization (Goodwin, 2018; Kastens and Manduca, 2012; Mogk and Goodwin, 2012; Streule and Craig, 2016). As such, students with lifelong disabilities or temporary health conditions can be left out of critical social interactions that advance learning (Atchison et al., 2019; Feig et al., 2019). These findings affirm the importance of work by Atchison and colleagues (2019), who advised broadening geoscientists' thinking about what places, activities, and interactions constitute fieldwork, if the goal is a more inclusive learning experience.

Finally, we found that for students at both sites, a central part of field-based learning involved managing social interactions as the salience of different identities or abilities increased. How social interactions unfold in terms of "context, frequency, and quality" can shape how students with diverse abilities perceive their roles and engage in these environments (Hurtado et al., 2012, p. 66). We observed examples of collaborating to improvise division of labor by delineating tasks that each partner could do; this practice has in fact been implemented in fieldwork interventions designed for people with disabilities (Atchison et al., 2019). We also observed women taking the lead in improvisation. Indeed, women may be inclined to interact and learn in more connected ways than men (Belenky et al., 1997), for whom the field's focus on physical toughness elicits tendencies toward conventional masculinity (Posselt, 2020).

### 6.1 Situating the Findings in the RJM and DLE Frameworks

In illuminating these dimensions of learning via fieldwork and how they affect participation and learning, this research confirms the benefits of employing ethnographic and naturalistic methods in inquiry about this topic—benefits that have been highlighted by other scholars (Atchison et al., 2019; Mattheis et al., 2019; Streule and Craig, 2016). This research also demonstrates the value of the DLE and RJM lenses to making sense of the organization of learning in the field by students with various abilities and identities.

The process of extending textbook knowledge to interpret a natural landscape's history is a prime example of an ill-structured problem that requires integrating knowledge and skills from different scientific disciplines. This work is central to geoscience at large (e.g., Apedoe et al., 2006; Holder et al., 2017) and to geoscience fieldwork in particular (e.g., Chan and Ho, 2013; Mogk and Goodwin, 2012). The RJM (King and Kitchener, 1994) provides a lens for understanding how undergraduate and graduate fieldwork affords opportunities to make critical leaps in cognitive growth and to sharpen skills of interpreting complex disciplinary problems through making sense of complex landscapes that resist more straightforward explanations. As we observed, fieldwork's emphasis on group work can provide critical opportunities for learners to engage in perspective taking (King and Kitchener, 1994) and to imagine a "Pandora's box" of explanations for the same problem.

However, in contrast to relatively rosy prior depictions of geoscience fieldwork as a fully collaborative activity (e.g., Mogk and Goodwin, 2012; Goodwin, 2018), we found the quality of social interactions can affect capacity for involvement and perspective taking (King and Kitchener, 1994). Further, the quality of social interactions is associated with abilities and social identities in which typically privileged groups remain privileged. For example, because of his heart condition, Jim missed out on opportunities to engage in perspective taking to address an ill-structured problem with his groupmates, as they involved him only at the final stage. Our findings therefore extend research on participation barriers in geoscience for students with disabilities (Atchison et al., 2019; Feig et al., 2019) to explain how marginalization within the field experience can compromise learning.

The DLE model (Hurtado et al., 2012) offered a complementary framework for exploring our data. We saw that instructors who might be unaware of disabilities, illnesses, or physical struggles might push students to move faster—or even leave students behind, out of eyesight. Without instructors at the back of the line (as in both classes we observed), instructors reinforce a "boot camp" culture, which can exclude some students from fully participating. Similarly, stating that slower participants are "slowing down the rest of the group" does not allow for multiple modes of movement or the potential for participants who work at different paces to contribute fully (Atchison et al., 2019). It is important to consider who is left out—literally and figuratively—in constructions of what full participation looks like in fieldwork.

The DLE model also emphasizes that students, faculty, and staff coconstruct the learning environment (Hurtado et al., 2012) and therefore can exercise agency in behaviors that positively affect learning. The example of undergraduate women setting their own work style, dividing up the labor so that the one with bronchitis collected measurements along a road cut while the other collected measurements at the top of a ridge, illustrates students' capacity to challenge fieldwork norms to hike fast, push hard, and hide struggles (Posselt and Núñez, 2018). In contrast to Goodwin's (2018) view, implying a simple generation-by-generation reproduction of field culture through socialization in the field, our findings suggest that students as apprentices (Streule and Craig, 2016) can coconstruct the learning environment as well as terms of participation.

## 7. CONCLUSIONS AND IMPLICATIONS

In congruence with other studies, we found that conducting fieldwork affords significant opportunities for cognitive growth by posing ill-structured problems that students must grapple with (King and Kitchener, 1994). Doing so requires students to advance the complexity of perspectives and evidence they apply to develop scientific explanations for geological phenomena (Feig, 2010; Goodwin, 2018; Mogk and Goodwin, 2012; Streule and Craig, 2016). Ideally, fieldwork also increases motivation to pursue geoscience careers and to develop valuable integrative knowledge and skills (Goodwin, 2018; Kastens and Manduca, 2012; Mogk and Goodwin, 2012; Streule and Craig, 2016).

However, our study indicates these very dynamics can enhance or impede opportunities for diverse students to participate fully in and benefit from this type of learning. We find a critical role for social interactions in fieldwork (Atchison et al, 2019; Streule and Craig, 2016), and the field presents myriad physical, cognitive, and social situations where particular social identities may become more salient. As detailed below, future research and practice should attend directly to relationships among the design of field-based experiences and the quality of social interactions within them in order to enhance participation and learning by all students.

### 7.1 Recommendations for Future Research

In alignment with scholars of geoscience education, we recommend that future research continue to broadly investigate the role of multiple social identities in relation to equitable participation and inclusion in geoscience fieldwork (Núñez et al., 2020; Mattheis et al., 2019; St. John, 2018). Our sample composition did not allow us to systematically examine how identities such as race, class, and LGBTQ+ status individually or intersectionally mediate experiences with learning and social interaction in the field. In particular, future research must explore the role of race given the especially low representation of Black, Latinx, and Native American individuals in geoscience in the United States (Bernard and Cooperdock, 2018).

Because the saliency of social identities and abilities can vary according to different learning contexts, such as fieldwork versus lab (Deaux, 2001), and students may or may not disclose all salient social identities to their instructors, it is important to attend to how the saliency of students' identities and abilities might shift when they enter fieldwork. Intentional and ethical sampling—with respect for how students self-identify and for protecting confidentiality—will be critical in extending what we know about the roles of race, class, and LGBTQ+ status in fieldwork (Mattheis et al., 2019). Attending to how different natural settings and subdisciplines in geoscience shape organizational learning in fieldwork is also important. Our research focused primarily on fieldwork in earth science, and addressing how cultural norms vary among different subdisciplines of geoscience (e.g., atmospheric science, ecology, oceanography) could inform more inclusive practices in these settings.

### 7.2 Recommendations for Policy and Practice

Our findings affirm the importance of designing field experiences that enable diverse modes of participation and enhance social interactions among all participants. In particular, setting clear norms for participation and clarifying how people with different abilities and orientations can participate is critical to engaging women, people of color (Nelson et al., 2017), and people with disabilities (Atchison et al., 2019; Feig et al., 2019). Implementing such norms for the whole group can mitigate stigma for students from backgrounds that have been historically excluded or marginalized. How these norms are framed may depend on the challenges of the fieldwork location and on the particular instructors and students involved, but the norms ought to be communicated up front and monitored along the way. Likewise, representations of fieldwork in promotional materials should portray participants with more diverse social identities in different kinds of natural settings and, where relevant, provide information about supports (e.g., financial support) for participation.

Our observations of geological field courses in mountain and coastal regions affirm recent calls for careful choice of locations for fieldwork toward facilitating more equitable participation, which could include settings with more stable and even terrain, such as outcrops along roads (Atchison et al., 2019; Feig et al., 2019). In addition, we observed that how an instructor selects locations for specific activities within the general region can matter much to who is able to participate—and on what terms. In addition to the type of terrain, how much hiking is required on a daily basis seems to be an especially important consideration. Human-designed learning environments like virtual field trips (Klippel et al., 2019) or geoscience gardens on campus (Waldron et al., 2016) can serve as alternative options to learning in the wilderness.

Personnel in geoscience departments may wish to collect data from faculty, students, and administrators to tailor and structure design considerations and norms for participation as they create accommodations or interventions. Some campuses, like the University of Washington, have already begun to do this (see Woodgate et al., 2018). A recent survey of 161 geoscience instructors revealed that instructors have addressed the needs of students with disabilities by (a) modifying pedagogy, (b) tailoring department or instructor accommodations, and (c) adjusting curricula, such as by establishing different tracks in the major, making field-based courses optional, or redesigning courses to be accessible to all students (Carabajal and Atchison, 2020).

In conclusion, there is still much to be learned about advancing more equitable cultural practices in geoscience fieldwork and geoscience more generally. Yet, more energy than ever is being dedicated to these issues, as evidenced by recent initiatives undertaken by professional associations like the American Geophysical Union's (2019) Ethics and Equity Center, specialized associations like the International Association for Geoscience Diversity (Atchison and Gilley, 2015; International Association for Geoscience Diversity, 2019) and Earth Science Women's Network (Hernandez et al., 2018; NSF, 2018), large fieldwork projects involving interdisciplinary and interinstitutional teams (Iversen et al., 2020), and grant-funded programs by agencies like NSF (Holmes et al., 2015; Karsten, 2019; Posselt et al., 2019). Changing the culture of a profession is never easy, but together these initiatives offer promise in advancing equitable participation of diverse geoscience scholars. Because of its key role in socializing the next generation of geoscientists (Goodwin, 2018; Streule and Craig, 2016), fieldwork should continue to be a central site of research and efforts to foster diversity, equity, and inclusion in the discipline.

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## APPENDIX A: INTERVIEW PROTOCOL FOR UNDERGRADUATE AND GRADUATE STUDENT COURSE

*Introduction:* As you know, I am a professor of higher education, and as part of an NSF study on field-based work in geosciences, I am interested in learning about your experiences as a student, both in this class and in any prior field-based research or teaching experiences. As a reminder, you are welcome to skip any questions you would like and/or to end our interview at any time. Do you have any questions for me before we begin?

<Confirm consent form has been signed. Confirm consent to audiotape.>

Tell me a little about yourself. What is your family and social background? When and how did you first become interested in the geosciences?

> *Probe:* Would you say you or your family was outdoorsy?
>
> *Probe*: [undergraduate]: How did you decide to pursue a bachelor's degree in geoscience? [graduate:] How did you decide to pursue a PhD? [graduate:] To what extent does your own research depend on fieldwork?
>
> What have been your experiences with fieldwork as a student?
>
> *Probe*: Tell me a story about a particularly memorable experience you had in the field as a student.
>
> *Probe:* What about during this class? If you were going to tell a trusted friend about the high point for you of this course so far, what would it be? What has been a low point so far?

Describe your view of the role of fieldwork in your own learning. What do you see as the value of fieldwork that is different from learning through books or in the lab?

Getting to field sites and being there mean all kinds of unexpected or unusual things may happen that fall well out of the scope of what's normal for professors and students. Can you tell me a story about a particularly challenging experience that you had?

*Probe:* How did you resolve the challenges it presented? How do you think it affected the students and their overall field experience?

*Probe:* What are some of the more typical challenges students face in fieldwork? What is your role in supporting them in handling these challenges?

For some students, their social or familial backgrounds can play an important role in their geosciences interest or learning. For example, their gender, race, social class, sexuality, or disabilities may be more prominent than in everyday life. To what extent do you see any of these dimensions as affecting your experience in fieldwork? In this class, specifically? Please discuss.

*Probe:* Positive and negative experiences

Can you share an example of a time that you either felt right at home or like you didn't quite belong in a field experience?

Have you ever experienced overt discrimination in the field, either in this course or otherwise? Please tell me about it, in as much detail as you are comfortable.

*Probe:* What might have prevented this from occurring?

Do you have any thoughts about how the type of field experiences you lead could be redesigned to better include people who often do not participate? To what extent do you think would changing field experiences draw in more students from underrepresented groups?

What advice might you give to students who are about to take part in their first field camp?

What advice might you give to students who are thinking about field camp or a course like this, but who are concerned about going to the middle of nowhere?

Is there a question that I should have asked you that I did not ask? If so, what is that question? How would you answer that question?

Do you have any questions for me as we wrap up?

Thank you very much for taking the time to meet with me. If this conversation has raised any personal concerns for you about your field experiences that you would like to report or process, I have a few trusted colleagues in the geosciences who are not part of your university and would be safe people to talk to. Please email me if you'd like to arrange that sort of conversation.