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# Professionally held perceptions about the accessibility of the geosciences

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## ABSTRACT

**The geosciences are considered by many to be inaccessible to individuals with disabilities. Challenging traditional perceptions of identity in the geoscience community is an important step to removing barriers for students and geoscientists with diverse physical, sensory, and cognitive abilities, and to broadening entry into the myriad fields that make up the discipline. Geoscientists' views of the extent to which a disability would inhibit access to a geoscience career were probed through three separate studies. Results indicate that although opportunities for people with disabilities are perceived to exist in the geosciences, the discipline is considered more accessible to people with some disabilities than others. Most notably, people with hearing impairments are viewed as the most capable of engaging in geoscience careers, visual and cognitive impairments are considered barriers to engagement in geoscience careers or tasks, and people with physical disabilities are perceived as capable of engaging in all but outdoor tasks. We suggest that these individual perceptions result in multiple barriers for people with disabilities: perceptual barriers, training barriers, and community-level barriers. Reducing these barriers will require action across multiple levels to change individual perceptions, training pathways, and social norms for professional engagement.**

## INTRODUCTION

The geoscience workforce is the least diverse of all science, technology, engineering, and mathematics (STEM) disciplines (Huntoon et al., 2015). Although scholars recognize barriers of entry for women and underrepresented minorities into STEM disciplines (Taber-Doughty, 2015), very little research has considered the role that social bias and stereotype play in creating barriers to the geosciences for individuals with disabilities. Ultimately, low enrollment of individuals with disabilities in geoscience training programs (Gonzales, 2009) translates into low representation of geoscience professionals with disabilities in the workforce (Wilson, 2014). Several factors could promote this underrepresentation: perceptions held by people with disabilities that scientific workplace environments are inaccessible; instructional norms that require inaccessible activities (e.g., fieldwork) as part of training requirements; and/or current geoscience practitioners' perceptions about the abilities of people with

disabilities. In many ways, the perceptions of people currently in the workforce can have a stronger effect on access and opportunity than any other variable (e.g., Moss-Racusin et al., 2012). Challenging perceptions of ability in the geoscience community may remove barriers to entry into a field that, by virtue of the diversity of workforce needs, offers unique opportunities for individuals with disabilities.

Disability will impact each one of us at some point during our lives. In fact, everyone lives on a spectrum of ability where the environment must be altered through assistive devices to accommodate our changing physical or sensory abilities. The majority of disabilities are acquired after birth, and not all acquired disabilities are temporary. For example, less than 17% of individuals with a disability in the UK are born with their disabling condition; the rest have acquired their condition through illness, accident, or normal aging (Employers Network for Equality and Inclusion [ENEI], 2014). Four out of five individuals who acquire a permanent disability are gainfully employed at the time of the onset of their disabling condition. Within two years of onset, only 36% of these same people remain employed (ENEI, 2014), suggesting that most workplace environments are unable to provide appropriate accommodation to keep their employees productive contributors to the workforce. Providing accommodation would include creating inclusive pathways into the workforce for career-seeking individuals, challenging social perceptions of ability, and providing opportunities for adaptation and accommodation for those individuals already in the workforce.

## DISABILITY AND SCIENCE

The underrepresentation of people with disabilities is evident in both STEM training programs and the workforce. Seventeen percent of Americans aged 21–64 report living with a disability (Brault, 2012), although only 6% of the 5.4 million members of the STEM workforce have a disability (National Science Foundation, 2013). Similarly, only 11% of undergraduate students and 7% of graduate students with a documented disability are pursuing STEM majors in the United States (Ellis et al., 2007), and only 4.8% of students entering the STEM workforce self-disclose a disability (Burrelli and Falkenheim, 2011). Taken together, there are ~75% fewer individuals with disabilities represented in the STEM workforce than in the general population.

Recruiting and retaining members of underrepresented groups into STEM disciplines may be a key to addressing anticipated workforce shortages in STEM fields (Tsui, 2007). Focusing on diversifying the workforce will allow access to a larger population of potential employees who possess diverse skills, abilities, and perspectives of the environment (Atkinson and Mayo, 2010; Gonzales and Keane, 2010). Despite significant effort, the STEM disciplines remain relatively non-diverse (NRC, 2013). In the geosciences, for example, several decades of efforts intent on recruiting and retaining individuals from underrepresented populations have had limited success (Velasco and de Velasco, 2010). Perhaps more than any other group, people with disabilities are severely underrepresented within STEM fields (Dick and Golshani, 2008).

Individuals with disabilities face unique challenges as they pursue STEM careers. First, many will likely encounter common social biases and stereotypes about physical and intellectual disability and the abilities required to engage in a STEM career (Slaton, 2013). During career training, access to inclusive education, particularly education aligned with current and anticipated career opportunities, is perhaps the most important variable for ensuring individuals with disabilities obtain gainful employment post-graduation (Dick and Golshani, 2008). Additionally, faculty who have undergone professional development around inclusive instructional design and utilizing accommodation strategies for students with disabilities have been shown to have more positive attitudes toward such students in the classroom (Lombardi et al., 2013), suggesting that faculty attitudes toward access and accommodation are both important and malleable.

## ■ DISABILITY AND GEOSCIENCE

Over the next decade, employment opportunities within many subdisciplines of the geoscience workforce are anticipated to grow as 48% of the current geoscience workforce approaches retirement (Wilson, 2014). Creating opportunities to broaden participation in the geosciences is one approach to expanding the talent pool of competitively trained candidates to meet projected workforce shortages (Karsten, 2003). Past initiatives to diversify the geoscience workforce have largely been aimed at increasing graduation rates across genders (Holmes et al., 2008) and ethnicities (Velasco and de Velasco, 2010; O'Connell and Holmes, 2011). Very few of these efforts consider individuals with disabilities (NRC, 2013), although people with disabilities are found within every population regardless of sex, race, or ethnicity. Recent efforts have been made to expand awareness for including more students with disabilities in geoscience programs (Atchison and Martinez-Frias, 2012; Atchison and Gilley, 2015; Gilley et al., 2015), including a growing discussion about the accessibility of geoscience training programs, mentorship, and employment opportunities (Atchison and Libarkin, 2013; Callahan et al., 2015).

Common barriers into many fields, including the geosciences, include physical access to training or field sites (Hall et al., 2002); attitudes of instructors, employers, and peers (ENEI, 2014); and institutional barriers such as

financial and logistical constraints and concerns about liability (Healey et al., 2002). A pervasive belief of the general public suggests that disabilities severely limit engagement in everyday activities, with a common notion that people with disabilities have low productivity (ENEI, 2014). Pervasive attitudes that the geosciences require physically fit practitioners working in the field are reinforced throughout promotional materials of most prominent undergraduate geoscience programs (e.g., Sexton et al., 2014) despite the fact that geoscience training and careers can be as varied and accessible as any other discipline. These subliminal messages may be actively discouraging individuals with disabilities from considering geoscience as a viable career option as well as reinforcing negative stereotypes about the role of ability in geoscience workforce development.

## ■ REQUISITE SKILLS IN GEOSCIENCE

A number of studies have considered the relationship between geoscience training and performance on specific skills, including systems thinking (e.g., Assaraf and Orion, 2005; Orion and Kali, 2005), spatial ability (e.g., Herrstrom, 2000), quantitative reasoning (e.g., Vacher, 2000), and conceptual understanding (e.g., Libarkin and Anderson, 2005). Despite this attention to the impacts of geoscience instruction on a variety of skills, the specific requisite skills needed for basic geoscience activities are still unclear. The diverse nature of the geosciences as a discipline and the range of potential careers in geoscience make articulating specific core skill sets difficult. In the UK and Canada, surveys of mining and oil industry employers indicate that employers value non-geologic skills, including computer skills, business skills, and a broad range of soft skills such as time management (Heath, 2000, 2005). Geoscience skills were actually viewed as less vital than these transferable skills by the surveyed oil companies. A similar study of mining, petroleum, and public sector organizations in Canada also highlighted the importance of transferable and non-technical skills for the successful geoscientist (2002). Geoscientists working in organizations that serve the oil industry were also found to need more computer skills and fewer geologic skills than those working for oil companies, again highlighting the importance of transferable skills for geoscience careers. Taken together, these studies suggest that the skills necessary for success in geoscience careers are not necessarily the ones upon which geoscience programs focus.

## ■ THE CURRENT STUDY

The projected shortage in the geoscience workforce creates an opportunity for academic programs to drive the development of future geoscience graduates who are uniquely qualified for specialized workforce needs. Individuals emerging from inclusive training programs with diverse skills, abilities, and perspectives about the natural environment would competitively align to growing workforce opportunities, and alleviate the impending work-

force shortage. Thus, the pathway from training to career can focus on the specialized strengths and abilities of individuals rather than limiting entry into the geosciences.

While some work has been done to include students with disabilities in specific settings, for instance, to allow students with visual disabilities to engage in oceanography (Fraser, 2008), a review of the literature did not identify any broader studies of the community-level factors that may hinder participation in the geosciences. Given the importance of individual perception on access (e.g., Moss-Racusin et al., 2012), this paper addresses this research gap through considering two questions: (1) What perceptions do professional geologists hold about the ability of a person with a disability to engage in the geosciences; and (2) How do these perceptions compare across disability types? This paper describes three separate studies that when combined investigate the perceptions that geoscientists hold about the ability of people with disabilities to perform geoscientific tasks and engage in geoscience careers.

## METHODS

This work is separated into three distinct studies that speak to the common research question. The first study utilized an open-ended survey collecting participants' perceptions of people with disabilities; the second disseminated a mixed-methods survey collecting perceptions of specific jobs; and the third used a mixed-methods survey collecting perceptions about specific tasks. Data were collected at three different professional geoscience meetings, two in the United States and one in Australia.

### Materials

Surveys were used in each of the three studies. All three surveys targeted perceptions of geoscience careers, with specific focus on openness to individuals with different kinds of disabilities. Each survey was designed in response to previous results, such that Studies 2 and 3 were informed by earlier studies. Each survey also collected data on key demographics, including age, gender, ethnicity, and geoscience experience.

Study 1 utilized an open-ended survey to probe participants' experience with people with disabilities and general perceptions of existing opportunities for people with disabilities in the geosciences. A set of questions asked participants to articulate career options that would or would not be viable for people with five types of disability: hearing impairment, visual impairment, severe learning or reading impairment, moderate physical impairment such as arthritis, and severe mobility impairment such as a paralysis or amputated limb.

Study 2 built on Study 1. The core of the Study 2 survey listed 20 geoscience careers sampled from a set developed by the American Geoscience Institute (<http://www.agiweb.org/workforce/brochure.html>). Participants were asked to indicate whether or not someone with a specific type of disability

would be able or unable to engage in that career. Five different types of disabilities were listed, as in Survey 1, with a modification of the language used to describe the two types of physical impairment based on respondent feedback.

Survey 3 built on the prior two studies. The core of the Study 3 survey asked whether or not people with disabilities would be able to engage in specific geoscience tasks; only four types of disabilities (visual, hearing, physical, and cognitive) were probed based on findings from the prior two studies. The geoscience tasks included on the survey were distributed across four types of activities that were identified in Survey 1 analysis (field, laboratory, technological, and educational), with three tasks listed per activity type.

## Participants

### Study 1

Seventy-three (73) attendees at a U.S. geoscience conference completed the Study 1 survey. The study sample was evenly divided between males and females, with one participant declining to respond. Participants had an average age of  $33.4 \pm 13.3$  years and were 84.9% Caucasian only, with additional African/African-American/Black, American Indian, Latino(a), and Asian participants. Educational level of participants ranged from undergraduate geoscience majors through professional geoscientists, with 20.5% holding doctorates.

### Study 2

One hundred forty-one (141) participants at an international geoscience conference responded to the Study 2 survey; subsequent removal of incomplete surveys yielded 121 surveys used in this analysis. The study sample was 62% male, had an average age of  $40.4 \pm 12.8$  years and was 61% Caucasian only, with additional African, African-American, Black, Latino(a), and Asian participants. Participants originated from 34 countries. Educational level of participants ranged from undergraduate geoscience majors through professional geoscientists, with 57% holding doctorates.

### Study 3

One hundred forty-nine (149) Study 3 surveys were collected from participants at a U.S. geoscience conference. The study sample contained one more female than male, with four participants declining to respond. The sample had an average age of  $32.7 \pm 15.1$  years and was 81.2% Caucasian only, with additional African/African-American/Black, American Indian, Latino(a), and Asian participants. Educational level of participants ranged from undergraduate geoscience majors through professional geoscientists, with 21.4% holding doctorates.

## Procedures

### *Survey Procedures*

Participants in all three studies completed the survey at a conference exhibit hall booth. Study 1 and Study 3 participants were offered a snack as incentive for completing the survey. Study 2 participants were asked to voluntarily complete the survey without incentive. Surveys required between 10 and 20 min to complete. Human-subject protocols were followed for all three data collections.

### *Analytical Procedures*

In Study 1, analysis of open-ended responses proceeded through thematic content analysis of dominant themes. Both authors analyzed responses separately and independently identified codes emerging from the data. The authors then discussed overlaps between codes and developed a common coding schema. One author independently re-coded the data, followed by a collaborative review of codes and collective re-analysis where needed. This re-analysis was necessary for <10% of the responses coded (91% agreement). The strong overlap between originally identified independent codes and the minimal re-analysis required after the second coding indicate strong interrater agreement and reproducibility. Qualitative analysis in subsequent studies followed these pre-identified codes.

For closed-ended questions in Studies 2 and 3, a response that a person would be able to engage in a career and/or task was scored as a “2”; an unsure response was scored as a “1”; and a response that a person would not be able to engage was scored as a “0.” Exploratory factor analysis (Costello and Osborne, 2011) was performed to identify underlying relationships between quantitative responses. The intent of the factor analysis was, first, to determine if participants responded to questions in consistent ways and, second, to calculate individual factor scores that could be used in further analysis. A varimax rotation was used to generate the simplest solution in which items loaded on one and only one factor—any items loading over 0.32 on two or more factors (Tabachnick and Fidell, 2001) were removed from the analysis. Cronbach's alpha for each factor was then calculated as measure of internal consistency of scales. Finally, average scores for each factor were calculated, and independent t-test analyses were run to determine differences in perceptions across demographic groups.

## ■ RESULTS

We report here on those data that are most helpful at understanding participant background and perceptions relevant to our research questions. We report each study separately and follow this with a discussion of the studies in aggregate.

## Study 1

Study 1 utilized qualitative measures and provided an opportunity to gain a better understanding of how geoscientists as a community relate to the concept of disability. An open-ended statement asked participants to describe what comes to mind when they read the word “disability.” Twenty-two percent of respondents considered disability to be something that hinders the ability to perform tasks, such as is seen in this description: “Having a mental or physical condition that makes the way you function different than what society sees as “normal.” Overall, 26% of participants used language such as abnormality, normal, or non-normal in their explanations. Interestingly, over half (52%) explicitly described general physical disabilities in their responses. For example, respondents wrote “Physical disability, e.g. wheelchair bound” and “not possible to do something because of physical reason related to someone's body.” Most often, discussion of physical disabilities was coupled with other types of disability. This often manifested as discussion of “physical or mental” limitations, such that the word physical could encompass mobility, visual, hearing, and other body-based disabilities. While cognitive (including “mental” or “neurological”) disabilities were mentioned by 31% of respondents, explicit discussion of psychological, visual, or hearing impairments occurred in less than 10% of responses.

Ninety-two percent of participants (n = 73) indicated that opportunity exists for people with disabilities to engage in the geosciences, with 25% of these participants placing limitations on the types of opportunities. Only two respondents indicated that no such opportunities existed. Participants tended to focus most closely on physical disabilities or technology when thinking about the intersection of geoscience opportunity and disability. For example, one participant articulated “Yes! Even physically disabled people can do lab work + computer - based geoscience (modeling, etc).” Similarly, one participant suggested that geoscience opportunities existed, “although field work would be difficult and some places impossible for a physically handicapped person to access.” Recognition of the potential for opportunities for people with visual or cognitive disabilities also occurred although in very few responses.

Participants also differed in their view of the geosciences as a field. For example, one respondent indicated that “[Being disabled in the geosciences is] definitely an uphill battle because geology is often very physical and sensory. That said, I think there are branches of geology which present opportunities ... and it's important to give these students a chance to learn about the natural world.” One participant suggested that the geoscience curriculum may be an impediment, stating: “... unfortunately there is so much focus on fieldwork which may not be done by some w/disabilities.” A different participant had the opposite view, suggesting that geosciences were perfectly accessible because “geosciences to me are more of a cognitive science, where your only limit is your imagination.”

Participants displayed a range of ideas about the viability of geosciences for people with disabilities (Fig. 1). In general, people with visual impairments were considered to be nonviable candidates for geoscience careers, with only

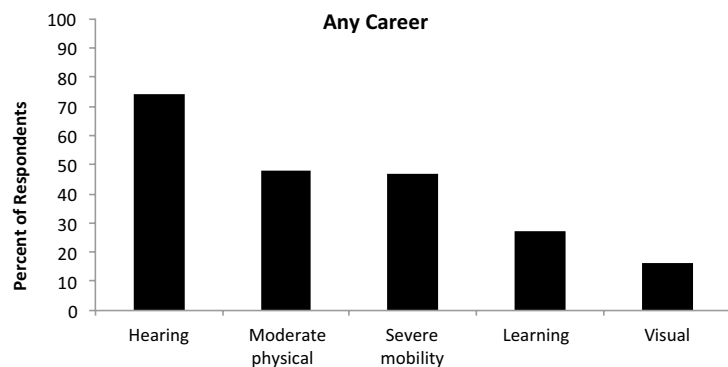


Figure 1. Percentages of participant responses suggesting availability of general geoscience career opportunities relative to various disability types.

16% of respondents indicating one or more geoscience career pathway for these individuals. Careers for people with learning impairments were also considered of low viability. People with hearing impairments were considered to be the most viable, with over 70% of respondents freely articulating at least one, and often multiple, career options. About 50% of participants considered individuals with physical impairments, regardless of severity, to be capable of engaging in geoscience careers (Fig. 1).

Tasks or careers described by participants in open-ended responses ultimately fell into four natural categories: field, laboratory, technological, and instructional, with perceived viability differing across both career and disability types (Fig. 2). In the radar graph in Figure 2, disability type is graphed against the percentage of participants who freely mention a viable career type for people with that disability. Overall, the larger the area encompassed by a disability line, the greater the percentage of participants who considered geoscience careers generally viable for people with that disability. People with hearing impairments, the larger outer polygon, were viewed as most able to engage in the geosciences, while people with visual impairments, the small polygon centered near the origin, were viewed as least able. The shape of the polygon also provides visual evidence about which career types are most viable. Instruction-related careers were viewed as least viable for all disability types, as evidenced by graphical distance from the origin. Careers that tend toward lab and technology represent the most viability for individuals with disabilities. Field-oriented careers were viewed as more viable for people with hearing disabilities than other disability type.

Further consideration of perceptions across each disability type indicates that 71% of participants considered technology-related careers as viable options for people with hearing impairments, and over 50% indicated that field or lab careers were also viable options. Interestingly, instruction-related careers for people with hearing impairments were only mentioned as viable by 34% of participants. Many participants saw hearing impairment as a minor impedi-

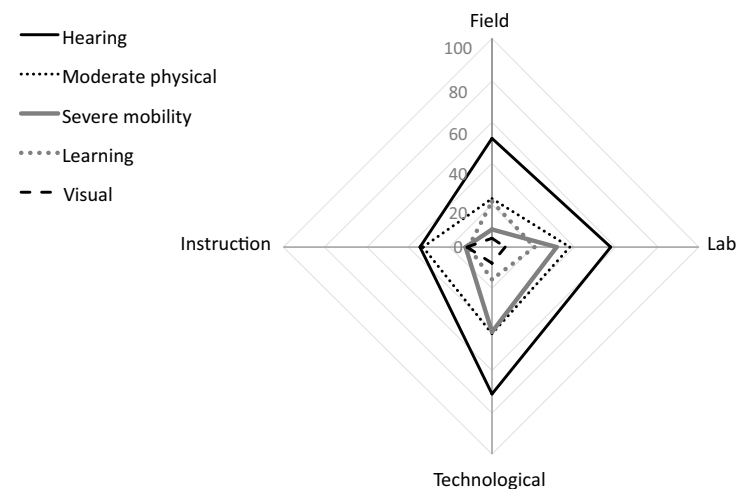


Figure 2. Radar graph of participant responses suggesting availability of specific geoscience career opportunities relative to various disability types.

ment, as in this response: “I don’t use my hearing to do geoscience work.” Less than 6% of participants explicitly indicated specific areas of geoscience that would not be viable for someone with a hearing impairment, suggesting that such a person would not be able to do “solo field work,” “lab or field heavy work,” or “teaching [since teachers] need to be able to communicate with students.”

Individuals with mobility impairments were also viewed as viable candidates for geoscience careers (Fig. 2), with over 40% of participants articulating one or more potential career paths. Technological, lab, and instructional careers were identified as generally viable, while field careers were generally not considered to be particularly viable for people with physical impairments. Over 30% of participants explicitly described field careers as outside the realm of someone with a severe physical impairment, as in this response, “Obviously, driving/field research will be limited, but laboratory/theoretical research should not be drastically affected.”

Participants generally articulated fewer career options for people with learning or visual impairments and were generally more likely to be explicit about nonviable career options (Fig. 2). Field and lab careers were considered to be the most viable for someone with a learning impairment and the least viable for someone with a visual impairment. Instruction and technology careers were considered to be viable for both disability types by a small number of respondents. Generally, respondents indicated a lack of understanding of possible career paths for people with visual or learning impairments. For example, one participant indicated: “Geosciences are really visual so if someone weren’t able to fully see things (sample, graphs, data), most geoscience

careers would not be viable." Similarly, another participant indicated, "Learning impairments would not go well with geoscience careers because I think the best geoscientists are keenly observant at all times - not just when their brain chemistries [sic] are "right!"

## Study 2

Study 2 probed participant perceptions of the accessibility of specific geoscience careers to people with disabilities via both qualitative and quantitative approaches. Much like Study 1, participants were asked to reflect on the nature of disability and their experience with people with disabilities. This set the stage for participants to reflect on the extent to which people with severe physical, limited physical, visual, hearing, and cognitive impairments would be able to engage in careers such as cartography, environmental journalism, and paleontology.

### Qualitative Results

Participant reflections on disability were similar to Study 1. Of most interest here are two questions—one related to perceptions of resources needed to help students with disabilities become successful geoscientists and one related to the necessity of fieldwork in geoscience training. Participant responses to the first question reflect the diversity of interpretations of what "disability" means. Many respondents reflected on specific accommodations that students might need, such as "visual aids," "ramps," and "for sight-challenged students—a more detailed description of features." Other respondents suggested individuals, either teachers or personal mentors, could serve as guides to students, and that instructors would need to be adaptable to student needs. Still other respondents suggested that geoscience might simply be inaccessible, indicating that "Sometimes it is just not possible! Depending on disability" and that changing the "mentality of the rest [of] society" might be necessary before geosciences could become accessible.

Focusing narrowly on fieldwork, an experience included in most geoscience undergraduate training, was insightful. The vast majority of participants (79%) felt that fieldwork was a necessary component of geoscience training. A much smaller group (19%) felt fieldwork was not necessary, and 2% were unsure of fieldwork's role in geoscience training. Proponents of fieldwork indicated that students needed to "see/feel/sense the rocks!"; that "Hands-on knowledge is always vital," and that "Without some field experience, an individual with a geoscience degree/career is greatly disadvantaged." One respondent went so far as to state that, "Unless one feels the work in its natural environment, nobody should aspire to call himself a geologist." Those respondents who felt fieldwork was not necessary indicated that "some laboratory work ... can be carried [out] without field experience"; that "Laboratory and modelling are also 'geoscience' and also allow a standard career"; and that "There are many areas where field experience is unnecessary [geochemistry, geophysics]."

Taken together, these responses suggest some respondents view geoscience as geology first, as evidenced by the view that fieldwork is necessary. Other respondents have a broader view of geoscience and recognize that fieldwork is one aspect of the broader geoscience endeavor.

### Scale Psychometrics

The factorability of all quantitative items in Study 2 was investigated through exploratory factor analysis. Initial analysis indicated little structure in the "severe" physical impairment items. This prompted removal of this category from the analysis. Criteria demonstrating factorability were then considered for the remaining 80 items (20 jobs by four disabilities). First, the majority of the codes correlated with many other items at a level over 0.3, indicating that a factor structure could be expected to emerge. The Kaiser-Meyer-Olkin measure of sampling adequacy was 0.792, well above the 0.6 value recommended for factor analysis. Bartlett's test of sphericity was significant ( $\chi^2$  (3003) = 12,882.8,  $p < 0.001$ ). Communalities for all but three items were above 0.3, with most over 0.7, indicating shared variance with other codes (Tabachnick and Fidell, 2001; DeVellis, 2012; Table 1). Given these data, exploratory factor analysis was performed on all items.

Four factors emerged from the exploratory analysis based on both eigenvalues  $\geq 1.0$  and standard scree plot analysis. Closer investigation of factor loadings indicated that all four factors contained at least three items that loaded at  $>0.32$ , and items were grouped based on disability category. Two physical ability items were poorly loaded and were removed from the model, resulting in the final factor structure (Table 1). The factor structure explained 62.6% of data variance, with the first factor explaining 29.5% of the data variance, the second factor 17.1%, the third 9.7%, and the fourth 6.3%.

As can be seen in Table 1, three careers did not factor into the job viability scale for people with physical disabilities: environmental journalism, park service ranger, and teaching. This lack of factorability indicates that these three careers are seen differently than other geoscience career types. Interestingly, these three careers can be considered communicative, since journalists, rangers, and teachers are all tasked with conveying information to non-experts. In Study 1, teaching careers were also generally seen as limited for people with more than moderate physical disabilities. The underlying cause for the lack of relationship between these three careers and the overall scale measuring ability to perform geoscience jobs may reflect underlying assumptions about disability and communication; this aspect of the study warrants further research.

Cronbach's alpha was calculated for each factor to consider internal consistency. All four factors resulted in alphas over 0.9, indicating high internal consistency across items. The Physical Ability Jobs scale produced an alpha of 0.91, the Visual Ability Jobs scale produced an alpha of 0.95, the Hearing Ability Jobs scale produced an alpha of 0.96, and the Cognitive/Learning Ability Jobs scale produced an alpha of 0.98. Taken together with the factor analysis, these results indicate that respondents were highly consistent in their views of the types of geoscience jobs people with various disabilities could perform.

TABLE 1. FACTOR LOADINGS AND RESPONSE AVERAGES FOR ABILITY TO PERFORM JOBS SCALES

Item	Factor loadings				Response averages (max = 2)			
	Physical	Visual	Hearing	Cognitive	Physical	Visual	Hearing	Cognitive
Atmospheric science	0.490	0.626	0.797	0.867	1.84	1.06	1.77	1.03
Cartography	0.359	0.436	0.752	0.817	1.74	0.58	1.83	1.19
Economic and petroleum geology	0.633	0.721	0.779	0.906	1.49	0.93	1.74	1.01
Engineering geology	0.630	0.717	0.728	0.941	1.48	0.90	1.69	1.02
Environmental journalism	—	0.431	0.634	0.815	—	1.38	1.65	1.12
Geochemistry	0.464	0.605	0.841	0.892	1.80	0.98	1.79	1.02
Geomorphology	0.551	0.765	0.831	0.942	1.45	0.71	1.74	1.04
Geophysics	0.684	0.688	0.787	0.919	1.64	0.81	1.76	0.98
Geospatial information science (GIS)	0.421	0.616	0.856	0.909	1.93	0.60	1.83	1.09
Hydrology	0.759	0.792	0.815	0.952	1.52	0.88	1.74	1.03
Oceanography	0.742	0.756	0.913	0.914	1.43	0.85	1.76	1.02
Paleontology	0.699	0.827	0.839	0.923	1.52	0.63	1.75	1.06
Park Service Ranger	—	0.709	0.542	0.704	—	0.60	1.37	1.12
Petroleum geology	0.649	0.811	0.808	0.946	1.58	0.82	1.71	1.01
Petrology	0.552	0.713	0.822	0.955	1.65	0.64	1.74	1.03
Remote sensing	0.541	0.619	0.867	0.927	1.79	0.62	1.75	1.03
Sedimentology	0.756	0.844	0.895	0.937	1.45	0.74	1.75	1.07
Soil science	0.743	0.822	0.850	0.920	1.40	0.77	1.74	1.01
Structural geology	0.677	0.759	0.850	0.944	1.20	0.62	1.74	1.02
Teaching	—	0.381	0.556	0.771	—	1.35	1.48	0.96
Average scale scores					1.58 ± 0.50	0.82 ± 0.65	1.72 ± 0.51	1.04 ± 0.81

Note: Dashes indicate items did not load on factor.

### Quantitative Results

Average scores across these scales indicate the extent to which the ability to engage in specific geoscience careers is perceived to depend upon disability status. An average score of “2” is the maximum possible, and scores close to this suggest that geoscience in general is viewed as a viable career. An average score close to “1” suggests that the community is unclear about whether or not the career is viable, and a score closer to “0” suggests that the community believes the career would not be viable. Across the different careers, people with hearing and physical impairments were viewed as most able to engage in the geosciences, with scores of 1.72 and 1.58, respectively. People with visual (0.82) and cognitive (1.04) impairments are viewed as least able to become geoscientists.

For each career, average scores across the four disability types are also illuminating. Average scores ranged from 0.58, the ability of people with visual impairments to engage in cartography, to 1.93, for the ability of people with physical impairments to engage in GIS. Almost all careers were viewed as unlikely for people with visual impairments, with 17 careers receiving an average score of less than 1.0. Three careers that were considered most possible for people with visual impairments were atmospheric scientist (1.06), teaching (1.35), and environmental journalism (1.38). Both teaching and journalism are

highly communicative fields, which may explain the smaller role that visual impairment appears to play in their perceived viability.

Only two careers, teaching (0.96) and geophysics (0.98), received scores lower than 1.0 for people with cognitive impairments, and no careers scored below 1.0 for physical and hearing impairments. The highest scoring career for people with cognitive impairments was cartography with a score of 1.19. The mean close to 1.0 and the small variance across careers suggest respondents were generally unclear about whether or not people with cognitive impairments would be able to engage in any geoscience careers. Although disabilities come in many shapes and sizes, cognitive disabilities might be the least well understood by respondents. Respondents may have been unclear about whether a person with a cognitive impairment had a learning disability or was more severely impaired.

People with physical and hearing impairments were seen as most able to engage in a variety of geoscience careers. The lowest scoring career for people with hearing impairments was park ranger (1.37); for people with physical impairment, the lowest scoring career was structural geologist (1.20). Note that the lowest scoring career for people with physical disabilities was higher than the highest scoring career for people with visual or cognitive impairments. In fact, 16 careers scored over 1.5 for people with hearing disabilities. A similar 12 careers scored over 1.5 for people with physical disabilities; careers that

require physical movement, such as structural geologist, were rated lowest for this group. Technological careers were almost universally seen as viable for someone with a physical impairment. Communicative careers such as teaching (1.48) were considered viable for people with hearing impairments, although data-intensive careers were considered most viable (e.g., oceanography, 1.76).

Independent t-test analyses were run to determine if perceptions of career viability related to respondent characteristics. An independent t-test indicates that women are more likely to believe that people with cognitive impairments would be able to engage in geoscience careers,  $t(119) = 2.57, p < 0.01$ . Respondents who indicated that they had attended a course with someone with a disability were more likely to believe that people with visual,  $t(78.9) = 2.22, p < 0.03$ , or hearing,  $t(108.5) = 2.28, p < 0.02$ , impairments could access geoscience careers. Similarly, respondents who have taught students with disabilities were more likely to believe that the geosciences are a viable career for people with visual impairments,  $t(119) = 3.44, p < 0.001$ , while respondents who had worked with someone with a disability were more likely to believe that hearing impairments would not limit geoscience career viability,  $t(117.9) = 2.03, p < 0.05$ . Other disabilities did not exhibit similar effects.

Finally, those respondents who indicated that they had personal, non-career-related experiences with people with disabilities were more likely to believe that the geosciences were a career option, regardless of disability (Table 2). Physical, visual, and hearing disabilities, and cognitive disabilities to a lesser extent, were seen as much less inhibitive relative to geoscience careers for those respondents with personal experiences through friends or family.

### Study 3

Study 3 extended the findings of Study 2 by probing perceptions of geoscience career viability relative to 12 specific work tasks (Table 3). Qualitative results were similar to the two prior studies and warrant only limited discus-

sion here. First, 93% of participants indicated that field-based experiences are necessary for geoscience training, somewhat higher than Study 2 findings with an international population. Second, Study 3 respondents made recommendations for enhancing the accessibility of the geosciences. Recommendations included one-on-one help in all types of settings, including classrooms, laboratories, and the field, as well as identifying individuals who could assist instructors in creating accessible materials. Ensuring access, whether to the field, classroom, or technology, was also mentioned. One respondent explicitly mentioned adaptation, rather than accommodation, as a resource, explaining that individual students needed “an open mind” and “flexibility in the path to the goal.”

### Scale Psychometrics

The factorability of the 48 items (12 tasks by four disabilities) was investigated through factor analysis based on expected groupings. Items were first considered in groups based on the type of task being performed to evaluate the extent to which task type might influence emergent structure. Analysis of items in four groups based on lab, field, technological, and educational tasks identified no emergent factor structure. Items were then analyzed based on

TABLE 2. INDEPENDENT T-TEST COMPARING RESPONDENTS WITH AND WITHOUT PERSONAL EXPERIENCES WITH PEOPLE WITH DISABILITIES

Disability type	df	t	p
Physical	88.4	2.88	0.005
Visual	119	2.56	0.012
Hearing	74	1.97	0.053
Cognitive	119	1.75	0.082

Note: Italics indicate the t-test was not significant at  $p=0.05$  level. df—degrees of freedom; t—test statistic; p—probability that populations are similar.

TABLE 3. FACTOR LOADINGS FOR ABILITY TO PERFORM TASKS SCALES

Item	Physical: Non-field	Physical: Field	Visual	Hearing	Cognitive
1. Run mass spectrometer to measure isotopic ratios	0.562	—	0.467	0.444	0.665
2. Collect fracture pattern data from rock outcrops	—	0.772	0.396	0.652	0.771
3. Teach a mineralogy course	0.470	—	0.511	—	0.766
4. Analyze resistivity data to describe subsurface stratigraphy	0.684	—	0.616	0.742	0.792
5. Use acid to etch quartz grains	—	—	0.508	0.784	0.647
6. Write GIS code to analyze geographic patterns	0.809	—	0.703	0.745	0.804
7. Evaluate student essays about plate tectonics	0.708	—	0.654	0.553	0.794
8. Build a laser for single-crystal analyses	0.657	—	0.598	0.728	0.760
9. Log GPS data points in the field	—	0.761	0.606	0.809	0.708
10. Collect and analyze earthquake data	—	0.584	0.801	0.697	0.843
11. Supervise undergraduate researchers	0.608	—	0.640	0.412	0.763
12. Take water samples for lead analysis	—	0.770	0.773	0.821	0.601

Note: Dashes indicate items did not load on factor.



the four disability groups, and criteria demonstrating factorability were considered for all four analyses. Within each grouping, the majority of the codes correlated with many other items at a level over 0.3, with communalities for final factor structure over 0.3 for all items. The Kaiser-Meyer-Olkin measure of sampling adequacy was 0.728–0.845, and Bartlett's tests of sphericity were highly significant for all four analyses. Poorly loading items (<0.32) were iteratively removed from the analysis until a stable structure was identified (Table 2). One factor was extracted for each of the visual, hearing, and cognitive scales, while two were extracted for physical (field and non-field).

Cronbach's alpha was calculated for each factor to consider internal consistency. All four factors resulted in alphas over 0.7, indicating high internal consistency across items. The Physical Ability Non-Field Tasks scale produced an alpha of 0.741, the Physical Ability Field Tasks scale 0.720, the Visual Ability Tasks scale 0.845, the Hearing Ability Tasks scale 0.823, and the Cognitive Ability Tasks scale 0.927. Taken together with the factor analysis, these results indicate that respondents were highly consistent in their views of the relationships between disability and task performance.

### Quantitative Results

Average scale scores provide insight into overall perceptions of the ability of different kinds of people to perform specific tasks (Table 4). An average score close to "1" suggests that the community is unclear about whether or not these tasks are possible, and a score closer to "0" suggests that the community believes these tasks would be outside the reach of specific people. Similar to Study 2, people with hearing impairments were seen as most able to engage in geoscience tasks (1.86), and people with physical impairments were viewed as highly able to engage in non-field-related tasks (1.78). Respondents felt people

with cognitive impairments might be able to complete geoscience tasks (1.32). Respondents were unsure if people with visual impairments would be able to engage in geoscience tasks (1.05), or if people with physical impairments could do field-related tasks (1.23).

Four tasks make up the Physical Ability Field Tasks scale: *collecting fracture pattern data from rock outcrops*; *logging GPS data points in the field*; *collecting and analyzing earthquake data*; and *taking water samples for lead analysis* (Table 3). Although the earthquake data task was intended as a laboratory task, the respondents viewed it as a field task. One task—*using acid to etch quartz grains*—did not correlate with either Physical Ability scale; respondents were split on their view of the physical ability needed to perform this task. All items corresponded to the other three scales, except *teaching a mineralogy course* for the Hearing Ability Tasks scale.

Average scores for each scale ranged from 0.53, for people with visual impairments collecting fracture pattern data, to 1.9 for people with physical impairments evaluating student essays. Five tasks, mostly laboratory or field activities, received an average score of less than 1.0 for people with visual impairments, and a sixth task received a score less than 1.0 for physical impairments. All other task averages were above 1.0 (Table 4).

Similar to Study 2, people with physical and hearing impairments were seen as most able to engage in a variety of geoscience tasks. The lowest scoring task for people with hearing impairments was *supervising undergraduate researchers* (1.51), which still received a very high rating; for people with physical impairment, the lowest scoring non-field task was *building a laser for single-crystal analyses* (1.50), also a high rating. All 12 tasks scored over 1.5 for people with hearing disabilities, and seven of the non-field tasks scored over 1.5 for people with physical impairments. In contrast, only three and one of the tasks scored over 1.5 for cognitive and visual impairments, respectively.

TABLE 4. RESPONSE AVERAGES FOR ABILITY TO PERFORM TASKS SCALES (MAX = 2)

Item	Physical: Non-field	Physical: Field	Visual	Hearing	Cognitive
1. Run mass spectrometer to measure isotopic ratios	1.65	—	0.78	1.83	1.20
2. Collect fracture pattern data from rock outcrops	—	0.95	0.53	1.90	1.43
3. Teach a mineralogy course	1.90	—	1.17	—	1.18
4. Analyze resistivity data to describe subsurface stratigraphy	1.83	—	0.85	1.88	1.30
5. Use acid to etch quartz grains	—	—	0.80	1.92	1.56
6. Write GIS code to analyze geographic patterns	1.88	—	1.14	1.94	1.15
7. Evaluate student essays about plate tectonics	1.96	—	1.25	1.93	1.19
8. Build a laser for single-crystal analyses	1.50	—	0.80	1.78	1.13
9. Log GPS data points in the field	—	1.16	1.04	1.87	1.56
10. Collect and analyze earthquake data	—	1.58	1.27	1.89	1.38
11. Supervise undergraduate researchers	1.90	—	1.51	1.70	1.24
12. Take water samples for lead analysis	—	1.14	1.37	1.89	1.63
Average scale scores	1.78 ± 0.28	1.23 ± 0.56	1.05 ± 0.51	1.87 ± 0.26	1.33 ± 0.53

*Note:* Dashes indicate items did not load on factor.

Independent t-test analyses were run to determine if perceptions of task-related ability corresponded to respondent characteristics. Women are more likely to believe that people with cognitive impairments can engage in geoscience tasks:  $t(140) = 1.98, p < 0.05$  (similar to Study 2). Respondents who indicated that they had attended a course with someone with a disability were more likely to believe that people with visual impairments could perform geoscience tasks,  $t(143) = 2.38, p < 0.02$ . Interestingly, no relationships were found between people who had taught students with disabilities and their perceptions of whether or not geoscience tasks could be performed by these groups.

## ■ DISCUSSION

These three studies collectively provide a window into practitioner perceptions of people with disabilities, perceptions that will impact how people with disabilities gain entry into the discipline. Based on these studies, we argue that the inclusion of individuals with disabilities in the geosciences is hindered by three levels of barriers: (1) perceptual barriers, (2) training barriers, and (3) community-based barriers. These three barriers result from perceptions of an individual's ability to participate in geoscience-related activities, the lack of opportunities for accessible training, and the ability to be included and engaged within the broader scientific community.

### Perceptual Barriers to Inclusion

Perceptual barriers to inclusion arise from social bias and stereotyping and the assumption that someone cannot perform a task or complete a job due to a disability (ENEI, 2014). In our studies, different disability types generated different reactions from study participants. Geoscientists perceived people with hearing impairments as having the most opportunity to engage in geoscience careers, although some participants had reservations about the ability of a person with a hearing disability to engage in field or classroom tasks. In general, participants indicated that someone with a physical disability would be able to engage in most geoscience-related tasks, albeit with limited opportunity to engage in fieldwork. People with visual or cognitive disabilities were viewed with either uncertainty or as essentially unable to effectively engage in geoscience careers. On face value, these results are mixed. On the one hand, based on these results, someone with a physical or hearing disability would face lower perceptual barriers at entry into the geosciences. On the other hand, individuals with visual or cognitive disabilities would likely be viewed with doubt or apprehension, inhibiting access to career opportunities.

Geoscientists' views of people with disabilities were quite similar to stereotypes and biases documented in the general public (Munyi, 2012; ENEI, 2014). Participants held a generally superficial view of disability that was misaligned with the actual prevalence of disability within society. In general, few participants held broader understandings of disability, which is similar to the lack of

understanding of disability found within society at large. This suggests that barriers to access in the geosciences are similar to social biases and stereotypes of ability found in society. For example, although only 1.5% of people with disabilities in the general population use wheelchairs (Braut, 2012), overt physical disabilities and wheelchair use were prominently aligned with views of disability. More realistically, the vast majority of disabilities are non-apparent. In fact, so many disabilities are nonapparent that it is likely geoscientists are simply unaware of the people with disabilities who surround them.

Much as scientists who identify as LGBT have been encouraged to become more visible (Waldrop, 2014), perhaps geoscientists with disabilities might also self-promote their abilities and successes. The lack of understanding about what people with disabilities can do, particularly in the context of geoscience careers, may also stem from limited publicity of people with disabilities within the geosciences. Very few first-person narratives from scientists with disabilities are publicly available. This is evident from the few cryptic references to people with disabilities made by participants in our studies; for example, a "famous blind paleontologist" was mentioned by several participants. Such documentation of the actual experiences of people with disabilities could go a long way to changing the perceptions of people with disability within the geoscience community.

### Training Barriers to Inclusion

Training barriers to inclusion arise from one's ability to physically and cognitively participate in geoscience-related tasks and activities and obtain the requisite skills necessary to become a geoscience practitioner. This study indicates, unsurprisingly, that geoscientists overwhelmingly believe fieldwork is a necessary component of geoscientific training, similar to what has been suggested by other scholars (McKenzie, et al., 1986; Orion, 1993; Potter et al., 2009). However, a belief that field tasks are a necessary part of practitioner training automatically disqualifies those people who are perceived as physically unable to engage in fieldwork. Based on our results, people with physical or visual disabilities would thus be disqualified by many from training within the geosciences, let alone pursuing geoscience careers.

The geoscience community has not yet reached a consensus about which skills are necessary for geoscience training since all geoscience subfields require different skills sets. Despite the perception that certain activities, such as engagement in fieldwork, are necessary for geoscience training, the geosciences are very clearly a conglomeration of multiple disciplines housed under one broad umbrella (AGI, n.d.). Existing research provides insight into the skills needed for successful careers in industry (Heath, 2000, 2002, 2005), although equivalent work to identify necessary skills in other areas—academia, government, and environmental consulting—is still needed. Perhaps because of this lack of understanding of workforce needs, undergraduate geology programs continue to focus on traditional instructional methods (MacDonald et al., 2005).

Although our studies suggest that the community is open to careers for geoscientists with disabilities, the community seems less open to actually creating inclusive training opportunities for these individuals. Geoscientists who have acquired a disability after training are more likely to remain as welcomed members of the community, whereas individuals with natal or developmental disabilities would have a much harder time gaining entry—this is particularly true where specific activities, such as fieldwork, are required of trainees. This logical disconnect seems to stem from beliefs about what people with disabilities can do or, as we noted earlier, about what actual skills are necessary in the geoscience workplace. Ensuring equitable access first requires that the larger community of geoscientists engage in meaningful discourse around necessary geoscience skills and then develop relevant training pathways open to diverse scholars. Only after we understand the boundaries of the field can we consider how someone with a disability might enter and thrive as a practitioner. Relatedly, understanding the range of diverse careers open to geoscientists will allow the community to adapt and develop training programs to ensure success for individuals with a diverse range of abilities. For example, gateway geoscience courses can be designed to allow differentiated instruction focusing primarily on academically rigorous learning objectives. An inclusive instructional environment, therefore, centers on teaching a range of requisite skills aligned to student ability, rather than a traditional, narrowed curriculum.

### Community-Based Barriers to Inclusion

Community-based barriers to inclusion result from the lack of accommodations made to include everyone in the scientific community. Equitable access to the geosciences goes beyond the classroom and into the geoscientific community of academics, researchers, and practitioners. The perceptual barriers and limited awareness of people with disabilities in the geosciences may result in the continued marginalization of geoscientists with disabilities and further inhibit participation in community-based scholarship and engagement. Individuals with sensory disabilities, for example, may lack opportunities to communicate effectively at professional conferences. Providing services to allow all individuals access to professional opportunities can be quite simple. For example, an individual with visual disabilities at a poster session can be accommodated through rich descriptions of the presentations in an audio conference guidebook, or sign language interpreters and closed-captioning services can provide an opportunity for a person who is deaf or hard-of-hearing to engage with a technical session discussion. Until we provide equal opportunities for access, we cannot be inclusive of the multitude of talents found in our community, and we are certainly not promoting opportunities for future students to consider the geosciences as an open and inclusive career option.

Professional societies and organizations are already considering the importance of access and inclusion. In 2014, the American Geosciences Institute conducted the first diversity leadership forum for their member societies

(Atchison and Houlton, 2014). As a result, a consensus statement focused on access and inclusion has been written and approved by many of the AGI member societies. This consensus statement details the promotion of educational and career opportunities for everyone through reduction of barriers to full inclusion and proactive engagement of individuals with disabilities. This action comes on the heels of the UK *Declaration on Diversity, Equality and Inclusion*, currently being adopted by member bodies of the Science Council, which focuses on challenging prejudice and discrimination and diversifying the STEM workforce (GSL, 2014). The Geological Society of London and the International Association for Geoscience Diversity (IAGD) have also hosted meetings and accessible events in the United Kingdom, the United States, and Canada that promote accessibility in the geosciences (Atchison and Libarkin, 2013; Stokes and Atchison, 2015).

We encourage future studies that engage geoscientists with disabilities in discussing adequacy and inclusivity of training opportunities, how geoscientists with disabilities self-advocate and adapt to a traditionally unaccommodating environment, and new ideas for facilitating access and inclusion. Most importantly, such a study would need to unpack implicit barriers, such as a preference for traditional fieldwork, which may exist within our inherent assumptions of what it means to be a “geoscientist”

Fostering an accessible educational environment for all members of society is a social responsibility (Munyi, 2012). Ultimately, promoting a climate of inclusivity that is focused on diverse skills and abilities, as well as core geoscience competencies, would be beneficial to the geosciences, both for addressing the ongoing workforce shortage and promoting enhanced innovation through diverse scientific perspectives.

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