A Synthesis of Instructional Strategies in Geoscience Education Literature That Address Barriers to Inclusion for Students With Disabilities

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ABSTRACT

People with disabilities make up the largest minority population in the U.S. yet remain sorely underrepresented in scientific disciplines that require components of field-based training such as the geosciences. This paper provides a critical analysis of broadening participation within geoscience education literature through the use of accessible and inclusive instructional practices that support students with physical and sensory disabilities. Common physical and nonphysical barriers that discourage the full participation of students with disabilities in classroom, laboratory, and field activities are illustrated in this review. In areas of limited reportable data relevant in the geoscience-focused literature, a broader science, technology, engineering, and mathematics perspective is provided. Gaps in the literature were identified to include limited empirical evidence on the effectiveness of inclusive curricular design and the limited opportunities for students with disabilities to participate in advanced, multiday geoscience field trips. The purpose of highlighting this collection of literature is to encourage the use of more equitable and inclusive instructional strategies, including alternative strategies and virtual learning environments that increase access and enhance participation for students with physical and sensory disabilities. © *2017 National Association of Geoscience Teachers*. [DOI: 10.5408/16-211.1]

Key words: access, inclusive geoscience education, disability

INTRODUCTION

Geoscience education research dedicated to broadening participation has increased over the last two decades (e.g., Cooke et al., 1997; Hall et al., 2004; Locke, 2005; Atchison, 2011; Atchison and Martinez-Frias, 2012; Gilley et al., 2015; Stokes and Atchison, 2015; Huntoon, 2016; Sherman-Morris and McNeal, 2016). However, a majority of this work has focused on ways to increase retention rates of racial and ethnic minority students (McCune, 2001; Huntoon and Lane, 2008; Baber et al., 2010; Huntoon et al., 2015; Huntoon, 2016; Sherman-Morris and McNeal, 2016). Since 2011, research focusing on access and inclusion for individuals with disabilities has become more prevalent in geoscience education (Adams et al., 2011; Atchison, 2011; Atchison and Martinez-Frias, 2012; Gilley et al., 2015; Stokes and Atchison, 2015; Hendricks et al., 2017). Individuals with disabilities are found in all majority and minority racial and ethnic groups, creating the largest minority group in the United States (Olkin, 2002). Including this population in the discussion of broadening geoscience participation is necessary for developing a more diverse community of geoscientists.

Diversity has been widely recognized as a necessary component of building a strong, innovative science workforce (Velasco and De Velasco, 2010; Atchison and Libarkin, 2013; Huntoon et al., 2015). Individuals with disabilities are not entering the geoscience workforce at the same rates as those without disabilities (NSF, 2017), and as a result, the geoscience workforce remains as one of the least diverse in all science, technology, engineering, and mathematics (STEM) fields (Huntoon et al., 2015; Atchison and Libarkin, 2016). According to the National Science Foundation (NSF, 2017), individuals with disabilities comprise just 9% of the geoscience workforce, lower than the percentage of people with disabilities in the U.S. population (12.6%).

In postsecondary institutions, individuals with disabilities represent 11% of the undergraduate population (NSF, 2017). However, Newman et al. (2011) state that only 28% of all students with disabilities (SWDs) request accommodation services in higher education. These statistical data on SWDs are potentially skewed due to laws (i.e., the Health Insurance Portability and Accountability Act of 1996) that protect individual health identity (NSF, 2017). In other words, data are only reported on students who self-disclose their disability in order to receive academic support services. A number of reasons potentially prevent this self-disclosure, a few of which are discussed later in this paper.

Laws and policies that are intended to support SWDs only support those who self-disclose a disability. These laws are also often vague and left to the interpretation of academic officials. The Americans with Disabilities Act of 1990 (ADA), Section 504 of the Rehabilitation Act of 1973, the Higher Education Opportunities Act of 2008, the Individuals with Disabilities Education Improvement Act of 2004 (IDEA), and the United Kingdom's Special Education Needs and Disability Act (2001) are examples of provisions that guarantee equal educational opportunities for SWDs in federal and privately funded postsecondary institutions. The ADA requires that institutions make reasonable accommodations to individuals case by case. By law, educators in the

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U.S. must provide accessible learning experiences for SWDs (Cooke et al., 1997; Atchison, 2011; Newman and Madaus, 2014). These accommodations should extend the opportunity for an individual to make adequate progress without fundamentally altering the program (McLaughlin, 2012). However, in the case of the geosciences, many instructors are unaware of how these laws affect departmental policies for providing equitable access to both laboratory- and field-based instructional settings (Miner et al., 2001; Locke, 2005). Thus, the determination of reasonable and necessary accommodations are left to instructors rather than to those creating institutional policy. This level of interpretation can create inconsistency across courses, programs, colleges, or even institutions.

MARGINALIZATION OF SWDs

All students are faced with challenges when negotiating certificate and degree programs, but SWDs face additional barriers (i.e., lack of role models, less access to accommodations, and misconceptions of student ability by teachers) that further impede in their participation at the postsecondary level (Alston and Hampton, 2000; Alston et al., 2002; Bargerhuff et al., 2010; Lee, 2011; Newman and Madaus, 2014). This can result in reduced involvement in career preparation in science and mathematics when compared to their able-normative peers (Lee, 2011). Disciplines with field-based study requirements for degree completion exacerbate these barriers (Hall et al., 2004; Locke, 2005; Atchison and Martinez-Frias, 2012; Atchison and Libarkin, 2016). Physical barriers (i.e., field sites and laboratories) and nonphysical barriers (i.e., social and institutional) directly affect the participation of SWDs in the geosciences, as well as other field-focused disciplines (Cooke et al., 1997; Healey et al., 2001, 2002; Miner et al., 2001; Hall et al., 2004; Hall and Healey, 2005; Locke, 2005; Atchison, 2011; Atchison and Martinez-Frias, 2012; Atchison and Libarkin, 2016).

Physical Barriers

The educational benefits of classroom and field-based learning experiences have been well documented in geoscience literature (e.g., Mondlane and Mapani, 2002; Elkins and Elkins, 2007; King, 2008; Pyle, 2009; Mogk and Goodwin, 2012), yet these instructional environments often present many challenges to students with physical and sensory disabilities (Cooke et al., 1997; Asher, 2001; Healey et al., 2001, 2002; Hall et al., 2004; Locke, 2005; Supalo and Mallouk, 2007). Physical barriers are particularly apparent in field-based learning experiences (Healey et al., 2001, 2002), but they can also be pervasive in laboratory and classroom environments (Miner et al., 2001; Norman, 2002; Milic Babic and Dowling, 2015). Educators have attempted to dismantle these physical barriers from instruction by implementing universal design for learning (UDL; Center for Applied Special Technology [CAST], 2012).

UDL is a framework for creating a flexible curriculum that enhances the learning experience for all students (Silver et al., 1998; Rose and Meyer, 2002; Dunn et al., 2012). The main principles of UDL extend access and inclusion to all students by providing multiple means of content representation, opportunities for everyone to participate and engage in the community of learning that best fits their abilities, and diverse strategies of evaluation that enable students to effectively express their knowledge and understanding (CAST, 2012). These principles can be found in the inclusive instructional design and accommodation techniques presented in the literature from many geoscience education researchers (Cooke et al., 1997; Asher, 2001; Greenberg, 2002; Atchison, 2011; Wild et al., 2013; Atchison and Gilley, 2015; Stokes and Atchison, 2015). Inclusive instructional design generates many innovative instructional strategies (i.e., tactile field maps, audio-recorded field guides, multiple representations of content, and alternative field access) to increase the participation of students with hearing, visual, and mobility disabilities and enhance the learning experience of all students (Cooke et al., 1997; Asher, 2001; Gardiner and Anwar, 2001; Wareham et al., 2006; Coughlan et al., 2010; Atchison, 2011; Horowitz and Schultz, 2014; Atchison and Gilley, 2015; Gilley et al., 2015). UDL is particularly useful in designing instructionally accessible and inclusive field studies (Bowe, 2000; Atchison, 2011; Gilley et al., 2015), although the principles have also been used extensively in classroom and laboratory instruction across science and engineering (i.e., Asher, 2001; Miner et al., 2001; Greenberg, 2002; Calderone et al., 2003; Benison, 2005; Duerstock, 2006; Thompson, 2008; Horowitz and Schultz, 2014; Supalo et al., 2014).

While UDL aims to provide universal access to teaching and learning, accommodation strategies that circumvent physical barriers and support student engagement are not one size fits all. For example, a field site that is assumed to be accessible for a student who uses a wheelchair may still present physical barriers for students with other types of mobility disabilities (Cooke et al., 1997). Physical barriers present a variety of challenges, and inclusive instructional planning must be integrated with personal support according to the specific needs and abilities of the individual student. On-campus disability service offices may be able to provide some assistance with these obstacles, but geoscience department faculty must ultimately ensure that all students are able to participate in all course activities. Educators must be willing to openly communicate with their students about potential barriers in order to create a supportive and inclusive learning community (Cooke et al., 1997; Atchison and Gilley, 2015; Gilley et al., 2015).

Nonphysical Barriers

Aside from the physical challenges that SWDs face engaging in higher education, nonphysical barriers often place additional burden on the opportunities for participation in postsecondary activities (Cooke et al., 1997; Healey et al., 2001; Locke, 2005; Atchison, 2011; Milic Babic and Dowling, 2015; Atchison and Libarkin, 2016). Nonphysical barriers such as prejudice, discrimination, and limited financial resources are more prevalent than the physical barriers described previously and are not unique to the geosciences (Miner et al., 2001). While all barriers are detrimental to student participation, nonphysical barriers can greatly affect student retention and lead to the marginalization of an individual or group within a department or institution.

Social barriers can be described as any discrimination, bias, or stereotype directed toward a marginalized population. These barriers are common and can be damaging, even if unintentional (Pivik et al., 2002; Locke, 2005). SWDs have reported that social barriers are not only the most common barriers faced in educational settings, but they are also "the most deleterious of their school experiences" (Pivik et al., 2002, p. 104). The most prominent social barrier in the geosciences is the judgement of individuals based on their physical ability (Healey et al., 2001; Hall et al., 2004; Locke, 2005; Atchison, 2011). This leads to the misconception that the geosciences are only for those who are physically fit and able to engage in rigorous fieldwork activities (Locke, 2005; Sexton et al., 2014; Atchison and Libarkin, 2016). This ableist perspective places undue social discrimination on SWDs (Lynch and Gussel, 1996; Ash et al., 1997; Holloway, 2001; McCune, 2001; Barnard-Brak et al., 2010; Huntoon et al., 2015; Atchison and Libarkin, 2016). Social discrimination causes many with nonapparent disabilities to refrain from publicly disclosing their need for accommodation services in order to fit in and avoid stigmatization (Taub et al., 2004; Barnard-Brak et al., 2010; Newman and Madaus, 2014; Libarkin and Atchison, 2016). This innate prejudice, which undoubtedly persists in campuses across the U.S., often causes students to downplay or deflect attention from their disabilities in order to circumvent social bias and stereotype (Goffman, 1963; Taub et al., 2004; Barnard-Brak et al., 2010).

Prejudice toward disability is not uncommon in the geoscience community (Locke, 2005; Atchison and Libarkin, 2016) and can lead SWDs to decide against participating in course activities (Healey et al., 2001) or even pursuing geoscience certificate and degree programs. In a study by Atchison and Libarkin (2016), professional geoscientists were surveyed to describe their personal perceptions about individuals with disabilities. Findings from this study suggest geoscience professionals perceive that people with hearing disabilities have the most opportunity to engage in geoscience careers. Alternatively, the same geoscience practitioners feel those with physical disabilities would have limited opportunities to engage in fieldwork, and people with visual disabilities would be unable to effectively participate in a geoscience career (Atchison and Libarkin, 2016). These perceptions reflect an inherent cultural bias against SWDs by assuming that they are unable to perform tasks because of their disability, underestimating the contributions they can make in the discipline and ultimately the workforce. To dismantle these social barriers, educators must work together to redefine the skills necessary to participate in the various geoscience disciplines. By providing more accessible learning opportunities and promoting access and inclusion in the geosciences, the geoscience community may change the negative perceptions regarding people with disabilities.

Institutional barriers include any policies or administrative decisions that impede the full participation of SWDs in a program of study. For example, policies driven by departmental practice (i.e., requisite completion of undergraduate field studies) can place financial burden on that department (i.e., renting accessible transportation or hiring sign language interpreters for field trips). Limited departmental funding may indirectly become a barrier to the student (Healey et al., 2001; Miner et al., 2001), thus revealing institutional support system failures (Fuller et al., 2004; Jenson et al., 2010; Gabel and Miskovic, 2014). In addition, a general lack of cooperation from faculty and administrators is often cited by SWDs as a common institutional barrier (Greenbaum et al., 1995; Barnard-Brak et al., 2010). Unless institutional policies and practices are able to provide safeguards to support students with specific accommodation needs, marginalization will persist for students who don't fit the able-bodied model (Locke, 2005) and an exclusive culture will permeate the educational environment (Holloway, 2001; Day, 2012).

PHYSICAL GEOSCIENCE ACCESSIBILITY

A review of the geoscience education literature of the last 20 y suggests that researchers have been investigating ways to make various geoscience learning experiences more accessible to students' disabilities. As the percentage of college SWDs continues to rise, educators will need to continue providing reasonable accommodations to ensure that SWDs have equal opportunities in field, laboratory, and classroom instruction. Reasonable accommodations are defined as the deviations in instruction, presentation, assignments, or environments that enable individuals with disabilities to participate in a course in a manner equal to their peers (U.S. Department of Education, 2007; McLaughlin, 2012). Instructors should become aware of the barriers students face inside and outside the classroom and work with students to create universally accessible curricula. Aligned to the principles of UDL, a variety of techniques and tools can be used to design more accessible learning experiences in the classroom, laboratory, and field-based instructional settings.

Classroom Accessibility

Although disability services offices are responsible in providing most of the requested accommodations for SWDs, instructors must be responsible for other aspects of in-classroom learning. These responsibilities generally involve the subtle aspects of instructional behaviors, including appropriate body language when lecturing (i.e., facing students when talking or writing on the board), and accessible material presentation (i.e., large or braille-print handouts or audibly describing presentation slides). In addition to basic classroom accommodations, geoscience educators have been creating tactile models to better assist students with visual disabilities (Travis, 1990; Asher, 2001; Horowitz and Schultz, 2014). In recent years, technological advances have made it less expensive to create high-resolution models using three-dimensional printing technology (Horowitz and Schultz, 2014). Physical models not only help students with visual disabilities improve their data visualization skills but also can help other students who are kinesthetic-based learners (Asher, 2001).

Laboratory Accessibility

Geoscience laboratories often contain hazardous materials that add extra risk to students conducting lab work, and even more so to SWDs. These safety concerns may pose a number of challenges to creating an accessible learning environment. Due to the risk of liability, department administrators and faculty may be unwilling to work with SWDs in the laboratory. Insufficient active learning experiences have been shown to negatively affect student self-confidence and may lead to attrition in the discipline (Supalo et al., 2014). Providing an accessible laboratory environment, along with the aid of personal assistance through lab partners, allows SWDs to fully participate in activities and assignments (Miner et al., 2001). Implementation of UDL creates more accessible laboratory environments and may

TABLE I: Approximate access requirements for students with mobility disabilities (adapted from Cooke et al., 1997).

Type of Access	Approximate Requirement
Curb cuts	Necessary for all wheelchairs
Loose sand or gravel	Unacceptable except for power chairs
Packed gravel and dirt roads	
Power chair	
Without knobby tires	Less than 1.5-cm-diameter gravel, no mud
With knobby tires	Most road surfaces
Manual chair	Less than 1.0-cm-diameter gravel, no mud (depends on person)
Walking or mobility impaired	No mud, no gravel
Steepness or grade	
Power chair	1:6
Manual chair	1:8–12 (depends on person)
Walking or mobility impaired	1:10–12 (depends on person)

reduce the amount of risk associated with the participation of students with diverse physical abilities.

When given appropriate accommodations, SWDs have been able to complete laboratory-based activities as successfully as their able-normative peers (Asher, 2001; Pence et al., 2003; Supalo and Mallouk, 2007; Wild et al., 2013; Supalo et al., 2014; Brown, 2016). For example, researchers in chemistry education have provided a detailed series of laboratory guidelines that instructors may follow to provide more accessible laboratory experiences for students with mobile, hearing, and visual disabilities (Miner et al., 2001). These guidelines include altering the laboratory environment (i.e., additional lighting and large-print labels for students with low vision or alternative figures for students with color-vision deficiencies) and providing students with materials that present data in an accessible manner (i.e. tools that provide tactile, audio, and visual feedback) and thus can help minimize physical barriers to participation (Miner et al., 2001; Shepherd, 2001).

The literature dedicated to broadening laboratory participation remains limited; scholarship has primarily focused on laboratory-based accessibility for students with visual disabilities at the introductory level (Travis, 1990; Asher et al., 2001; Wild et al., 2013). Despite the existence of broad guidelines on accessible geoscience instruction (Gardiner and Anwar, 2001; Healey et al., 2001; Shepherd, 2001; Wareham et al., 2006), inclusive lab-based practices are only briefly mentioned. Opportunities for SWDs to conduct laboratory studies will remain limited unless more definitive guides on how to implement universal design in geoscience laboratories exist.

Field-Based Accessibility

Field studies present students with opportunities to integrate geoscience theory and practice in the natural context (e.g., McKenzie et al., 1986; Mondlane and Mapani, 2002; Garrison and Endsley, 2005; Whitmeyer et al., 2009; Mogk and Goodwin, 2012). Through these experiences, students develop a particular set of skills and techniques that can be used to observe, collect, and interpret data (King, 2008; Maskall and Stokes, 2008). Research suggests in-field learning "should be process-oriented rather than context-oriented in order for students to gain knowledge" (Elkins and Elkins, 2007, p. 126), meaning that hands-on exercises promote better application and retention (Orion, 1993; Elkins and Elkins, 2007). Despite the importance of fieldwork to geoscience education, creating hands-on learning opportunities for SWDs in the geosciences have been slow to develop (Bennett and Lamb, 2016). Data suggest that geoscience field trips can be designed both to be fully inclusive and to maintain a high level of academic rigor (e.g., Gilley et al., 2015). With thoughtful consideration toward site selection and the removal of unnecessary physical rigor that does not align with learning objectives, field trips can be designed to better serve the needs of all students (Day, 2012). Before designing a field course, instructors should enlist the expertise of their campus office of disability services, sharing the instructional objectives of the learning experience and discussing any potential barriers that would prevent a student's full participation (Cooke et al., 1997; Gardiner and Anwar, 2001; Healey et al., 2002; Hall et al., 2004; Atchison and Gilley, 2015; Gilley et al., 2015).

Most accessible geoscience field course literature has focused on promoting inclusive practices to better serve the needs of students with mobility disabilities (Cooke et al., 1997; Gardiner and Anwar, 2001; Gaved et al., 2010; Atchison, 2011; Atchison and Feig, 2011; Atchison and Gilley, 2015; Collins et al., 2016). Mobility disabilities include any condition that can limit of a person's locomotive range of motion. Disabilities may be apparent (i.e., paralysis, amputation, multiple sclerosis, or cerebral palsy) or nonapparent (i.e., arthritis, asthma, or diabetes) and can affect participation in a multitude of ways. To ensure field-based learning experiences are inclusive, instructors must carefully select field sites that are accessible for students with diverse mobility abilities. The selection of primary, and sometimes secondary or contingent, field sites could better align the field content to the range of student ability, even when these abilities change as a result of a changing physical condition. In addition, by selecting accessible site localities, SWDs avoid the potential stigmatization of receiving preferential treatment by not fully participating or even slowing down the group because they need more time to navigate and explore rugged terrain. To better assist with site selection, Clark and Jones (2011) created a fieldwork audit tool to assist instructors in recognizing potential barriers that may exist in their field-based courses. Some of these potential barriers included weather conditions, slippery or uneven surfaces, terrain gradient, lighting conditions, and ambient noise. Once the learning objectives, outcomes, and course activities are designed, open communication with student participants would ensure that modifications can be made to accommodate specific student needs after enrollment. Cooke et al. (1997) describe the benefits of maintaining an open dialogue through the development of approximate access requirements for students with a variety of mobility disabilities, as noted in Table I. The opportunity for students to have ownership in the accommodation decisions being made would not only promote access but also create a fully inclusive and respectful learning community.

Students with hearing disabilities may face fewer physical barriers than students with mobility and visual disabilities. However, traditional in-field experiences present a unique series of challenges for students with who are deaf or hard of hearing (Wareham et al., 2006). Before any field instruction occurs, instructors are encouraged to provide the student with the expectations of the excursion, including the learning outcomes and detailed, written contingency plans and directions on how to perform in-field activities (Healey et al., 2001; Wareham et al., 2006). Despite that in-field lectures may present some of the most common barriers for students with hearing disabilities, Wareham et al. (2006) state that these can be avoided with effective communication practices (i.e., lecturing to students face to face and positioning the student nearest the instructor). An instructor's responsibility is also to ensure that students with hearing disabilities are fully engaged in the learning community and not alienated during group activities. Students should be briefed on best practices for inclusive social interaction, such as facing one another when engaged in conversation for those who also read lips.

Students who are blind or have low vision face many barriers to participating in geoscience field courses. Navigating an unfamiliar environment may present significant disorientation (Hall et al., 2004), which would prevent the student from focusing on the learning objectives. After first consulting with the student about potential barriers, a more engaging and safe learning experience can be facilitated by pairing the student with a guide (Asher, 2001; Shepherd, 2001; Hall et al., 2004; Wild et al., 2013).

Although the geosciences are viewed as a visually intensive discipline (Shepherd, 2001), studies show that students with visual disabilities can comprehend high-level, visually specific scientific concepts as successfully to their sighted peers after proper accommodations are provided (Jones et al., 2006; Wild et al., 2013). Tactile geologic and topographic maps have been used in providing accessible visualization tools for students with visual disabilities in the field (Asher, 2001; Shepherd, 2001; Wild et al., 2013; Horowitz and Schultz, 2014; Atchison and Gilley, 2015). Tactile geologic maps and models can be created from a number of materials, such as sandpaper or felt, to distinguish geologic features (Asher, 2001; Atchison and Gilley, 2015). These maps embrace the notion of multiple representation of the content, a tenant of universally designed instruction, and can enhance the learning experience of all students regardless of a disability status.

ALTERNATIVE GEOSCIENCE ACCESSIBILITY

Geoscience learning outside of the classroom is not always feasible and may put some students at undue risk if physical access may increase liability. When no accessible options to field learning locations are available, students "may face the unenviable choice of either participating in events in a partial, limited way, or leaving. Both options are self-defeating" (Carr, 2011, p. 187). Simpson (2002) asserts that geoscience departments should be as ready as possible to accommodate students before the need arises. Virtual learning environments (VLEs) have been implemented in a growing number of educational fields for teaching and learning activities (e.g., Warburton, 2009; Dieterle and Clarke, 2007; Tuthill and Klemm, 2002) and have the potential to be an effective means of significantly reducing barriers to participation (Seymour, 2005; D'Aubin, 2007). The ability to use technology to access information that would otherwise be difficult or impossible to obtain has been shown to contribute to a sense of equality, inclusion, and empowerment for people with disabilities (Anderberg and Jönsson, 2005; Parsons et al., 2006; Söderström, 2009). However, alternative access can have a unique set of challenges that must be considered before implementation.

For the most meaningful and successful VLE experience, both content engagement and social engagement must be achieved. Content engagement is the interest the student has in carrying out the learning activities within the VLE and the interest the VLE sparks in the subject being taught. Content engagement is key for successful learning outcomes. The ability to carry out tasks and interact with the surroundings must be present within the virtual environment to provide a satisfying and engaging experience (Saini-Eidukat et al., 2002; Joel et al., 2004; Whitelock and Jelfs, 2005; Stokes et al., 2012). Stokes et al. (2012) argue that students who feel as if they have no control over what occurs during the VLE become bored and disengaged, which can affect their ability to learn.

Social engagement is the ability to project one's own personality into the virtual environment and interact with others (Garrison et al., 1999; Warburton, 2009). It is the sense that a person is included in, and belongs to, a community. The connection between collaboration and student learning and satisfaction is well established in education research literature, and it is no less true in virtual environments (Arrowsmith et al., 2005). The ability to communicate with teammates or other users within a VLE builds camaraderie and is an important factor in creating a positive experience for users (Jackson and Winn, 1999; Coughlan et al., 2011). Social engagement is not only beneficial for learning outcomes but also critical if students are to feel included in the learning community. As with content engagement, social engagement during fieldwork is a natural product of the activity. Within a VLE, however, social engagement must be purposefully integrated into the experience.

A number of researchers have studied the implementation of synchronous and asynchronous applications in laboratory exercises as a means of access (i.e., simulations and remotely controlled laboratory equipment) (Cooper and Ferreira, 2009; Corter et al., 2011; De Jong et al., 2013). In a comparison of in-person, remotely controlled, and simulated lab activities, Corter et al. (2011) found that immersion—within the data-collection process and within a group of collaborators—was a key factor in both student satisfaction and performance in all modes of accessing the laboratory activity. The authors surmise that immersion in the data-collection process creates a sense of personal ownership of the data and engagement within a team allows for the establishment of a social group identity. When these two aspects are combined, they foster a higher level of commitment and participation throughout the learning activity. Pallant et al. (2016) also brought attention to a potential link between immersion and engagement during remotely accessible deep-sea research by pointing out that the longer students had to wait for data and/or contact from their remote collaborators, the lower their overall engagement became in the project.

Virtual Field Trips

A subsection of VLEs, virtual field trips (VFTs) have most commonly been used to introduce or reinforce concepts

TABLE II: Descriptions of various forms of VFTs as defined throughout the available literature.

Formats of Alternative Access	
Static web tour	A premade VFT in the form of photos and text, a website, or a series of websites. There is no live presence in the field and no interaction with the environment or other users within the VFT (e.g., Stumpf et al., 2008).
Single-user virtual environment	An interface that allows a user to navigate, interact with, or modify a computer-simulated environment. May include interaction with guide characters in the game, but not with other users. Created with gaming software, Google Earth, or geographic information system technologies (e.g., Arrowsmith et al., 2005; Granshaw, 2011).
Multiuser virtual environment	An interface that allows more than one user to navigate, interact with, or modify a computer-simulated environment and allows interaction with other users. Created with gaming software (e.g., Schwert et al., 1999; Saini-Eidukat et al., 2002).
Immersive systems	Virtual-reality simulations that require special hardware beyond a computer, such as goggles or projection walls (e.g., Kelly and Riggs, 2006; Atchison and Feig, 2011).
Asynchronous remote connection	Communication with students in the field that is not in real time; instead, communication and/or data transmission happens sporadically throughout the activity (e.g., Pallant et al., 2016).
Synchronous remote connection	Communication with students in the field that occurs in real time or with a delay of only a few minutes. An onsite synchronous connection has the same real-time connection, but its users are in the field at the closest accessible location to the field site (e.g., Gaved et al., 2008; Collins et al., 2016; Gaved et al., 2010).

taught in the field before or after a physical field trip (e.g., Kelly and Riggs, 2006; Stumpf et al., 2008; Granshaw, 2011), but they may also have the potential to provide an alternative to the traditional field experience. For this review, a VFT is defined as a digital representation of or remote access to a field site, real or fictional, through which students engage in learning activities. As outlined in Table II, technology has diversified the options for simulating or accessing field environments to include multiuser virtual environments (Dieterle and Clarke, 2007; Nelson and Erlandson, 2008), state-of-the-art fully immersive reconstructions of natural environments (e.g., Schuchardt and Bowman, 2007; Atchison and Feig, 2011), and remote access through real-time synchronous networks (e.g., Collins et al., 2016).

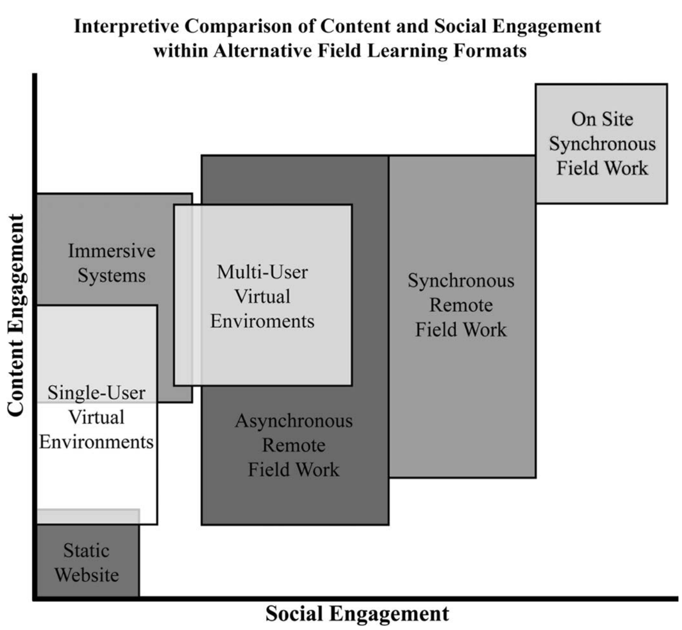

FIGURE 1: Interpretive comparison of alternative field learning environments based on the literature. Larger boxes indicate a high degree of variability in the published results for the indicated method.

The affective component of VFTs has always been one of the biggest challenges to overcome. When offered as a stand-alone or preparation activity, studies generally report that students have positive opinions of the VFT experience; however, when the VFT is offered as a replacement to a physical field trip, the positivity disappears (e.g., Poland et al., 2003; Arrowsmith et al., 2005; Stokes et al., 2012). Yet VFTs come is a range of styles and approaches, and some may present a more satisfying content and social experience than others.

VFTs described in the literature vary significantly in content, technology, and design. While it is difficult to directly compare the social and content engagement of VFTs, which are each designed with different objectives in mind, a theoretical comparison based on the literature would indicate that some VFTs are far more effective than others in creating an engaging learning experience (Fig. 1). To provide engagement in a VLE or remote learning environment, VFTs must incorporate two key elements: immersion and interaction. Immersion, the feeling that users are experiencing the environment, has been linked to a greater understanding of content (Moore and Gerrard, 2002) and may contribute to a more positive affective experience (Lenkeit Meezan and Cuffey, 2012). Interaction, the ability to carry out tasks, manipulate the environment, and/or collaborate with others, is critical for content engagement and a positive affective experience in a virtual setting (Saini-Eidukat et al., 2002; Joel et al., 2004; Whitelock and Jelfs, 2005; Corter et al., 2011; Stokes et al., 2012). Premade VFT websites that consist of a fixed set of photos, videos, and text are therefore at a distinct disadvantage. VFTs within virtual environments have the capacity to provide a great deal of engagement. Multiuser virtual environments have a greater capacity for both content and social engagement when compared to single-user platforms because of the increased ability for users to interact with other participants inside the virtual world (e.g., Jackson and Winn, 1999). Immersive systems (i.e., virtual-reality headsets and projection walls) are difficult to place within the spectrum of content and social engagement. While there is a high level of immersion, content engagement can become challenging when users are so engrossed in—or overwhelmed by—the virtual environment that they struggle with where to focus their attention for learning activities (Nelson and Erlandson, 2008; Lin et al., 2011). The challenge of finding the ideal level of immersion that promotes learning while avoiding the pitfalls of excessive cognitive loading is not unique to immersive systems and must be considered when using any form of virtual access for educational purposes (Wu et al., 2013).

Remote access to live fieldwork has tremendous potential for both content and social engagement. The social experience of traveling to and experiencing a field site with the rest of the group, as well as the opportunity to physically interact with the field location, even to a limited extent, adds valuable opportunities for immersion and interaction. Outside of STEM fields, studies that directly compared engagement between synchronous and asynchronous remote access have shown that the level of content engagement is often the same between the two approaches, but social engagement is much stronger when synchronous communication is used (Ocker and Yaverbaum, 1999; Rockinson-Szapkiw, 2009). The findings of Coughlan et al. (2011) support this by showing that the addition of low-resolution synchronous video communication during remote access to geology fieldwork did not contribute much in the way of content engagement but greatly improved social engagement.

Two good examples that illustrate the potential of remote field access have been examined in the UK. The enabling remote activity (ERA) project allowed students parked in a nearby vehicle to communicate with partners in the field via wireless technology (Gaved et al., 2008; Collins et al., 2016; Gaved et al., 2010; Stokes et al., 2012). Being in the same landscape as the rest of their classmates and participating in field activities in real time through the sharing of photos, videos, text, and voice were big contributors to social engagement and feelings of inclusion. While the learning experience of the ERA project was a leap forward for inclusion, remote learners perceived their environments to be less immersive and, as previously mentioned, less engaging (Stokes et al., 2012). A potential solution to this inequity was developed in the Out There and In Here project, which sought to give remote participants a more active role in the learning experience (Adams et al., 2010; Coughlan et al., 2010; Adams et al., 2011; Coughlan et al., 2011). In this iteration, students worked in two groups: one in the field and one at an indoor base station. The base team had access to a variety of resources, such as maps, books, and digital information, while the field team had access to physical outcrops and field observations. The teams worked together by sharing information in real time to complete an assigned project. This approach is not without logistical challenges but illustrates how thoughtful design can provide an inclusive, synchronous learning opportunity from remote locations.

While there is no universally accepted set of guidelines for accessibility of VFTs specifically, several practitioners offer guidelines toward accessible online learning (e.g., Dell et al., 2015) and the application of universal design in virtual worlds (e.g., Krueger and Stineman, 2011). In general, inclusive VLEs are achieved by ensuring that the mode of presentation is readily accessible, usable by people with a range of abilities, and not overly complex (Bühler, 2001; Stendal, 2012). Technology may seem to be the simple solution to inclusion, but an inclusive climate cannot be achieved simply by assigning a VFT or remotely connecting a student to a field site. Conscious effort must be made to provide an experience that is comparable to the physical field trip in terms of content and social engagement.

DISCUSSION

A review of geoscience education literature suggests that efforts in promoting access and inclusion do not fully extend to the discussion of broadening participation. The last two decades of inclusive geoscience education research have predominantly supported the development of accessible laboratory- and field-based curricula at the introductory level. This lack of upper-level undergraduate and graduate coursework suggests that many SWDs are not advancing to these stages. Extrapolated further, the underrepresentation of individuals with disabilities in geoscience programs is undoubtedly reflected in the underdiversification of the workforce.

The geoscience education literature dedicated to broadening participation of SWDs in field-based study presents many challenges involved with providing accessible experiences in the natural environment. Much of the literature reviewed consists of practitioner articles, dedicated to improving geoscience accessibility through the design and practice of an individual course and provide insight into how to promote access in short-term field trips (i.e., 1–3 days). These instructional vignettes serve as an important foundation for further study, although most are void of empirical evidence on the effectiveness of curriculum design. In addition, geoscience degrees often require the completion of advanced-level residential field studies, which can last 4–6 weeks. Investigating the educational outcomes of accessible geoscience instruction for both short-term and long-term field studies would allow instructors to better understand the most effective methods of providing content and social engagement for reaching all students within the learning community.

The literature suggests that creating universally accessible and academically rigorous educational opportunities can be accomplished through basic modifications of learning environments, alternate field site selection, and provision of reasonable accommodations. Before designing or modifying a course, we recommend faculty openly communicate with students about course expectations, anticipated learning objectives and outcomes, and potential barriers to participation. Opportunities to actively participate in the decision-making process will allow students to take ownership of their engagement and feel valued within the community of learning. These steps are crucial to creating a learning environment that encourages the participation of all students regardless of physical ability.

Virtual access to geoscience learning opportunities present a promising avenue for accommodation. Further research regarding the use of virtual environments in the geosciences is needed to better understand the most effective ways to utilize this approach. The affective views of the general student population regarding virtual learning in the geosciences have generally been negative regarding the use of a virtual experience in place of a physical presence. Absent from the literature is research examining how SWDs view virtual learning as a means of access to field sites, laboratories, or other areas that would otherwise be inaccessible. For SWDs, VLEs may be viewed not as a lesser way to access coursework but rather as a way to achieve access that was previously denied to them. As a result, the affective component of participation in fieldwork may be more positive for students who would otherwise be unable to access the physical learning environment.

Based on the findings of this review, we encourage a reevaluation of the traditional view of instructional practice. We must end the promotion of rigorous physical activity as the only way to learn geoscience skills and knowledge. Doing so will enable every geoscience student, instructor, researcher, and practitioner to contribute his or her own experiences, according to his or her level of ability, in an inclusive community of learning. Working together to change the assumption that someone with a physical disability is unable to equally contribute to a community of learning will create a more dynamic and innovative discipline that encourages diverse perspectives regardless of our physical differences.

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