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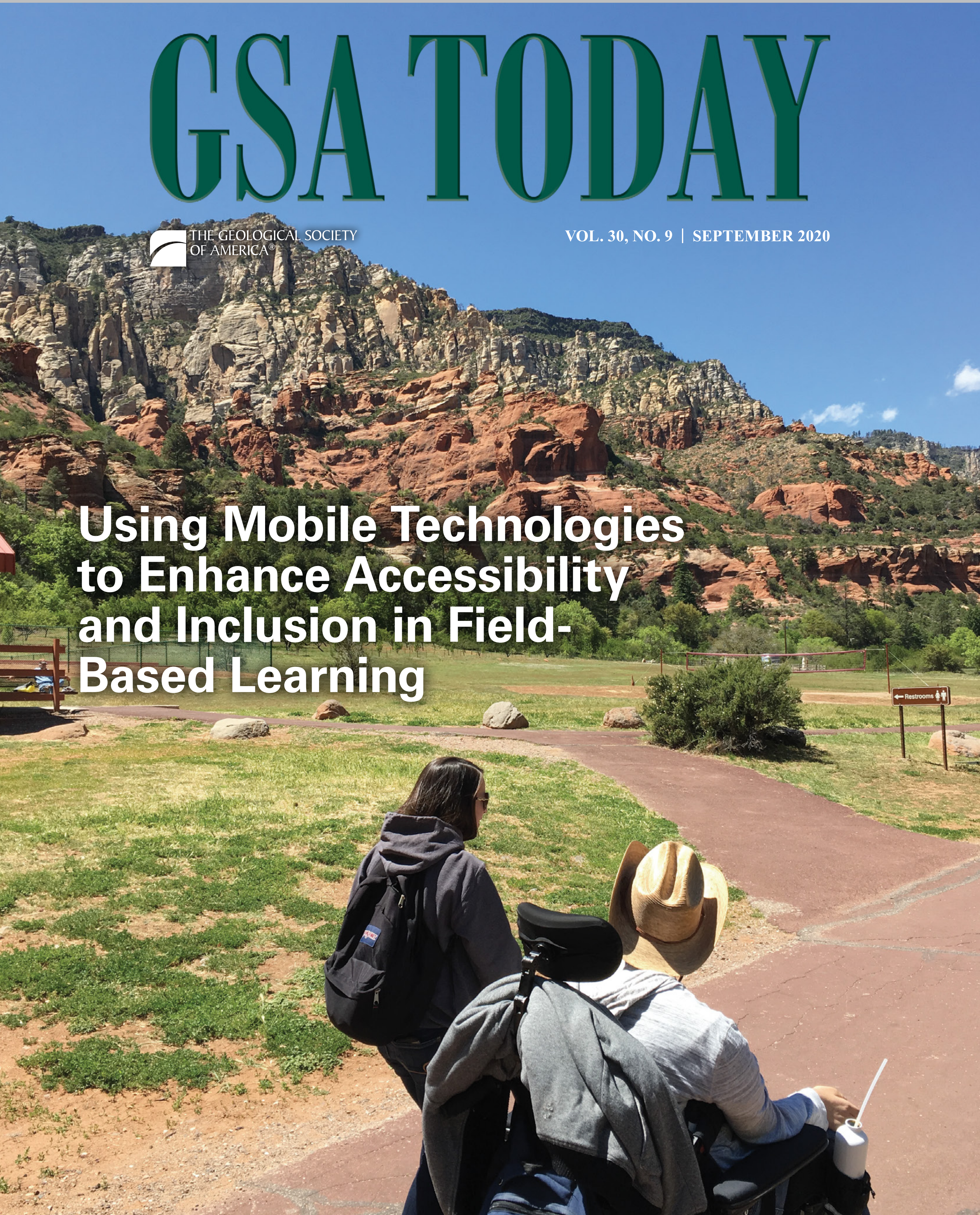

Using Mobile Technologies to Enhance Accessibility and Inclusion in Field-Based Learning

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ABSTRACT

The relevance of field education in the geosciences has been subject to increasing scrutiny, in part due to the exclusionary nature of traditional field practices that require independent work and physical agility. As an alternative, this article presents strategies for increasing accessibility and inclusion in collaborative field-based education through the use of mobile technologies. We present a series of examples to show how the use of mobile technologies in the field can enable collaborative observation, data collection, data sharing, and interpretation. The strategies developed in these examples provide equitable access to instruction, peer engagement, and participation in every field exercise. We suggest that technological approaches to accessibility and inclusion in the field can facilitate opportunities for all students to gain field experiences that are an important component of geoscience education.

INTRODUCTION

Field investigations are often a component of geoscience research, and consequently field-based education has been included in geoscience curricula. However, the relevance of field education has been subjected to increasing scrutiny (Drummond, 2001; Dohms, 2011), partly due to an increased focus on lab-based research. Another concern has been the "exclusivity" of traditional fieldwork, where independence (Healey et al., 2001; Maskall and Stokes, 2009) and physical conditioning (Kirchner, 1994; Maguire, 1998; Feig, 2010) were lauded (Hall et al., 2002; Atchison et al., 2019a; Stokes et al., 2019). The attributes cater to outdoor enthusiasts that may be considering a geoscience career, but it has become clear that many others are disenfranchised by these restrictions.

Field mapping and data collection are often viewed as individual experiences, where a geologist collects data in the field without much, if any, contemporaneous input from other field workers. However, field-based investigations by a group of participants have been demonstrated to build strong ties and increase morale within student peer groups through collaborative strategies that enhance learning in the field (Mogk and Goodwin, 2012; Kelley et al., 2015). In addition, collaborative fieldwork can yield high-density geologic maps, which can facilitate improved geologic interpretations (Whitmeyer et al., 2019). Thus, collaborative fieldwork can be an important approach to effective field data collection and field-based learning experiences.

Mobile devices provide new methods of communication and interaction in field settings and are now commonly used for field data collection and even data analyses (Pavlis et al., 2010; Collins, 2015; France et al., 2015; Allmendinger et al., 2017; Walker et al., 2019). In addition, mobile technologies can enhance real-time communication in the field, facilitating a level of interaction and collaboration that was previously unattainable. Real-time communication can increase participation for people with physical disabilities by enabling collaboration with peers and engagement with field locations that are remote and inaccessible (Coughlan et al., 2011; Stokes et al., 2012; Collins et al., 2016).

In this paper we outline a strategy for increasing accessibility and inclusion in field-based education and research using mobile technologies. The context of this work is presented, followed by short descriptions of field trips and a summary of the contrasting uses of technology across these trips. Opportunities and challenges with integrating technology and teaching strategies intended to improve access and inclusion are discussed, concluding with recommendations for practitioners.

APPROACH

Our approach to enhancing accessibility and inclusivity in the field focused on pairing students with physical (mobility) disabilities with students who were fully ambulatory on a variety of projects that replicated field exercises in an undergraduate geoscience curriculum. The student cohort consisted of six students who self-disclosed various mobility disabilities and six students who did not disclose any mobility disabilities. In the first year of the project, field exercises were located at several sites in Arizona, while the second year focused on sites in western Ireland. Project outcomes subsequently were disseminated on three accessible field trips at Mount St. Helens National Volcanic Monument (2017), Mammoth Cave National Park (2018), and Petrified Forest National Park (PEFO; Atchison et al., 2019b). Field trip participants (n ≈ 80) included several project participants, along with undergraduate and graduate geology students with disabilities, and geoscience instructors, some of whom had disabilities.

Mobile communication and data collection devices (see Supplemental Table SD1[1]) facilitated interaction among project students

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[1]Supplemental Material: Table SD1 and Figures SD1, SD2, and SD3. Please visit https://doi.org/10.1130/GSAT.S.12501404 to access the supplemental material, and contact editing@geosociety.org with any questions.

(during the project exercises) and field trip participants (during the dissemination field trips) across sites that were easy to access (roads, well-groomed paths, etc.) and locations with more challenging terrains. Field environments ranged from arid, dry conditions (Arizona, PEFO) to colder and wetter conditions (Ireland, Mount St. Helens).

EXAMPLE FIELD TRIPS

Arizona Field Sites, Year 1

We visited field locations in central Arizona in May 2015, including Slide Rock State Park in Oak Creek Canyon, The Trail of Time on the south rim of the Grand Canyon, and SP Crater north of Flagstaff. These trips paired undergraduate-level geoscience students with and without physical (mobility) disabilities on shorter duration (single day) field exercises. A variety of communications and technology devices enhanced collaborative inclusion and access to the field sites. Summaries of each exercise follow, including objectives, technology used, and an overview of site accessibility.

1. Slide Rock State Park

The geologic features of interest at Slide Rock State Park (see Supplemental Fig. SD1 [see footnote 1]) consist of 50–100 m cliffs of horizontal, layer-cake stratigraphy of the Colorado Plateau transition zone. This introductory exercise introduced student teams to using iPads to record observations and annotate photos of the layered stratigraphy. Goals included team-building, effective recording of observations, and interpretations of unfamiliar geology. The exercise concluded with a full group discussion of the geology, followed by discussions on the accessibility of the site and collaborations between student team members.

Technology used: iPad cameras and Evernote app.

Accessibility: Equitable access to the site; paved and packed dirt paths available for all to explore the park, but cliff outcrops were only viewable from a distance (~500 m).

2. The Grand Canyon

This exercise focused on the Trail of Time (ToT), a 1.6 km paved trail along the south rim of the Grand Canyon, with tactile exhibits that document two billion years of regional geologic history (Karlstrom et al., 2008). Students worked in teams across ability levels to visit sites along the ToT that displayed rock samples obtained from deep within the canyon, which illustrate the classic stratigraphy of the Grand Canyon. Student teams used the StratLogger app to record lithologic descriptions and construct a stratigraphic column of the Grand Canyon units.

Technology used: iPad cameras and StratLogger app.

Accessibility: Equitable access to the ToT, although the distance traveled along the ToT proved challenging for some students with disabilities. Students traveled chronologically along the ToT, starting at the Grand Canyon Village Visitor Center and heading toward the Yavapai Point Visitor Center. Traveling in this direction included a slight incline in elevation, and, depending on the number of visitors, few available benches for seating. With the exception of the powered wheelchair users, students with mobility disabilities were negatively impacted by the length and incline of the trail. Hot and dry conditions were an issue for all participants.

3. SP Crater

SP Crater is an ~1000 m cinder cone located north of Flagstaff (Fig. 1; Ulrich, 1987). Student teams were separated during this activity: those with disabilities stayed with the vehicles at the base of the mountain, while those without disabilities hiked to the summit from two approaches. One trail wrapped around the mountain and ascended the back side, and the other took a direct path up the front of the mountain. Students used two-way radios to communicate during the hike. However, students who hiked around the back of the mountain lost line-of-sight and radio contact with their partners at the vehicles, while those who took the front path to the top maintained line-of-sight and communications with the group at the base. Once at the top of the mountain, all students were able to communicate with their partners at the base using two-way radios as well as the Livestream app for real-time video broadcasts of the summit views.

Technology used: Two-way radios, GoPro video cameras, iPad cameras, and Livestream app.

Accessibility: A physically inaccessible field site where several students remained with the vehicles at the base of the mountain, while others climbed the mountain via the steep, loose-cinder front, or a longer path around the back; communication was hindered by loss of line-of-sight and a significant (1–2 min) delay in the Livestream video relay from the summit.

Western Ireland Field Sites, Year 2

Year 2 focused on field sites in western Ireland, where challenges to field access and participation were very different from Arizona. Field sites in western Ireland were typically windy, cold, and often rainy. The field exercises during the second year featured the same cohort of students and expanded on the experiences of the previous year. Exercises were longer, more involved, and often incorporated different technological solutions.

1. Kilkee, County Clare

This half-day exercise focused on describing and interpreting sedimentary structures

Figure 1. The SP Crater cinder cone that was only accessible to half of the cohort (left), the group that remained at the base used two-way radios (middle) and a Livestream video broadcast (right) to communicate with students at the top of the cinder cone.

Figure 2. Students at the exposed seaside cliffs near Kilkee (left) using the camera and Skitch application on the iPads (middle) to record and annotate the sedimentary structures and deformation features (right) to share with their peers who did not access this location.

and deformation features in rocks exposed along seaside cliffs near the town of Kilkee (Fig. 2). Most of the features, such as ripple marks, cross-beds, and soft-sediment deformation structures (Martinsen et al., 2008) were viewable by all participants from a paved path along the top of the cliffs. Some smaller-scale features, such as sand volcanoes and fault surfaces, required descending steps to an eroded cliff platform and thus were not accessible to everyone. Students used iPad cameras and the Evernote and Skitch apps to record, sketch, and describe features; remote communications were facilitated with two-way radios. A full group discussion of the exercise occurred indoors later in the evening.

Technology used: iPad cameras, Evernote and Skitch apps.

Accessibility: Paved paths did not extend onto cliff exposures, which were only accessible by stairs. Foot paths were narrow and steep in locations, inaccessible to wheelchair users. High winds made group communications difficult.

2. Lough Derryclare, Connemara

This three-day exercise focused on bedrock mapping in a boggy field area along the southern shore of Lough Derryclare in Connemara. Geological features included folded schists and quartzites of the Connemara Dalradian sequence (Leake and Tanner, 1994). Outcrops along a gravel road were accessible to all students; other outcrops required traversing boggy fields and were not accessible to students with mobility disabilities. Cell signals in the area were weak and ineffective, so a local area network (LAN) was set up to facilitate real-time communications between team members (see Network Connectivity section). Students recorded field data (lithologic descriptions and orientation measurements) with the FieldMove app in order to create a collaborative geologic map. Students with mobility disabilities mapped outcrops along the gravel road, while mobile students mapped outcrops in more distant and less accessible locations. Students communicated in real time via two-way radios and iPads using the AirBeam app. Photos were shared in near real time with the PhotoSync app. Videos were recorded asynchronously with GoPro cameras and shared between team members upon reconvening in common locations.

Technology used: Two-way radios, GoPro cameras, iPad cameras, FieldMove, AirBeam, and PhotoSync apps, with real-time communications facilitated by a LAN.

Accessibility: Outcrops along the gravel road were accessible to all students; remote outcrops were not accessible to students with mobility disabilities due to intervening uneven bogs. Rainy and cold weather negatively impacted all participants.

3. Renvyle Point, County Galway

The coastal bluff at Renvyle Point consists of an ~15 m vertical exposure of glacial till that lies unconformably on a wave cut platform of Dalradian Schist. The bluffs are not visible from the parking area and can only be reached after descending an uneven field of beach cobbles and boulders (see Supplemental Fig. SD2 [see footnote 1]). The half-day exercise focused on examining and interpreting deformation and fluidized flow features within the glacial till in order to determine the movement of the glacier. Due to the challenging terrain of the field area and the rainy weather, students with mobility disabilities remained in the vehicles and collaborated with their peers using two-way radios and iPads via a LAN.

Technology used: Two-way radios, GoPro cameras, iPad cameras, AirBeam and PhotoSync apps; real-time communications and data exchange with iPads were facilitated by a LAN.

Accessibility: Exposures of glacial till were only accessible by climbing down large, wet boulders along the shore. Rainy and windy weather made outdoor audio communications difficult.

TECHNOLOGY TO ENHANCE FIELD ACCESS AND INCLUSION

Synchronous and Asynchronous Communication

We used both synchronous (real-time sharing of audio or video) and asynchronous (delayed sharing) methods of communication while in the field. Synchronous communications were facilitated by a cell network at SP Crater to broadcast a video stream from the summit to students at the base of the hill. We used the Livestream web broadcasting app, but the 1–2-minute delay between transmitting and receiving the video stream made synchronous interactions between team members challenging. Students found the discrepancy between the faster audio communications and the slower video transmissions awkward. Students ascending the hill also used two-way radios for audio communications with team members at the base, which had no time lag as long as line-of-sight was maintained. Two-way radios typically have a strong signal across distances of 2–3 km and were frequently used by student teams when WiFi was not functional. In locations where a LAN was available, the AirBeam app was used for synchronous video streaming, and PhotoSync was used for photo sharing.

In field settings where cell signals or a LAN were not available, data sharing among participants across field sites was accomplished with asynchronous methods, although real-time communication could still be accomplished with two-way radios. Participants asynchronously recorded video with GoPro or iPad cameras and collected field data with a variety of iPad apps. Data were shared when participants were once again in close proximity. Once a cell or WiFi signal was available, participants uploaded their field data to Dropbox so that others could view and download it.

Network Connectivity

The level of connectivity between participants distributed across a field site can determine the degree of synchronicity available for interactions. Typically, cable or fiber connections are not practical in the field, cell network coverage can be unreliable, and satellite connections are expensive. A more manageable communications solution is to "bring your own network" to the field in the form of a LAN using battery-powered outdoor WiFi routers. The local topography, and the distribution and mobility of students across the site, affects the number of routers required to provide effective connectivity. Panel and omni-directional antennas are used to target the WiFi signal in a directed beam or over a local area (respectively) and moved as needed to maintain coverage across the site. The routers are configured as access points, providing connectivity for local devices, or in a chain of point-to-point links to connect field site locations (Collins et al., 2010). Some knowledge of computer networking is required, but once configured, a LAN can be used flexibly in a range of field scenarios.

The LAN was used at the Lough Derryclare and Renvyle Point field sites to stream video between iPads using the AirBeam app and share photos using the Photosync app. At Lough Derryclare, as students were distributed across the field site, up to six WiFi routers were used in a network as line-of-sight signal repeaters to maintain connectivity across the rough and hilly terrain. This configuration provided network coverage of up to two square kilometers of the field area. At Renvyle Point, access points were used at the two student locations (the car park and shoreline) connected by a 40-m network cable.

iPad Apps

Fieldwork activities were supported through a range of iPad apps (see Supplemental Table SD1 [see footnote 1]). Photos and videos were captured asynchronously using iPad or GoPro cameras. Photos were shared with the PhotoSync app, and synchronous video feeds were attempted with the Livestream and AirBeam apps. Field notes and students' reflections were recorded using the Notes, Evernote, or Notability apps, and photos were annotated with the Skitch app. Orientation measurements were collected and geologic maps were constructed using the FieldMove app. Two apps were used to construct stratigraphic sections: StratLogger was used in year one, and Strat Mobile was used at PEFO (see Atchison et al., 2019b). Dropbox was used to share files among participants and between the iPads when connected to the Internet. Flyover Country was used on the PEFO field trip to bring geologic maps and information into the field as reference materials. Many of these field mapping and data collection applications can now be accomplished with the StraboSpot app and database system (Walker et al., 2019). However, that was not available to us during the period that we conducted the project exercises.

DISCUSSION

The primary objective of this project was to determine ways to enhance collaboration across instructional activities in field sites with limited accessibility. Challenging terrain and changing environmental conditions impacted participation in field activities across a spectrum of physical abilities. We attempted to mitigate the issues of accessibility in field-based teaching and learning through the integration of technology and collaborative strategies that promote full inclusion. The sociotechnical solutions highlighted in this paper resulted from the usability of mobile technologies, levels of social and academic engagement, and environmental conditions.

Inclusion and Accessibility

Accessibility and inclusion are not synonymous terms but are often used as such (Carabajal and Atchison, 2020). In this project, accessibility and inclusion were both partially addressed through the use of technology. Participants with disabilities achieved better access to less-accessible field sites through photo and video imagery from peers and colleagues and imagery from apps such as FieldMove and Flyover Country. Inclusion, however, deals with the group dynamic, social engagement, and collaborative nature inherent in most field activities. The use of technology in this sense enables participants to collaborate through real-time video and photo sharing and two-way radios to share observations and interpretations with peers and colleagues. The opportunity for the entire learning community to draw from multiple perspectives of an individual field site (close-up, from a distance, through aerial imagery), including the ability to discuss disparate observations across distances for the purpose of developing collective interpretations, strengthened the overall understanding of the entire group (see Atchison et al., 2019a).

Inclusive Collaboration through Technology

We addressed data collection and communication in the field with both synchronous (real-time connectivity) and asynchronous (delayed) solutions. In many situations, asynchronous solutions were used as a backup when real-time solutions were ineffective—such as the time delay (buffering delay) between broadcast and reception when using the Livestream app at SP Crater, or when a WiFi network was unavailable (e.g., Kilkee). In the discussion of technology that follows we consider both successful and less successful solutions, in the hope that others can make use of, and expand on, our experiences.

Geologic Mapping and Data Collection

We used the StratLogger app for the ToT exercise at the Grand Canyon to record lithologic and stratigraphic data. After an introduction to using the app, students were fairly efficient in recording data and building their stratigraphic columns. We switched to the Strat Mobile app for the PEFO field trip after we found that StratLogger did not work with the latest operating system of the iPads. Often, the most effective software for geoscience fieldwork is developed by tech-savvy geoscientists, but it can be a challenge for geoscientist developers to keep their software compatible with continuous updates to operating systems. Commercial software solutions are usually up-to-date with operating systems but are often less effective for specialized field tasks.

We used the FieldMove app for geologic mapping in the field. FieldMove includes a digital compass that records orientation measurements and plots them in real time on a basemap of the area (road map, terrain map, or aerial photo). Alternatively, a hand-held compass can be used to take measurements and entered manually in FieldMove. Concerns have been expressed about the accuracy and precision of measurements taken by digital compasses. However, recent analyses suggest that digital compasses, such as those in FieldMove, can produce results at a similar level of accuracy and precision as analog compasses, as long as the digital compass is calibrated correctly (Novakova and Pavlis, 2017; Whitmeyer et al., 2019). We noted an advantage to using the iPads for measurements when several of the students with mobility disabilities had difficulty getting close enough to utilize a handheld compass on an outcrop surface.

Field geologists who predate the mobile technology revolution are accustomed to using paper field books for notes and sketches, and often find note-taking apps for mobile devices less intuitive to use. However, students who are accustomed to using mobile devices for communications and social interactions easily adapted to using apps like Notability, Evernote, and Skitch to record field observations. Students appreciated the capability of these apps to import pictures taken with the iPad cameras, making it easy to associate field photos with text annotations and explanations, and to draw interpretive sketches on photos.

Another advantage of mobile devices is the ability to preload data and maps on the device for later asynchronous use. Mapping apps like FieldMove allow users to preload georeferenced aerial photos or topographic base-maps for fieldwork. Geologic reference data and information can be preloaded on iPads with an app like Flyover Country. We used this app to load state-level geologic maps and information for southern and eastern Arizona for our journey from Phoenix to Holbrook during the PEFO field trip. This provided participants with background geologic and cultural information for reference as they traveled through a region of interest.

Audio and Video Communications in the Field

We experimented with video broadcasting apps that were less successful (e.g., Livestream), prior to settling on the AirBeam app for video streaming with a LAN. This facilitated video communications among team members with a minimal delay (<5 seconds). At both the Lough Derryclare and Renvyle Point field sites, students with mobility disabilities found that video communications with their partners provided a level of accessibility to remote outcrops that would not have been possible without the technology. In some situations, near real-time transfer of photos and still images between team members effectively substituted for video communications. Where weather or connectivity challenges precluded effective video links, students used the PhotoSync app to share still images and discussed the geologic features in the photos using two-way radios.

Even with our attempts to secure robust wireless signals for real-time communications, we still encountered many situations where asynchronous methods of data collection were necessary. Students always had the option of taking photos or recording videos using the iPad's native camera, which could be shared with their team members at a later time. GoPro wearable video cameras were extensively used to record traverses across a field area and to highlight important geologic features. Photos and recorded videos served as important field data that were used to both complete field exercises and to document field experiences.

Facilitating Connectivity in the Field

As with any field equipment, there is a degree of contingency planning needed when introducing mobile technology. Most crucial is the time taken to set up equipment in the field or fix problems that could impact students' learning experiences. Preconfiguring the LAN (e.g., connecting the routers, testing them, and packing them ready for deployment) helps minimize the setup time in the field. Knowledge of the field sites and the activities at each site is crucial to ensure that network coverage is sufficient (while minimizing redundancy). Revisiting known sites enables the re-use and rapid deployment of effective technology configurations. Bringing spares of essential components (e.g., batteries, cables) into the field enables faulty equipment to be easily replaced. Also important is to prepare alternate resources (e.g., two-way radios) and activities to be used in the case of technology failure.

Effective use of a LAN in larger field areas usually requires the services of a field technology expert. The expert not only configures the network, but also tests it and deploys it in the field prior to the arrival of students. Invariably, unforeseen challenges occur during a field session, and it is essential to have the tech expert available in the field to troubleshoot problems that develop. We often used two-way radios for communication between participants and the expert in order to resolve issues. Some technological challenges were not solvable in the field and necessitated the development of new solutions after returning from the field in order to mitigate future problems.

Student Engagement

This study was initially focused on evaluating learning outcomes related to geoscience field content, but soon expanded to identify overall collaborative inclusion and engagement of field activities in sites with limited physical accessibility. Engagement and overall enjoyment were palpable, mostly because a geoscience field study of this kind, which included multiple students with similar physical disabilities, was designed specifically to address student needs. All students realized they were part of a foundational study to enhance access to field learning and were aware that their personal well-being was considered in the design. The study remained flexible to enable their voices to drive the direction of the activities, especially when unavoidable changes in environmental conditions (e.g., daily weather) caused us to reevaluate our plans. Taken as a whole, students were not used to having an opportunity that was meant to include them, their strengths and abilities, which undoubtedly impacted overall engagement and enjoyment. However, not everything was enjoyable and engaging all of the time. The students without disabilities, who generally had more field experience than their disabled peers, were often left feeling as if they were only being used to collect data in sites that their colleagues could not access. Additionally, switching between technologies that were new to most of the students, and the occasional lag-time between audio communication and photo/video sharing, negatively impacted engagement and collaborative outcomes overall.

CONCLUSIONS AND IMPLICATIONS

The integration of mobile communication and data collection technologies can have a positive impact on teaching and learning in field-based activities. Increased collaborative engagement and social inclusion in the learning community is achievable, even when students are separated across field sites with variable accessibility. Real-time communication between groups enables data sharing, shared observations, and interpretations that are not commonly done when working groups are separated. This social inclusion and collaboration is important because it gives students ownership in the learning environment. However, the integration of technology can introduce additional challenges to the student field experience. Students often have varying levels of field experience, geology content knowledge, and comfort with using technology to collect data and communicate. Varying levels of confidence in the use of mobile technologies can amplify anxiety and develop an unwelcome stratified community of learning within the group.

Not everything we tried was successful, but even the small failures drove the evolution of the project through a constant attempt to overcome physical barriers to field-based teaching and learning. Outcomes of the project that demonstrate how technology can be used to enhance access to field sites and increase collaborative inclusion across all participants during field exercises include:

1. The inherent flexibility of digital tools recognizes diversity and enables personal choice (i.e., fieldwork does not have to be restrictive).
2. Specialized field apps are typically the best solutions for geoscience fieldwork but are often developed by domain specialists and not always well maintained.
3. Always have contingency plans—technologies and strategies can fail for a variety of reasons, so have back-up equipment and alternate options (e.g., asynchronous can succeed when synchronous fails).
4. Be prepared—preconfigure the technology and ensure that everyone knows how to use it before going into the field. Know how to get help when things go wrong.
5. Ensure you have adequate resources—fieldwork is unpredictable, so make sure you have the expertise to adapt (especially when technology is involved).

We have discussed our experiences with this exploratory pilot study, encompassing both successes and challenges, and some possible strategies for implementing the use of mobile technologies for enhanced fieldwork. Expanding the scope of our approaches will require a significant change in how most of us conduct research and education in the field. Doing so would not only provide improved experiences for students, but also would enhance the pedagogic toolkit available to field instructors. We envision the next phase of this work as focusing on the geoscience community as a whole, to expand the outcomes of this work and develop new strategies to make multi-day and residential field experiences accessible and inclusive of all geoscientists. In addition, now that we have identified the capabilities and potential of using various mobile technologies to increase access and engagement in a field-based inclusive learning community, we recognize the need to align the content of inclusive field experiences to typical field-camp learning objectives (e.g., collecting accurate data in the field, synthesizing data to create geologic map interpretations, synthesizing field data and interpretations to write a summary of the geologic history, among others). Evaluation of the effectiveness of the methods discussed in this paper against student learning outcomes will indicate the utility of these methods.

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