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A critical incident analysis of inclusive fieldwork with students as co-researchers

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ABSTRACT
This paper presents findings from a collaborative research project with students and lecturers that explored the integration of technology to enhance accessibility and inclusion in fieldwork education. The project set out to involve students as co-researchers to broaden the insights of the research team, and purposely included the diverse perspectives and experiences of students and lecturers with physical-mobility disabilities. Through analysing three critical incidents from two residential field trips, we developed a set of practical recommendations for using technology to facilitate the inclusion of students with disabilities in field courses. Reflecting on this study and the process of engaging with students as co-researchers, we offer recommendations for implementing equitable and inclusive fieldwork and working collaboratively with students to develop inclusive field experiences.

Introduction

The importance of the practical application of geoscience content in field learning environments for geoscience education has been demonstrated through decades of geoscience field trips and courses (e.g. Butler, 2008; Whitmeyer et al., 2009 and references therein). However, evaluations of students’ experiences in the field suggest that traditional methods of field education are not equally effective across the spectrum of student backgrounds and abilities (Hunton & Lane, 2007; Mogk & Goodwin, 2012). More specifically, initiatives focused on enhancing field access for students with disabilities (Atchison & Feig, 2011; Cooke et al., 1997; Gilley et al., 2015; Hall et al., 2004; Hendricks et al., 2017) have highlighted that traditional field pedagogies are likely to discourage the participation of students with disabilities that might otherwise be interested in studying the geosciences. Additionally, due to the over reliance on inaccessible field sites and physically demanding learning activities, field education can also limit the participation of students with disabilities (Atchison et al., 2019; Houghton et al., 2020). Perhaps the culture of inherently requiring physical ability to successfully engage in geoscience activities and navigate the natural environment provides a rationale for why the
geosciences are one of the lowest STEM disciplines in representation of students and scientists with disabilities (National Center for Science and Engineering Statistics, 2021).

Often utilized interchangeably in the discussion of equality and diversity, access and inclusion are not synonymous. Access is the opportunity for students to have a physical and sensory connection to the environment, while inclusion is the social connection these students have within and across a community of learning. While developing a physically accessible field course can be a monumental pedagogical challenge, reframing the experience of engagement within an inclusive community of learning can dramatically alter both the design and outcome of the field course, focusing on student assets (e.g. skills, knowledge, abilities) that may enhance the entire field learning experience rather than any deficits (e.g. physical disabilities).

Fieldwork can, and should be done collaboratively, where students share observations, perspectives, and work together to create interpretations of the applied scientific content. With this in mind, why then, should all students need to view the field from the same vantage point? Considering the guidelines of Universal Design for Learning (Meyer & Rose, 2000), students can be actively engaged in the learning experience through a variety of methods, and without being up close to the desired outcrop. Full participation does not necessarily mean that all students have physical access to all the field sites. Full participation means full inclusion in the activities and community of learning, which may or may not be on site.

In this paper, we present findings from a collaborative research project with students and lecturers that explored the integration of technology to enhance the access and inclusion of students with disabilities in authentic and collaborative field investigations. Additionally, the project set out to involve students, with and without disabilities, as co-researchers to broaden the insights of the research team to purposely include the diverse perspectives and experiences that will enable future fieldwork to be more inclusive of all students’ skills, knowledge, and abilities.

Approach

Student-staff partnerships have been defined as “a collaborative, reciprocal process through which all participants have the opportunity to contribute equally, although not necessarily in the same ways, to curricular or pedagogical conceptualisation, decision making, implementation, investigation or analysis” (Cook-Sather et al., 2014, p. 6–7). In practice, the power relationships between lecturers and students impact issues of ownership and expertise, where presumptions made by either side can undermine effective partnerships and collaboration (Seale et al., 2015). Here we critically reflect on a partnership involving students and lecturers as co-researchers to investigate the development of inclusive field experiences through onsite and nearby remote access.

This work aligns with recent initiatives in Higher Education (HE) that have shifted towards a relational form of student engagement, positioning students and lecturers as partners in learning and teaching (Bryson, 2014), where:

Partnership is framed as a process of student engagement, understood as staff and students learning and working together to foster engaged student learning and engaging learning and teaching enhancement . . . It is a way of doing things, rather than an outcome in itself (Healey et al., 2014, p. 7).
Working in partnership is a non-trivial challenge within HE, particularly with regard to identity, the imbalances in power, and the associated issues of ownership and expertise (Bovill, 2019; Cook-Sather et al., 2014; Healey et al., 2014; Hill et al., 2016; Matthews et al., 2019; Moore-Cherry et al., 2016; Seale et al., 2015; Thorogood et al., 2018). This study uncovers some of the challenges of working with students as co-researchers and beneficial insights that this approach brings to disability studies and inclusive education. While this work focuses specifically on fieldwork education, we argue that the Students as Partners approach is a powerful mechanism for enabling discipline-based educational research to break down the barriers of physical access and social inclusion affecting students with disabilities in HE.

**Methodology**

The primary objective of this study was to increase engagement and retention of students with disabilities, specifically students with physical-mobility disabilities, in the geosciences by instilling excitement and confidence in their subject knowledge and ability to participate in authentic field investigations and research. This investigation, with a mixed group of undergraduate geology students, piloted the use of mobile and network technologies to facilitate group work over two residential field trips: one in northern Arizona, USA, and another a year later in Connemara, Ireland (see Whitmeyer et al., 2020 for more details).

A collaborative-research approach was adopted throughout the project, valuing the range of expertise brought by the participating students and lecturers (Fuller et al., 2009; Healey et al., 2002, 2014). This positioned the work within a pragmatic research paradigm (Creswell & Creswell, 2018), focusing on what works for the participants, in order to draw out a set of findings to provide an authentic basis for specifying an inclusive fieldwork toolkit and guidelines for using the toolkit effectively. The sections below introduce the student recruitment process, the technology used to support group work, the form of data collection and analysis used in this study, and the context of the two field trips.

**Student recruitment**

Similar to past inclusive field courses (Atchison & Gilley, 2015; Atchison et al., 2019; Houghton et al., 2020; Stokes et al., 2019) and to ensure a broad participation pool from which to select, promotion of the project and recruitment materials were distributed through several social networks, including the International Association for Geoscience Diversity (IAGD), the Geological Society of America (GSA), and the Geoscience Education (GeoEd) listserv. Promotional materials indicated that the focus of the project was to pilot the use of technological solutions to improve field access and inclusion for undergraduate students with mobility disabilities. Recruitment materials also highlighted the design plan to group students in mixed ability pairs, and noted that students with and without physical-mobility disabilities were needed for the project.

Over 250 students from higher education institutions across the U.S. applied to participate in the project, nearly 40 of whom self-disclosed a variety of disability types. Applicants were asked to submit a statement of interest for participating in
the project, along with a curriculum vitae that documented their undergraduate coursework and field-based learning experiences. Ultimately, six able-normative students and six students with physical-mobility disabilities were selected to participate in the two-year project. All students were undergraduate geoscience majors selected from 12 different two- and four-year institutions from 10 different U.S. states. While all of the students with disabilities were assumed to have limited field experience, the able-normative students were deliberately selected within the first two years of their degree program to ensure the students’ level of field expertise was as uniform as possible across the student participants.

**Technology**

As noted in the previous section, the barriers faced by students with disabilities participating in fieldwork are the interconnected challenges in providing opportunities of physical access and social inclusion. To address these challenges this study focused on the integration of technology, pedagogy and content knowledge (Koehler et al., 2014). Technology will inevitably have affordances and limitations that affect what can be done; however, what should be done is also shaped by the content (i.e. geology) and pedagogical approach. In this study, we applied group work in the field, which encouraged students to work together to describe and interpret their environment by applying and extending their scientific understanding of geology. This involved making observations and measurements that describe the environment, and collating those descriptions over a geographical area in order to develop potential interpretations. These interpretations included sketches of landforms and geologic features, as well as models of geologic and environmental processes, including geologic maps and cross sections. The students were provided with two-way radios for voice communication and iPads with a pre-loaded set of applications to support note taking and information sharing (see Table 1).

**Data collection**

To capture the immediate responses from the participants, each of the students and lecturers were asked to keep reflective diaries individually, noting things they found

| Application     | Deployment | Functionality and use                                      |
|-----------------|------------|-----------------------------------------------------------|
| Camera          | Both       | Taking photos and videos of outcrops and landscapes.     |
| DropBox         | Both       | File syncing application for sharing files (requires internet connection). |
| Evernote        | Both       | Note taking application used for field notes.             |
| Google Docs     | Both       | Note taking application for reflections and report writing.|
| Livestream      | Arizona    | Video broadcasts between separate locations (requires internet connection). |
| Skype           | Arizona    | Video calls between separate locations (requires internet connection). |
| StratLogger     | Arizona    | An app for collating geo-located sediment and stratigraphic data in a stratigraphic column. |
| AirBeam         | Connemara  | Video streaming application to access remote sites (requires local network connection). |
| FieldMove       | Connemara  | Digital clinometer application for taking and mapping dip and strike measurements. |
| PhotoSync       | Connemara  | Photo sharing application (requires local network connection and web server). |
| Skitch          | Connemara  | Photo annotation for labelling and sketching over photos. |
personally challenging, rewarding or surprising, as well as any suggestions for improvements to the field exercises. Whole-group discussions were also recorded at the end of the two field trips, where students were asked to comment on the two main themes of the project, inclusiveness and technology. Towards the end of the second field trip the students were also asked to participate in one of two focus group interviews – one involving the students with disabilities and one with the able-normative students. The groups discussed what they learned about geology, their sense of inclusion, and their experiences with using the technology.

Data analysis

Critical incident analysis is a qualitative research method developed originally in aviation, that has been applied within the medical and education fields as a means of facilitating reflection (Flanagan, 1954; Green & Crisp, 2007; Sharples, 1993). Critical incidents are events of significance (positive or negative) that are used as a focus for reflection in order to review and improve practice. In the context of this study, these were incidents in which physical access and social inclusion were enabled or thwarted through the use of technology. The data from the participants’ reflections, group discussions and focus group interviews were used to gather multiple perspectives of these incidents. Thematic analysis was undertaken to identify and code issues within and across the critical incidents data (Braun & Clarke, 2006). Critical incident analysis provides a basis to review the participants’ experiences and feelings, and to evaluate and make sense of situations, in order to identify what else could have been done and propose alternate actions (Dye, 2011; Gibbs, 1988; Kolb, 1983).

Analytical framework

As well as the critical incident analysis, we draw on Matthews’ five propositions for genuine students as partners practice (Matthews, 2017, p. 2) as an analytical framework to discuss the critical incidents from the two residential field trips and reflect on the benefits and challenges of the collaborative research approach (see Discussion). The propositions include the following: fostering inclusive partnerships, nurturing power-sharing relationships through dialogue and reflection, accepting partnership as a process with uncertain outcomes, engaging in ethical partnerships, and enacting partnership for transformation.

Arizona field trip

During the first year of the project, twelve students, three personal assistants, and six project team members (i.e. three lecturers, two postgraduate students, and a project evaluator) travelled to northern Arizona. The research objectives for the first year were to establish an inclusive learning community and to study the effectiveness of using real-time audio and audio-visual communication to connect students with various types of access challenges that were physically separated across field sites. Students with mobility disabilities were paired with able-normative students in teams to tackle a variety of exercises intended to mimic geologically focused problems that undergraduate students
would typically encounter in course-based, day-long field trips. These exercises included sketching and interpreting faulted strata exposed in cliffs in Oak Creek Canyon, building a stratigraphic column of the classic lithologic sequence in the Grand Canyon by using the Trail of Time display at the South Rim, and investigating and describing volcanic landforms in the San Francisco Peaks volcanic field near Flagstaff. Students also visited Meteor Crater, but access restrictions imposed by the owners of the site precluded more than a cursory examination of the geologic features. Upon arriving in Arizona, the project staff presented the activities for the week and discussed the expectations for active participation and maintaining an inclusive learning community, which were deemed as outcomes for a successful project.

**Connemara field trip**

In the second year, the group travelled to Connemara, western Ireland. This region was specifically chosen to present environmental and geologic challenges that were clearly different from what the students experienced in the first year of the project. Western Ireland features a considerably wetter and colder climate as compared with the typically hot and dry conditions of Arizona. The geology of the Connemara region is dominated by folded metamorphic rocks, which contrasted with the sedimentary and volcanic rocks that comprised most of the year 1 field sites in Arizona. Thus, in year 2 the students were challenged with different environmental and geologic situations, mimicking the increasing complexity of experiences that students typically experience as they progress through their undergraduate courses and curricula.

The project team in year 2 included eleven students (one able-normative student dropped out of the project after year one), two additional lecturers who were unable to attend the Arizona trip in year 1, and an expert in the local geology. In addition, based on outcomes from the first year that highlighted challenges with maintaining connectivity between mobile devices in the field, a field-focused educational technology researcher joined the research team. The field activities in year two began with half-day exercises intended to replicate some of the year one challenges (e.g. sketching and interpreting geologic features), while introducing students to the geology of an unfamiliar region. The students again worked in teams of able-normative students and students with mobility disabilities.

The principal field activity in year two was a three-day field mapping exercise, in which the students with mobility disabilities digitally mapped the geology along an accessible, but secluded gravel road. Able-normative students mapped geology in the same region, but in areas that were inaccessible to the less mobile students. Through the use of a Local Area Network (LAN), the students on the gravel road were in audio and video communication with the students in more remote locations (see Table 2 for details). Communications were both synchronous and asynchronous – largely dictated by the level of connectivity between mobile devices. As a final test of using a LAN for field connectivity, the students sketched, described, and interpreted a seaside exposure of glacial till and debris, where the less mobile students could not see the exposure from their location. Thus, the able-normative students were tasked with using real-time audio and video communications to include their less mobile peers in the investigation and evaluation of the outcrop.
Table 2. A recommended equipment list for a flexible field communications toolkit.

| Category                          | Item                          | Example device                        | Quantity |
|-----------------------------------|-------------------------------|---------------------------------------|----------|
| Local Area Network (WiFi)         | WiFi Router and Ethernet Switch | TP-Link A×1500 Gigabit Dual Band Wireless Router | 1        |
|                                   | Outdoor WiFi Routers          | Ubiquiti NS-SAC NanoStation           | 4        |
|                                   |                               | Ubiquiti B-DB-AC Bullet               | 2        |
|                                   | 24 V Power over Ethernet Injectors | Tycon Power USB 5 v − 24 v USB PoE | 6        |
| Wide Area Network (4G/5G)        | Mobile Broadband Modem        | TP-Link M7350 4G LTE MiFi             | 1        |
| Audio                             | Two-Way Radios                | Motorola TLKR T92 H2O                 | 6        |
| Video                             | Video Streaming App           | iPad: AirBeam, NDI HX Camera          |          |
| Photos                            | Photo Sharing App             | iPad: AirBeam, PhotoSync              |          |

Results

Across the two field trips three incidents stood out as having a significant impact on the group: a one-day split group activity at the S P Crater cinder cone in Arizona, USA; the three-day mapping exercise at Recess in Connemara, Ireland; and a half-day exercise exploring glacial till and debris at Renyle Point in Connemara, Ireland. The three critical incidents are presented here as rich descriptions followed with illustrative quotations from the data collected from the participants.

Quotations are attributed using a label made up of the participant’s role in the project (i.e. S= student, F = Faculty and G = postgraduate student), a numerical identifier (i.e. 1 to 12), and the associated data source (i.e. D = Diary, GDB = Group Debrief, FG = Focus Group, and ON = Observation Notes). For example, student one’s diary entry would be denoted as S1-D. Students 1 to 6 did not indicate having a disability and students 7 to 12 had self-disclosed a physical-mobility disability.

Incident 1. S P Crater, Arizona

Near the end of the Arizona trip, the group visited S P Crater, a 250-meter-high cinder cone in the San Francisco Peaks volcanic field northeast of Flagstaff (see Figure 1). During previous exercises of the Arizona trip, students worked together in close proximity at specific locations. The S P Crater exercise was the first time during the trip that the students were split into two groups, where eight students ascended to the crater summit (three from the east side and five from the west) and four students stayed at a vehicle-accessible viewpoint 500 meters east of the base of the cinder cone. The goal of the exercise was for the students ascending the volcano to be in continuous communication with the students at the base in order to compare volcanic features (e.g. lava flows, cinders, lava bombs) across the full spectrum of the cinder cone. Not all of the students who attempted the climb reached the crater summit, as the climb was challenging due to its steepness and the instability of the cinder surface.

At this location, the groups attempted to use two-way radios for voice communication, GoPros for asynchronous video recording, and iPads running the Livestream app for web-enabled synchronous visual communication. There were issues with the
technology, specifically, the quality of the radio connection and the choice of video streaming options. The distance from the summit to the base and lack of line of sight (for the climbers on the west side) adversely affected the radio link. The video broadcasting application used a cellular data network, which resolved some of these issues, but the video streaming application introduced a buffering delay (over one minute) that resulted in video communications being out of sync with the two-way radio conversations. Additionally, there were issues with the activity design, in that the students at the base station were left with nothing to do but wait until students arrived at the top of the crater and (re-)established communication.

The combination of the physical and psychological challenges of the climb, the uniqueness of the geology, and difficulties with communication made this a key event in this field trip. Two of the eight students that attempted the climb didn’t reach the summit, several other students commented that it had been a physically difficult day:

Today I was nervous to summit because I didn’t think my knee would be able to handle the pressure, but I managed pretty well with little to no pain (S1-D);

I was disappointed not to make it to the top, but I know better than to let my will power overcome my body’s abilities (S4-D);

Physically it was challenging to climb up S P Crater as it was like climbing up four steps then going down four steps . . . (S6-D).

The difficulties with using the two-way radios during the assent resulted in a lack of communication between the groups and led to feelings of frustration and concern:

The walkie-talkies were not much help, felt in the dark and worried about our partner and others (S7-D base);

I think there were team members that remained at the base of S P Crater that felt left out of the exercise. We should have had more for them to do while they were waiting for the summit teams to climb the crater (F1-D).

Once at the summit, the radio signal between the base and summit groups improved and the groups were able to use the two-way radios and try the Livestream application to broadcast video from the summit to the group at the base (using the cell network):
Once people got to the top of the cinder cone, the Livestream worked, sort of. Only my tablet with the Wi-Fi hotspot was able to get video, and it had a long delay (more than a minute – may be two) . . . But the walkie talkies worked at the summit, so we used those to talk, and the delayed video to see’ (G1-ON);

(S11) was receiving good images on the live feed after they reached the top. Would have been helpful to possibly have a few more cameras, was hard sharing just one. The pictures and information was great (S7-D).

However, by this stage the coordination of activities between the groups made further collaboration between the summit and base difficult:

I had a hard time communicating with everyone but mostly we got to the top and had no idea what to do at the top and didn’t know what we were looking at (S2-D west side assent);

I was sort of accidentally in charge of all the livestreaming stuff . . . we just experimented and played with Zoom and Livestream to see which would work best . . . I wasn’t necessarily prepared with handling how to use all these different streaming options (G2-GDB east side assent);

We will need to do significantly more testing of tech solutions before next summer. I don’t think we can expect the students to help with “testing”; they want something that works out of the box (F1-D).

Taken as a whole, this experience catalysed the evolution of the project objectives for inclusion and connectivity. This was a physically challenging day for many of the students, and although the individuals that reached the summit had a sense of achievement, many of the other students were either frustrated by not reaching the summit or by the wait time and lack of connectivity and communication with those that did reach the summit.

**Incident 2. Recess, Connemara**

On the fourth day of the Ireland trip, the group started a three-day geological mapping exercise at Recess (east of the town of Clifden, Connemara, western Ireland). The students collaborated in three mixed-ability groups, with the able-normative students investigating the less accessible areas of the site and their partners working from the more physically accessible outcrops (see Figure 2). All of the students collected orientation measurements (strike and dip of foliation) and lithographic observations. The split groups generally worked asynchronously, collecting measurements and observations at the field site during the day and coming together in the evenings to collate and interpret their group data in order to write a group report and create a group geological map.

A local area network (LAN) was set up using Wi-Fi to connect student groups working in various locations across the site. Two-way radios were used to support communication between distant group members, along with the use of the AirBeam and PhotoSync apps for video streaming and photo sharing between groups. The students worked their way across the site, individually recording their orientation data and notes using the FieldMove app, taking photos with the iPad camera, and taking additional field notes using the Evernote app.
As the students were free to choose where they collected their data, it was challenging to predict and maintain the network coverage needed to keep everyone connected as they moved across the site over the three days. There were also challenges with coordinating communication across the groups once they were spread out across the site. This was addressed in part by demonstrating the use of the technology in a “classroom” setting prior to returning to the site on the morning of the second day, which enabled the students to make more effective use of the technology when working together at the site.

Organizing the group according to mixed abilities resulted in students having multiple perspectives of the mapping exercise. When asked what was the most important thing they learned during the trip, several of the able-normative students commented on the complexity of the fieldsite and the importance of description.

So, the most important thing I learned this week about geological fieldwork is really how complex it can be . . . Recess was pretty cryptic . . . There are a lot more dimensions to consider than I’ve needed to before (S3-FG);

I realised how important descriptions are than interpretations . . . So I would just go into the field and be like “oh, this is a gneiss rock”, but no, you need to, like why is it gneiss? It has compositional banding and things like that . . . you just need to write down everything you see (S1-FG).

In contrast the students with disabilities commented on their lack of understanding and confidence, noting differences in their educational experiences compared to some of the able-normative group. . .s

because we have a disability, for some of us that might have changed our educational background or track of courses . . . these different backgrounds in geoscience often because of our disability . . . might explain why some of the educational inclusion is coming into it . . . besides being physically accessible . . . the education needs to be brought up to like a comparable level for everyone (S8-FG);
It was very much the blind-leading-the-blind . . . to go and look at these outcrops where you can’t really get close, some guidance is explicitly necessary and definitely lacked on some of the trip (S11-FG).

During the first day in particular, the faculty were spread across the site, which also contributed to the students with disabilities feeling unsupported. . . .

when you don’t have an expert with you on site . . . it makes the field sites very difficult to interpret . . . when you’re not being properly guided in the field to look for things. And I’m not saying being given the information, but leading questions to help you go on the right path would be really important (S11-FG);

. . . despite that really unfortunate first day of the field mapping, the educational aspect of the second day when we had the expert with us . . . was phenomenal (S11-FG)

Across both groups, the students commented on a lack of communication from the faculty, in terms of the logistics, instruction and expectations.

If we had gotten, like, more direct instructions on what we needed to do and where our priorities needed to be, I think we might have gotten more done (S3-FG);

We weren’t really kept in the loop . . . I feel like they didn’t give enough, you know, and so we didn’t really know what to expect (S5-FG).

In this activity, it seems that the underlying issue of communication was linked to the asynchronous design of the activity, in that the students were effectively working independently in the field and then pooling their data afterwards.

“The mapping project wasn’t conducive to communication because we were both doing different things . . . We didn’t really need to talk to each other . . . we’d go back together at the end of the day, and we’d be like “OK, here’s what we got, here’s what you got, let’s put our stuff together” (S2-FG);

. . . when we were doing the mapping project, it felt like we were two separate groups (S2-FG).

Again the perspectives of the two groups differed, in terms of the group formation. The physical accessibility of different areas of the site effectively determined the split. Although unintentional, this separation from their peers was perceived very negatively by the students with disabilities as segregation by ability.

. . . we felt un-included, the disabled people, because we were all with each other (S7-GDB);

. . . the issue was dividing by ability completely, the two cohorts, where as in Arizona that never occurred. So I think that’s where some of the frustrations might be coming from (S8-FG);

. . . for at least the three-day mapping project, it was everyone with disabilities was lumped together in one group; everyone with physically-able bodies in another group; and the purpose was inclusion? . . . why would you segregate based on ability level? (S11-FG)

Overall, the mapping exercise was an asynchronous split-group activity, which, at the field site, the students engaged with individually or in pairs, rather than as distributed
groups. The spread of students across the site brought challenges for providing support and coordination, which was exacerbated by the variation in the students’ level of geological knowledge and fieldwork experiences.

**Incident 3. Renvyle Point, Connemara**

Based on some of the communication issues that students encountered at the Recess mapping area, we set up one final half-day exercise to see whether the LAN could work effectively for real-time video communication in a fairly inaccessible location. Mobile students walked along a rough, rocky shoreline to a seaside exposure of glacial till and debris, which was not visible to less mobile students who remained in the accessible location where the vans were parked (see Figure 3).

Synchronous collaboration between the groups included two-way radios for audio communication and the AirBeam app on iPads for video communication. Similar to the Recess exercise, asynchronous data collection was accomplished via GoPros, the iPad cameras, and note-taking apps. Cold, rainy and windy weather provided an additional challenge for group work, as the less mobile students sought refuge in the vans from the inclement weather. However, this resulted in a good test for the technology to see if the mobile students could effectively collaborate with their van-bound partners to tackle the geological problems in evidence at the outcrop.

At this site, the students worked in their mixed-ability groups, with some students on the shoreline communicating back to the students in the vans, parked at one end of the shore. The site was relatively compact (a shoreline section of about 150 meters) which made setting up a Local Area Network quick and straight-forward. The student groups were then in constant communication. They used the two-way radios to talk to one another, the AirBeam video stream to show the remote students around the site, and the PhotoSync app to share photos from the field site. The work of the students in the vans was captured using the GoPro cameras.

The two-way conversations supported by the video stream and photos were exploratory and collaborative.

I still noticed things that my group didn’t and asked them to go look at this, asked them to tell me what this was like, to zoom in to this, or to stop at that point, which I felt was very important (S12-GDB);

![Figure 3](image_url). A glacial till and debris exposure at Renvyle Point in Connemara, where students on the rocky shoreline (left) collaborated synchronously with students parked nearby (right) using two-way radios for conversation and the AirBeam iPad app for video streaming and photo sharing over a Local Area Network (middle).
what this was like, to zoom in to this, or to stop at that point, which I felt was very important.

... it doesn’t matter how able I am, someone who even has a different perspective than me can show me stuff that I don’t know, even if they’re not there (S5-GDB about S12);

... it just seemed like the people that were in the vans about 100 yards away were able to just be right there with us and were able to tell as much or were able to give insight on geologies (S6-GDB).

The students in the field were excited and motivated to use the technology to communicate with the remote students.

[S5] and I were taking turns, one of us would talk into the walkie-talkie, and [S12] and [S9] were both communicating with us, oh like zoom in on this part or like, what ... can you tell me more about the grain size is, like um, give us a scale or something. And I thought that was really awesome that we were, like all four of us were really having a conversation (S1-FG);

“I really liked the glacial day because it really allowed people to get out there who weren’t out there ... to me, the fourth day is, we got more things done in a day than we did in all the days together beforehand” (S12-FG).

When the students did feel included, this was attributed to the social atmosphere of acceptance and mutual support. ... we are all at different levels academically ... but once I got it down, once he showed me the first couple of things, you realize you can learn this, you can do this, you got this. ... especially socially, you figure out how to work with each other; what you can do, what can’t you do, what can I help you with ... (S2-FG referring to S3);

The social atmosphere is the most important part ... that makes the biggest difference ... Everyone is weird ... we can all be weird together and we can all just get along (S5-FG).

Overall, the use of the LAN to provide a reliable video connection to the field site for the three remote groups, coupled with the conversations over the two-way radios, enabled the remote and field-based students to explore the site collaboratively. The students who were not able to directly access the site made valid contributions to the students that were there and were able to offer observations that supported their group’s description and interpretation of the geology.

Discussion

The three critical incidents presented in the Results (above) were selected because they had a significant impact on the direction and approach of the project. Additional technology and expertise were brought in for the Connemara field trip in response to the challenges and frustrations experienced in Arizona. The additional technology also introduced logistical challenges that required better communication and teamwork across the group to use it effectively. Here we use Matthews’s (2017) five propositions to reflect on the extent to which our collaborative research approach enacted partnership practices.
**Foster inclusive partnerships**

The proposition of fostering inclusive partnerships explicitly questions the diversity of student and staff populations, and reflects on the opportunities and barriers to participation for specific groups. The student recruitment process selected an equal proportion of able-normative students and students with physical-mobility disabilities. The project leadership team (staff) also included two people with mobility disabilities. The group was balanced by gender, but ethnic diversity was limited (i.e. primarily White, U.S.). Although the proportion of people with disabilities was much higher than the wider population, this was justified by the remit of the project to investigate ways of authentically including students with disabilities in fieldwork.

Our findings demonstrate that each individual’s sense of inclusion and opportunity to participate varied across situations, highlighting that inclusion is active social engagement rather than physical access to the field site. Reflecting on the overall experience, the form of partnership supported through collaborative research with students will be shaped and influenced by the stage that students and staff get involved in the research and the roles they undertake. Rather than aspiring to an ideal of equality, it may be more pragmatic to adjust to each individual’s lived experiences and educational background and work towards developing and maintaining equitable collaboration.

**Nurture power-sharing relationships through dialogue and reflection**

The project description and opening presentations of each field trip positioned this work as a collaborative research project, where all the students’ and staff perspectives were valued. The students and staff were asked to write a reflective diary and participate in debriefing discussions at the end of each field trip. The students were also invited to contribute to a focus group discussion at the end of the second field trip to reflect on their experiences across the project.

The level of reflection and dialogue across the group enabled open and direct feedback. Where synchronous communication in the field was successful across the group (i.e. Renvyle Point) collaboration between the physically separated group members was effective, resulting in a strong sense of social cohesion. For the activities where the students were working asynchronously (i.e. Recess) and synchronous communication was not possible (i.e. S P Crater) the group felt unconnected, and imbalances in subject knowledge and access to support were more evident.

Although the project was orientated as a collaborative research project, the roles of field instructors and learners maintained a hierarchy of knowledge and power between the lecturers and students. Over the two years of the project, the students’ subject knowledge and experiences of fieldwork further differentiated the student group as the able-normative students had more opportunities to participate in fieldwork at their home institutions.

**Accept partnership as a transformative process with uncertain outcomes**

The project set out to explore the use of technological and social solutions to make fieldwork more inclusive for students with physical disabilities. The approach was
exploratory and experiential, and everyone involved was aware of the challenges involved. However, the overall level of uncertainty was problematic. The students and staff were visiting unfamiliar environments, undertaking fieldwork investigations (often for the first time), and exploring the potential of mobile technologies that they had not used previously. Everyone was focused on a common goal, but with hindsight the process was not always made clear enough to everyone involved, which resulted in anxiety and frustrations.

**Engage in ethical partnerships**

Ethical partnership is related to, but distinct from, research participant ethics. It refers to reciprocal, mutually beneficial practices that share power, have a justifiable moral basis and can be of wider benefit than to those individuals that are directly involved (Matthews, 2017, p. 5). Although this work aims to have a wider benefit and strong moral purpose, knowledge and power imbalances can threaten ethical validity particularly when working with students that are systematically disadvantaged (Seale et al., 2015). An ethic of care is key to addressing the impact of differential educational experiences (Cook-Sather & Felten, 2017).

In our case, enabling physical access to fieldwork was not sufficient, further support was needed to mitigate prior experiences and ensure inclusion within the discipline. Although the recruitment process tried to involve students with similar levels of subject knowledge and field experience, over the course of the project the differences in the students’ knowledge and opportunities to engage in fieldwork became more pronounced, which at times may have heightened the students’ anxiety and undermined their confidence in the learning community. Alternatively, where peer-support or lecturers with expertise were available in the field the students’ confidence and collaboration increased. Therefore, it should be noted that while fewer fieldwork opportunities for students with disabilities to participate in fieldwork persist, additional (social) scaffolding may be needed to mitigate differences in students’ confidence and subject knowledge.

**Enact partnership for transformation**

The transformational impact on students and staff of mutual respect, reciprocity, and a shared responsibility for learning and teaching is the fifth proposition for genuine students as partnership practice. Across the field trips we can say that this has been achieved, the three critical incidents were the kernels for that transformation, but there have been longer term changes in the ways these individuals have subsequently engaged in fieldwork and in sharing their experiences. The able-normative students have become advocates for disability inclusion within their home institutions, and all of the students have subsequently presented their work at national conferences and workshops (Haddock et al., 2017; Thatcher et al., 2017). The lecturers have also disseminated their experiences to the broader community, through presentations and accessible field trip workshops at professional geoscience conferences (Atchison et al., 2019), publications in journals with wide distribution (e.g. Whitmeyer et al., 2020), and by advocating for reform of field experiences at their respective institutions.
Conclusion

In this study we adopted instructional strategies that used technology to provide remote access (either synchronously or asynchronously) to inaccessible field sites (Carabajal et al., 2017). The authentic field experiences provided through the Arizona and Ireland field trips did achieve the objective of increasing engagement and retention of students with disabilities in the geosciences. This study found that synchronous communications technology can be used to bridge the physical separation of students working in groups and enable students with physical-mobility disabilities to be socially included and participate equitably in geoscience fieldwork.

For more isolated field locations (i.e. less populated areas), the infrastructure for synchronous communication may not be readily available, and there are financial and logistical implications for attempting to provide it. Drawing on our experiences, Table 2 provides a list of recommended equipment for a flexible field communications toolkit to support nearby remote access for students with physical-mobility disabilities. We found that for nearby connections (a few hundred meters) a Local Area Network (LAN) can be set up quickly and provides sufficient bandwidth for local video streaming, photo sharing and data collection. For groups moving over larger areas the work involved in maintaining a LAN is significant, and it therefore may be better to use the mobile phone network (where available) or structure the task as an asynchronous group activity.

Regarding the learning design of field exercises, collaboration and communication between students in the field is necessitated through synchronous group work. Tailoring a group field exercise to accommodate diversity, therefore, becomes a choice between a co-located or distributed group. Fully accessible field sites enabling co-location are preferable, but for sites that are not physically accessible for some students, communication technology can mitigate the separation of the group members. However, if the technology infrastructure is not available or the overhead of using technology is prohibitive, equitable asynchronous group work is preferable to inequitable synchronous group work.

Reflecting on this study and the process of engaging with students as co-researchers, we offer the following recommendations in two main areas: fieldwork inclusion and collaborative pedagogical research with students.

Fieldwork inclusion

- Inclusive learning design – Tailor the design of the field exercise to the physical abilities of each group to ensure physical endurance is not a barrier to learning and that each students’ personal knowledge and experience are valued and included within the community of learning.
- Assistive technology – Explore how technology can assist and enhance learning for the whole group and ensure everyone is familiar with operating the technology.
- Integrate technology – Where technology is used, ensure it is embedded in the design of the field exercise as a necessary tool and everyone knows how to use it effectively.
- Robust contingencies – Plan for technology and operator failure by including options and alternate tools, resources, or exercises.
Collaborative research with students

- A *culture of participation* – Establishing and maintaining a productive culture within the group of acceptance, respect, and accountability values diversity and promotes social and academic inclusion.
- *Early and ongoing engagement* – Co-design and co-development are necessary preparations for co-delivery and are more likely to lead to shared ownership and more productive partnerships.
- *Roles and responsibilities* – Where professional (e.g. education or medical) responsibilities require a level of control to be maintained by any individual, it is important to communicate their roles and responsibilities at an appropriate level of disclosure.
- *Manage power dynamics* – Differences in knowledge will inevitably create (or maintain) power dynamics and social hierarchies. Therefore, developing a partnership requires engagement over time to recognize and establish respect for the different forms of knowledge within the group.

Limitations and future work

This study purposely focused on developing authentic field experiences with a group of 12 undergraduate students from 10 universities, including six students with a range of physical-mobility disabilities. The selection of the target group limits the extent to which the findings can be generalised to students with other (non-mobility) disabilities, and the study did not focus on any intersectional issues such as race or gender. Nonetheless, we would argue that working with diverse groups of students as collaborators in the research process takes us a long way towards developing a better understanding of each individual’s experiences and enhances our capacity to provide appropriate forms of support to one another.

Further work is needed to promote disability inclusion within the geosciences. However, studies, such as this one, are contributing to the wider awareness and adoption of inclusive and accessible teaching practices and the recruitment of a more diverse student body. It is hoped that the use of technology developed and shared through this project will encourage more colleagues to critically consider (and mitigate) their use of inaccessible field sites and physically rigorous learning activities.

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