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More than fun in the sun: The pedagogy of field trips supports student learning in higher education

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ABSTRACT

Field experiences are a fundamental and well-loved tool for teaching in the natural sciences. However, a number of concerns threaten continued incorporation of field experiences into courses, including increased class sizes, strained finances, legal liability, accessibility concerns, and the effects of COVID-19. Because of these barriers, it is critically important to investigate and articulate the value of field trips to better advocate for their continued implementation. By reviewing existing literature on traditional field trips and courses, virtual field experiences, and accessible field trips, we have identified several attributes that contribute to the value of field trips as a pedagogical tool. The strength of field activities lies in 1) the integration of active learning, 2) the co-creation of knowledge through collaborative, problem-based activities, 3) place-based learning that provides real-world context, and 4) rapid feedback between peers and instructors. These strategies are well-represented in scholarship on teaching and learning, and further, strategies implemented in field learning may help to reduce the achievement gap for underrepresented groups. Applying the four attributes of field trip pedagogy to classroom and virtual classroom activities, as well as to virtual field trips, can improve teaching and learning when field trips are not possible. Instructors should aim to re-create as many of these attributes as possible to design courses that are as impactful as those involving traditional field trips.

INTRODUCTION

Field trips, here defined as any formal field experience with a learning objective, are a long-established tradition in the natural sciences (Behrendt & Franklin, 2014; Fleischner et al., 2017; Malbrecht et al., 2016; Malone, 1999; Mogk & Goodwin, 2012). Field trips are viewed as a crucial component to teach students the skills and content that they need to be successful scientists. In particular, field trips provide hands-on experience with professional equipment and measurement techniques (Fryar et al., 2010; Fuller, 2006; Ghail & Standing, 2019; Malbrecht et al., 2016) and promote professional and study skills like note taking, sketching, and hypothesis testing (Hefferan et al., 2002; Malone, 1999; Wheeler et al., 2011). Field trips can also enhance personal skills like self-efficacy, autonomy, and sense of ownership over work, and interpersonal skills like collaboration, ability to provide feedback, and building a peer network (Atchison et al., 2019; Fleischner et al., 2017; Fuller, 2006; Hefferan et al., 2002; Houser et al., 2011; Larsen et al., 2017; Lei, 2010; Wheeler et al., 2011). Importantly, field trips have been shown to increase student learning gains, particularly in higher-order forms of learning from Bloom's Taxonomy, such as applying and analyzing knowledge (Bowler et al., 1999; Elkins & Elkins, 2007; Houser et al., 2011; Kern & Carpenter, 1986; Kolivras et al., 2012; Seifan et al., 2020).

Field trips promote higher-order learning because of the ingrained pedagogical practices. Students take knowledge learned in the classroom and apply it in the field setting, actively contextualizing their knowledge and transitioning it from being theoretical to practical (Kent et al., 1997; Krakowka, 2012; Schiappa & Smith, 2019). By allowing students to embody their learning, work in groups, and hear lectures, instructors can vary the delivery of information (Kent et al., 1997). This type of varied content delivery, known as multimodal learning, is an important component of inclusive instruction and assessment (Qualters, 2016). Though the benefits of field trips are widely recognized, the pedagogies that lead to learning in the field have not been synthesized to create a template for reaching higher-order thinking and student learning.

Despite their pedagogical and disciplinary benefits, field trips are declining at many academic institutions (Barrows et al., 2016; Fleischner et al., 2017; H. Wilson et al., 2017). Whether it be for lack of institutional support (H. Wilson et al., 2017), lack of funding (Behrendt & Franklin, 2014; Lei, 2015), large class sizes (Lei, 2015), students having family duties (Zavaleta et al., 2020), the potential for liabilities (Lei, 2015), the threat of disease (Scott et al., 2006; personal experience with COVID-19 pandemic), online class offerings (Bursztyn et al., 2017), or accessibility concerns (Carabajal et al., 2017; Hendricks et al., 2017), field trips are more difficult to implement. This is detrimental to courses where field experiences are central, such as in the natural sciences. Understanding the value of field trips helps to ensure administrative support for their continued use. Further, applying the pedagogical practices learned from field trips to emerging virtual and asynchronous field experiences will improve student learning and boost the value of online or hybrid courses.

Both authors were privileged enough to attend small liberal arts colleges as undergraduates, where fieldwork was well-incorporated into the curriculum. We have both moved to larger institutions in our graduate careers and do not see fieldwork incorporated to the same degree. In light of our personal experiences and studies that document an overall decline of fieldwork in higher education (Barrows et al., 2016; Fleischner et al., 2017; H. Wilson et al., 2017), we came to this work with several research questions: Do field trips actually enhance student learning? What is it about field trips that affects learning? And how do we re-create the part of the pedagogy that makes field trips successful when we cannot bring students into the field?

Literature Processing

To answer these questions, we reviewed existing literature on traditional field trips and courses. We did not attempt a systematic review of literature, rather we were reading literature that related to our questions. Our process was similar to the qualitative evidence synthesis described by Grant & Booth (2009), which aims to identify and interpret themes across multiple studies in order to broaden understanding of a subject. Using Google Scholar and Web of Science, we searched terms like *field trip*, *field course*, *field experience, and virtual field trip* with terms like *higher education*, *undergraduate*, *graduate*, *natural science*, *science*, *ecology*, *environmental*, *geology*, and *teaching*. We eliminated papers that were field trip or lab lesson plans and other papers that did not address learning attributes of field experiences, drawing mainly on higher education literature (not K-12). The papers we considered were those specifically describing the effects a field trip, field course, or field experience had on students' skills, learning, attitudes, and growth as scientists.

After reviewing all the skills and concepts associated with field trips, we looked for themes aligned with highly regarded teaching practices and summarized our findings into four categories: active learning, knowledge co-creation, feedback, and place-based values (Figure 1). Though these categories are not exhaustive (i.e. field trips engage other teaching practices), they capture much of the value that we identified and are well-known learner-centered practices (Hoidn & Klemenčič, 2020; Snyder et al., 2019). Below we describe each of these in the context of traditional field trips, and provide guidance on how these attributes can be applied to non-field activities. We also discuss the potential of these high-impact teaching strategies to promote recruitment, learning, and retention of students from underrepresented groups.

CONSIDERING PEDAGOGY: WHY FIELD TRIPS ARE EFFECTIVE

One: Integration of active learning

Active learning involves "activities that students do to construct knowledge and understanding" (Brame, 2016). In other words, active learning is an instructional practice where students complete activities, use higher-order thinking to consider what they are doing, and focus more on skills than information. Sometimes a field trip is simply a lecture in the field (Higgs & McCarthy, 2005), but most often, field trips are active (Krakowka, 2012). When field trips provide hands-on, problem-based activities, students engage in higher-order thinking and develop as scientists.

Field trips offer experiences unavailable in a classroom that allow students to engage all of their senses. Being immersed in a complex, new place supports real-world problem solving and hands-on work, which students both appreciate and enjoy (Bruening et al., 2002; Fuller, 2006; Jolley et al., 2019; Lei, 2010; Schiappa & Smith, 2019; Tonts, 2011). Because the experiences on a field trip are grounded in the complex occurrences of the real world, students can actively engage in experiential learning, where the purpose of the trip is to solve a problem or make a discovery (Malbrecht et al., 2016; Malone, 1999). Connecting classroom ideas to real-world experiences demonstrates the relevance of theoretical concepts and allows students to integrate their lived experience with course content. This uplifts the student perspective as a valuable, empowering part of the learning process (Tuitt et al., 2018). By extending learning beyond the content and forcing students to confront the complexity of the real-world, field lessons become an especially valuable mode of learning (Lei, 2010; Pyle, 2009).

The active, experiential nature of a field trip promotes higher-order thinking and skill development. Field experiences cause students to observe, question, re-evaluate, and inspire the search for explanations (Fleischner et al., 2017). Students have the opportunity to experience something new, reflect on it, analyze their data or knowledge, and test the idea to develop new knowledge (Behrendt & Franklin, 2014). These deep-thinking effects are accompanied by numerous skills, both personal and professional. For example, attributes strengthened during field-based lessons can include attention to detail, keen observing, personal organization, a sense of ownership of one’s work, interpersonal skills, self-efficacy and autonomy, time management, scientific identity, creating and evaluating hypotheses, and more

(Jolley et al., 2019; Wheeler et al., 2011). In addition to problem-based field lessons, student-led teaching in the field can deepen learning and create a sense of place and empowerment (Marvell et al., 2013), as well as allow students to bring their culture and emotions to the lesson (Tuitt et al., 2018).

Two: Co-creation of knowledge

The co-creation of knowledge is a collaborative process where students and instructors generate ideas, learn skills, and produce data, culminating in novel information for both parties (Gorzycki, n.d.). Many of today's college students want to be active partners in higher education courses, working closely with their professors to become valuable members of the field (Dollinger et al., 2018). Field trips can provide a setting for this kind of student-instructor collaboration and co-creation of knowledge where, in addition to mastering course content, students contribute to the discipline. Mogk and Goodwin describe, “The field setting is one of the important crucibles where science and scientists codevelop: Learning in the field has always been about creation of new knowledge by direct observation of Earth while providing an important foundation in the training and professional development of the next generation of geoscientists” (2012). Posing as valuable to the instructors’ and students’ knowledge and discipline-specific advancements, field trips are fundamental to the higher education process, especially in the natural sciences.

Field trips can promote the co-creation of knowledge because they are often project-based and exploratory. When field trips are used to conduct a study expanding on class content, the knowledge is not being handed from the professor to the students, but rather, they are discovering it together. In my [author SW] personal experience at Allegheny College, ecological and environmental science field trips were often centered around a question, sometimes involving a local land management or private partner. The whole class participated in data collection in the field, analysis during later classes, and writing of a report, which was sometimes publishable later on (such as Bowden et al., 2019; Wayman et al., 2014; also see 'Allegheny Environmental Publications' at https://sites.allegheny.edu/envsci/student-resources/). These discovery-based activities promote collaboration between established scientists and scientists-in-training.

Three: Peer-instructor feedback

The collaborative and intensive nature of field experiences creates opportunities for rapid feedback between students and instructors. Rapid feedback is beneficial to reinforce positive interpretations and skills and to dispel misconceptions before they become solidified (Friess et al., 2016; Mogk & Goodwin, 2012; Wheeler et al., 2011). Instructors can also help direct students if they feel overwhelmed by the amount of information in a new field setting (Bentley, 2009). Some studies suggest that students receive more feedback in the field than in a classroom (Demirkaya & Atayeter, 2011).

Though not explicitly stated in literature about field trips, this type of feedback can be viewed as a type of formative assessment. Formative assessment is a set of practices that elicit, interpret, and use evidence about student learning to guide decisions about instruction. Using this type of assessment will likely lead to better instruction than would have been offered in the absence of the evidence (Black & Wiliam, 2009). In effect, instructors use formative assessment to understand what students are learning and to adjust their teaching to increase student learning. This can take a variety of forms that can be (and already are) implemented in field experiences, including informal conversations, peer feedback, self-reflection, daily presentations, turning in draft materials, and drawing diagrams in the sand (e.g. Fagan & Sturm, 2015; Hesthammer et al., 2002) . Formative assessment has been uplifted as a valuable learning tool that increases student learning, promotes self-efficacy and autonomy, and improves teaching by forcing instructors to reflect on their teaching (Gibbs & Simpson, 2005; Kingston & Nash, 2011).

Feedback between students and instructors can also lower perceived barriers in the hierarchical educational structure. Informal moments such as transit between field sites, cooking, and sitting around a campfire at night allow students to ask questions and express ideas in a low stakes environment (Núñez et al., 2020). This builds the relationship between students and instructors and reduces the intimidation that students feel to ask for help from professors. This extends beyond the time in the field, as students feel more comfortable visiting office hours and asking questions in class after field experiences (Houser et al., 2011; Kamen & Leri, 2019; Kern & Carpenter, 1986; Stokes & Boyle, 2009).

Field trips also provide opportunities for interaction and feedback among peers. These interactions produce academic benefits, including active engagement, greater investment in the material, and greater depth of understanding (Duran, 2017; Goldschmid & Goldschmid, 1976). The social aspect of group work is also important. Interpersonal skills are valuable career skills, as most professions require collaborative work. Students also leverage the social connections that they build during field experiences to form study groups (Hefferan et al., 2002; Houser et al., 2011). Further, students consistently rate the social aspects of field trips as highly valuable, regardless of the learning benefit. These social connections contribute to a positive affective (i.e. feelings, emotions, and attitudes) response, which can improve learning outcomes and encourage students to remain in the natural sciences (Kortz et al., 2020; Mogk & Goodwin, 2012; Stokes & Boyle, 2009).

Four: Place-based education learning

Formally, place-based education is a relatively new teaching philosophy, first detailed in the 1990s (Elder, 1998). Place-based education (PBE) aims to teach students by situating learning in a place- using local context, knowledge, and understanding. A ‘place’ in this usage is distinct from a geographic location because it is given meaning by human experience. Though the strict definition of PBE is relatively new, the practice parallels methods of teaching before formal schools were established, traditional Indigenous ways of knowing and teaching, and the practices of natural history, which center human relationships to physical locations (Semken et al., 2017). PBE has clear ties to the natural sciences through the collection of spatially explicit data and the recognition of the uniqueness of places. Semken (2005) identified five central characteristics of a geoscience-based PBE model: a focus on the natural attributes of a place, acknowledgment of the diverse meaning that a place holds, creation of authentic experiences within that place, promotion of sustainable living, and enrichment of sense of place. Ultimately, place-based education aims to increase students' engagement with a place by allowing them to experience it fully and develop their own sense of meaning.

Traditional field trips typically engage three of these five characteristics. Trips are focused on the processes and features of the location where they are held, providing specific local examples and context to concepts covered in the classroom. These trips provide authentic experiences such as self-paced exploration and the collection of primary data, as opposed to instructor-moderated exercises in classrooms. Participants are imbued with a sense of place by physically operating in the space and having new experiences that are tied to a specific locale (Jolley et al., 2019). Less frequently in the natural sciences, field trips discuss the diverse meanings that a place holds (e.g. discussing the history of a National Park when observing the geology) or engage in discussions of sustainable practices (though some disciplines are explicitly concerned with these aspects). By incorporating the diverse meanings of places and issues of sustainability, field trips can be enriched with multicultural and multidisciplinary viewpoints. Many of the great challenges in the natural sciences require cross-disciplinary collaboration, and explicitly introducing these concepts can help students understand and appreciate interdisciplinarity (Gosselin et al., 2016).

The development of a sense of place can improve student retention in the natural sciences. Many natural scientists cite early field experiences as strong determinants of their interest in science. By camping, working, and interacting with peers in the field, students develop attachments to the places where they work (Jolley et al., 2019). These experiences are also important to developing an identity as a scientist, which is tied to retention (Atchison et al., 2019; Streule & Craig, 2016). Aesthetic beauty, a sense of wonder, and affinity for nature promote positive emotional response and enhance sense of place (LaDue & Pacheco, 2013; Semken et al., 2017; Stokes & Boyle, 2009). The importance of place continues into our professional work as field scientists; we think of places where we conduct research as 'our' field sites due to numerous hours of work and important personal and professional experiences that occur in the field, and we often return to these locations to teach or as visitors.

IMPORTANT CONSIDERATIONS FOR STUDENTS FROM UNDERREPRESENTED GROUPS

Inclusive Pedagogy

We have demonstrated that the specific pedagogies employed on field trips support student learning. There is also research to suggest that these pedagogical approaches are particularly impactful for students from groups underrepresented in science, technology, engineering, and math (STEM). Here, we explain how active learning, co-production of knowledge, feedback, and place-based education can provide learning gains for underrepresented students and improve the inclusiveness of higher education natural science courses. Our conclusions align with recent work suggesting field-based courses contribute to reducing the achievement gap for underrepresented groups (e.g. Beltran et al., 2020) and improve retention of underrepresented students by stimulating the development of scientific identity and confidence (Zavaleta et al., 2020).

Active Learning & Equity

As a teaching technique, active learning has been shown to benefit all students; however, those from underrepresented backgrounds reap the most benefits (Theobald et al., 2020). The combination of increased structure within the activities and the promotion of selfconfidence and belonging through team interactions renders active learning beneficial for students (Ballen, 2020; Collins et al., 2019; Jordt et al., 2017). Further, actively working in groups can make large classes feel smaller, improving participation and reducing the feeling of invisibility among students (Ballen, 2020). Consequently, field trips may play a role in equitable learning experiences in higher education because field activities are often inherently active and group-oriented, providing the foundation for the aforementioned benefits.

Co-Producing Knowledge & Anti-Racism

Co-constructing knowledge has been identified as an anti-racist pedagogical practice. By engaging with students through the co-production of knowledge, the instructor demonstrates humility, openness, and allyship (Akamine Phillips et al., 2019). Further, the collaborative nature of the practice reduces the hierarchical structure of the class, allowing more voices within the class to be heard and building a learning community where many types of knowledge and beliefs are valued (Cooper, 2006). In the field, co-producing knowledge may involve students and instructors collecting data for a class research project. Working together in this manner can make students feel like colleagues and give them a sense of what it's like to be a scientist (e.g. Fleming, 2015). Structured undergraduate research projects, such as through the Research Experience for Undergraduates (REU) programs, which involve a high proportion of underrepresented students and occur in field settings, have been shown to help students envision themselves in science careers and increase retention in STEM (Blake et al., 2013; A. E. Wilson et al., 2018). Further, underrepresented REU students have been shown to make greater learning gains through their experiences (Lopatto, 2007). Taking advantage of natural settings by incorporating research projects into field (and classroom) activities may benefit learning and retention of underserved students.

Feedback & Belonging

Receiving constructive feedback and having shared experiences with peers and instructors helps students feel more comfortable within their discipline. Peer and instructor feedback may be especially beneficial for first-generation students and students from other underrepresented groups. First-generation students may be less likely to ask questions during lecture and attend office hours, so lowering the barrier between professor and student is helpful (Collier & Morgan, 2008; Kim & Sax, 2009; Means & Pyne, 2017). The frequency and informality of communication in the field can help students feel more comfortable talking with their instructors and asking questions, even after returning from the field (Kern & Carpenter, 1986; Stokes & Boyle, 2009). Similarly, peer connection and group work have been shown to be effective for students of color and first-generation students (Eddy & Hogan, 2014; Nelson, 1996; Toven-Lindsey et al., 2015; Treisman, 1992). Working in groups helps to build social and intellectual contacts, create a sense of belonging and self-efficacy, and to de-stigmatize academic achievement. A strong sense of belonging is important for students of color in predominantly white disciplines, who may doubt their ability to succeed without prior knowledge of the discipline or representative role models (Karsten, 2019; Zavaleta et al., 2020). Field trips often involve group work and provide an opportunity to build interpersonal connections with peers and instructors.

Place-based education & Identity

Place-based curricula provide a more meaningful method to teach natural science in urban settings. Focusing on natural attributes and explicitly linking them to the structure of cities (and vice versa) allows students to view the city as a complex natural environment (Apple et al., 2014; Barnett et al., 2006; Fleischner et al., 2017; Kirkby, 2014; Semken et al., 2017). Further, the inclusion of diverse values in place-based education allows students to incorporate their prior knowledge and lived experiences, deepening their connection to the course material (Kirkby, 2014). This approach is beneficial for schools located in urban and suburban areas that do not have the ability to take students far from campus, and urban field trips have been successfully implemented asynchronously as well (Kirkby, 2014; Shinneman et al., 2020). Additionally, centering natural science in urban areas helps students to see their homes as settings that are worthy of study, rather than believing that interesting science only occurs in ‘more natural’ areas (Apple et al., 2014; Barnett et al., 2006; Fleischner et al., 2017; Kirkby, 2014; Semken et al., 2017). This can increase the number of students from urban areas interested in science, particularly if conducted in partnership with K-12 education (Blake et al., 2015; Bouillion & Gomez, 2001; DeFelice et al., 2014). There are obvious implications for racial diversity in urban recruitment, as cities have greater proportions of students of color (Snyder et al., 2019).

Place-based education has also been championed as a method to engage Indigenous students with the natural sciences. As noted, PBE parallels Indigenous teachings that emphasize the interconnectedness of humans and the natural environment and stands in stark contrast to the discipline-dominated view of western science (Ericson, 2017; Semken et al., 2017). There are many examples of place-based curricula that explicitly incorporate Indigenous viewpoints; these include the use of knowledge from tribal elders, direct work with tribal resource managers, and artwork and cultural narratives (as reviewed by Semken et al., 2017). In all of these cases, Indigenous knowledge was incorporated through collaboration and relationship-building with Indigenous communities. This is critical, because trying to incorporate these elements without the involvement of Indigenous communities can be harmful and further promote colonial habits of knowledge appropriation and extraction (Cartier, 2019; Gewin, 2021; Held, 2019). However, when Indigenous knowledge is authentically incorporated, it is uplifted as a legitimate way to understand the world (Johnson et al., 2014; Lemus et al., 2014). This can be especially impactful for Indigenous students by validating their cultural heritage and allowing them to see themselves reflected in their scientific learning (Semken, 2005; Semken et al., 2017).

Equity on field trips

While field learning is undoubtedly valuable, and can be especially impactful for students from underrepresented groups, the pedagogical benefits will not be effective without considering factors that affect the equity of the learning experience. Field work has historically been a barrier for students from underrepresented groups for a variety of reasons, including finances, family responsibility, accessibility, comfort in the outdoors, and safety (O'Connell & Holmes, 2011; Posselt et al., 2019; Sherman-Morris & McNeal, 2016). The many identities that students bring to the field, including race, nationality, gender, class, ability, and others, impact comfort and learning (Demery & Pipkin, 2021). If instructors do not plan with these factors in mind, field trips will continue to be barriers to students from underrepresented groups (O'Connell & Holmes, 2011).

Financial status is one barrier to participating in field trips or having an equitable field experience (Table 1). Course fees associated with field trips or field courses can prevent some students from signing up (Zavaleta et al., 2020). Dedicating a scholarship program to cover field trip fees could help to alleviate financial burdens, and fully enumerating the expected cost of a course (e.g. fees, gear, time away) will help students make informed decisions. Additionally, low-income students may not have information, access, or funds to acquire field gear required for a variety of situations (Anadu et al., 2020; Giles et al., 2020; Núñez et al., 2020). I [author JJ] struggled to afford outdoor gear as an undergraduate and occasionally dealt with physical discomfort on field trips (e.g. being cold and wet). Creating clothing guides for different field settings and having a borrowing closet or gear drive could help students feel more prepared for field trips (Table 1). In an internship or professional setting, field research positions that offer low or no salary may not be viable for students from low-income families, preventing them from gaining field experiences (Jensen et al., 2021). Ensuring a fair wage and potentially accommodating childcare needs, e.g. through explicit funding in a grant budget (Fournier &

Bond, 2015), could help students afford to participate in field experiences; funding for both personal and professional needs has been identified as a key component for the success of REU programs (A. E. Wilson et al., 2018).

A student's living situation can also impact their ability to attend field trips. Students with jobs and family duties may have limited time to attend a field trip or field course, which may disproportionately impact first-generation and minoritized students (Hughes, 2016; Shinneman et al., 2020). Establishing the field trip schedule as early as possible, designing asynchronous field experiences, and having a policy for accomodations can help prepare students for the course. When conducting field activities asynchronously and from home (as during the COVID-19 pandemic), socioeconomic status can affect the level of biodiversity and amount of green space that students have access to (Table 1). Lower-income neighborhoods are less biodiverse than wealthy neighborhoods (Kinzig et al., 2005; Lerman & Warren, 2011; Melles, 2005; Schell et al., 2020). Additionally, there are differences in home ownership rates and proximity to green or blue space among racial groups in the United States, so students from some groups will have less opportunity to sample soils, make field observations, etc (e.g. Wolch et al., 2014). Rather than ignoring these differences, instructors should emphasize the diversity of settings and spatial patterns, to emphasize the importance of all habitats and the differences in student experiences (Washko, 2021).

Fear of racial violence is another barrier that prevents students from having equitable field experiences. Visiting largely white, rural areas can be uncomfortable and even unsafe for students of color (Anadu et al., 2020; Demery & Pipkin, 2021; Hughes, 2016). This may be especially true of students who do not have much experience recreating or working outdoors. Discussing risks and how problems will be addressed prior to the field trip can help students feel more safe, prepared, and understand that the instructors are allies who want to protect them (Table 1). Scaffolding field experiences - so that field trips in early courses are less intensive and those in upper level courses are more involved - can build competency and comfort as well

(Hughes et al., 2016). Speaking from personal experience, I [author JJ] am African-American from an urban, lower-middle class family and I have done extensive fieldwork in rural, largely white areas in the US. I have felt uneasy on numerous occasions - encountering Confederate flags on the way to field sites, coming across hunters in secluded locations, and I once had camping equipment stolen during a personal trip at a remote site. Though anecdotal, my experience is not unique, and illustrates that extra safety and logistical considerations are important when bringing students of color into the field.

Another safety aspect to consider is sexual harassment and gender-based violence. Some individuals, often women and members of the LGTBQ+ community, are at higher risk of being sexually harassed or assaulted in the field, especially when constituting the minority of the group (Clancy et al., 2014; Olcott & Downen, 2020; Sexton et al., 2016; Warren et al., 2018). Demoralizing comments about competency, value, and ability based on gender role norms can cause students to lose confidence in their capabilities in the field (Hill et al., 2021; Warren et al., 2018). Harassment may occur more frequently in field situations where the physical conditions are strenuous or remote (Hill et al., 2021). Having a clear and enforced safety policy or code of conduct for all participants, mandating allyship training, using gender-neutral language, focusing on team-building, and giving all students a chance to be leaders while in the field can reduce the risk of gender-based violence in the field and empower students (Table 1). Further, taking care of participants' physical needs and safety can lead to fieldwork positively influencing mental health (John & Khan, 2018).

Lastly, physical accessibility is a barrier for many disabled students interested in field experiences. Field sites may be inherently inaccessible, taking place in areas that are steep, unstable, require a lot of walking, are underwater, etc. Mobility-disabled outdoor recreationists have limited access to wilderness, preventing them from having equitable outdoor experiences (Lovelock, 2010), and the same could be said of natural science students. Selecting accessible field trip locations and embracing universal design during field trip planning (Table 1) can allow mobility-impaired students to participate in field experiences (Atchison et al., 2019; Carabajal et al., 2017). Further, providing tactile diagrams for visually-impaired students and captions or interpreters for hearing-impaired students enhances the inclusivity of field trips (Hendricks et al., 2017).

ADAPTING FIELD TRIP PEDAGOGIES

Shifting from the field to the classroom or virtual classroom

We have established that field trips are important components of natural science curricula and beneficial for student learning. Certain circumstances, however, prohibit field trips from occurring. To overcome biases and barriers and give students the best learning experience despite a lack of field opportunities, we can bring attributes of field trips to the classroom by designing problem-based activities involving a sense of place and the opportunity for constructive feedback. Further, the activity could encompass a novel question, allowing for the co-creation of knowledge between the instructor and the students.

Active Learning

In the field, students partake in active learning through hands-on work like taking measurements. In the classroom, the hands-on work is indirect. For example, if students could not take a field trip to a nearby outcrop and measure fracture spacing, the instructor could create an activity where students can measure fracture spacing in the classroom or virtual classroom (Figure 2). The instructor could provide photos of the fractures and include a meter stick in the photos. The student groups could use ImageJ (or similar software) to measure the fractures with the reference meter and log the data. Despite taking place indoors, these activities allow students to complete measurements and somewhat grasp or visualize what it’s like to work in the outdoors. Although these activities require preparation by the instructor, the engaging activity is worthwhile. For an in-depth explanation of how to combine inclusive teaching and active learning in online instruction, see Harris et al. (2020).

Knowledge Co-Production

By designing experiments, students and instructors can co-construct knowledge. For example, if students learning about aquatic food webs wanted to know how larval caddisflies contribute to the breakdown of leaf litter in a local wetland, they could create multiple treatments of leaf packs or litterbags, deploy them in a nearby wetland, and later retrieve them and analyze the data. The instructor simultaneously learns how the local wetland functions and can build upon this knowledge during subsequent iterations of the course. If repeated trips to the field for measurements are not possible, students could scour literature for studies similar to what they would have done in the field, solicit data from the authors or collect data from an online repository, and analyze the data as a class to create a meta-analysis (Figure 2). While students do not experience setting up a field experiment, they can still co-construct knowledge with their mentors, form hypotheses similar to those involved in field studies, contribute to the discipline, and gain experience with scientific exploration.

Feedback

One of the advantages of feedback in the field is the informality and frequency, which helps to guide students in a low-stakes environment. Most classroom activities and assignments incorporate feedback from instructors, but that often comes exclusively as grades. Students may have difficulty differentiating useful feedback from criticism when feedback is attached to grades, depending on the nature of the comments and other factors (Guskey, 2019). In the classroom, providing opportunities for routine and low-stakes feedback can recreate the benefits seen in the field. For example, students could submit anonymous questions after each lecture that would be addressed via email to the class or at the beginning of the next class session

(Figure 2). This can quickly dispel misconceptions and provide extra context that students deem relevant. For larger assignments, drafts or individual consultations can be required so that students can receive feedback prior to turning in work. Both of these strategies may help students see their instructors as more approachable, and remove barriers between instructors and students.

Place-Based Teaching

Principles of place-based education are perhaps the most difficult to implement in the traditional framework of science courses. Content coverage is often prioritized in science courses due to institutional standards (credit hours, course sequencing), tradition, and professional and student expectations (Barr & Tagg, 1995; Luckie et al., 2012; Petersen et al., 2020). Place-based education devotes time to topics that are beyond the traditional scope of these classes, but investing in place-based methodologies is worthwhile to engage students from underrepresented backgrounds and to inspire interdisciplinarity and critical thinking. When a field trip is not possible, focusing on the area around the campus is a sound strategy, as the campus is familiar to students and allows them to link their everyday activities with scientific inquiry and processes. When working with remote data, activities can be imbued with a sense of place by including historical and contemporary photographs and narrative stories by residents or scientists (Figure 2). For example, in a geomorphology course in Fall 2020, I [author JJ] used the example of the Mississippi River flood of 2011 to examine the geomorphic consequences of flooding as well as the complex social and political dimensions of rivers through the case of Pinhook, Missouri, which was destroyed during the flood. The unit included work with aerial imagery, geomorphic change detection, and hydraulic model outputs, as well as a podcast, a short documentary, and an excerpt from an ethnography written about the residents of Pinhook (Center for Investigative Reporting 2018; Goodwell et al., 2014; Lawrence & Lawless, 2014, 2018; Luke et al., 2015). Though I sacrificed a lecture to a non-scientific podcast, the discussions about the case were rich and students thought critically about how to connect science to real-world issues, a valuable skill for those who go on to careers in science.

Putting these attributes together, a multi-faceted activity arises. Students should learn about the environment and history of a place, work with data from that place, brainstorm an answerable question about that place's ecology/geology/etc., and work with the instructor and peers to answer the question. Throughout the process, students give and receive feedback to guide learning and promote growth. Ideally, this structure can be implemented throughout a course by using backwards design, where assignments are devised to align with specific course objectives. For example, instructors should consider these attributes when designing course objectives and outcomes, within course modules, as the capstone of a course or multi-week exploration of a topic, as well as in a singular lab, class activity, or assignment. These types of projects can introduce students to working in different facets of a discipline, helping them discover a specialization or area to improve. Giving students the opportunity to engage in field-inspired activities may facilitate a sense of belonging and contribution to the discipline, demonstrating that they can pursue careers in the natural sciences.

Faculty are notably constrained by time and resources, which can prevent them from implementing innovative teaching strategies (Hovey et al., 2019; Shadle et al., 2017). However, instructors are motivated by improvements to student engagement (Hovey et al., 2019; Shadle et al., 2017). The pedagogies that we outline above have clear benefits for students that can serve as motivation for instructors. Research also suggests that building upon current practices, such as iterating on activities from existing field trips, makes innovation more manageable (Hovey et al., 2019; Shadle et al., 2017). Additionally, institutional training about learner-centered teaching and ongoing teaching support can improve adoption of new teaching strategies (Andrews & Lemons, 2015; Ebert-May et al., 2015). These teaching changes could make the difference for student success in science. Positive undergraduate experiences and supportive instructors can be key to retention of underrepresented students in the natural sciences (Sherman-Morris & McNeal, 2016).

Implications for Virtual Field Trips

As virtual field trips (VFTs) become increasingly common, there are more published assessments of their effectiveness. While VFTs have been shown to increase appreciation for the environment and natural sciences (Bursztyn et al., 2017; Markowitz et al., 2018), student enthusiasm for novel technology (Pringle, 2013), and provide important introductions or preparation for traditional field trips (Burden et al., 2017; Jolley et al., 2018), there are few studies comparing the effectiveness of a VFT to a traditional field trip. Current research on these comparisons has yielded mixed results, with a couple instances where traditional field trips were better (by author metrics of student performance or appreciation) than VFTs (Kolivras et al., 2012; Seifan et al., 2020), and many instances where there was no difference between traditional field trips and VFTs (Garner & Gallo, 2005; Klippel et al., 2020; Ruberto, 2018; Shinneman et al., 2020; Stumpf et al., 2008). We did not find any instances where a VFT was better than a traditional field trip. Importantly, there are many instances where having a traditional field trip, or a VFT, is better than not incorporating one (Bowler et al., 1999; Elkins & Elkins, 2007; Houser et al., 2011; Jolley et al., 2018; Kern & Carpenter, 1986).

Although VFTs can be highly effective teaching tools, several shortcomings of VFTs have emerged. These include a lack of immersion (Lei, 2015), reliance on instructor direction (Mead et al., 2019), difficulty with higher-order questions (Friess et al., 2016; Kolivras et al., 2012), technological difficulties (Jolley et al., 2018), lack of flexibility once an activity is created (Lei, 2015), demanding preparation (Pringle, 2013), and a lack of classmate interaction (Klippel et al., 2020). The four concepts that we outline above (active learning, co-production of knowledge, place-based learning, and feedback) may address the shortcomings noted in the VFT literature.

Most VFTs use active learning, as students are required to navigate through activities at their own pace and zoom in and out of images to make measurements and observations. VFTs are place-based in that they focus on specific locations, but often do not incorporate multiple interpretations of place. Adding this element (e.g. via video or audio interviews) might help students feel more engaged with the material and might lessen the abstraction of working virtually. Feedback between class members is difficult in a virtual reality setting, unless everyone is in the same virtual space. Making VFTs group-oriented could provide opportunities for feedback. Further, VFT programs with adaptive feedback settings can respond instantaneously to student actions and enhance interactivity, and has been linked to instances of marked student learning gains within a VFT (Mead et al., 2019). Co-production of knowledge might be most difficult because VFTs are pre-made, thus cannot promote unexplored territory. While VFTs have shown to be valuable educationally, they cannot offer the same full-body experience and novel research opportunities as a field trip. We recommend that instructors plan field trips when possible, and arrange a VFT or other activity based on pedagogies of field trips for instances when field trips are not possible.

CONCLUSION

Field trips are widely regarded as formative experiences in the natural sciences that are integral to student learning. We find that learning on field trips stems from the pedagogy embedded in them- including active learning, co-creation of knowledge, peer-instructor feedback, and strong sense of place. Due to their numerous benefits, we need to promote the continuation of field trips, provided instructors consider the experience of underrepresented groups during planning. As field trips become more difficult to conduct due to institutional barriers, transitioning field trip pedagogies to the classroom may be a way to promote higher-order learning, academic skills, and personal development. Using pedagogies inherent to field trips, indoor activities will hopefully impart the knowledge gains of a traditional field trip and continue to inspire natural science aspirations in undergraduate students.

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Figure Captions

Table 1. Inclusion issues to consider when designing field experiences for students and recommendations for preventing and mitigating those issues. Sources listed provide a starting foundation for concerned instructors.

Figure 1. Field trips are important to the natural sciences because they promote enhanced technical skills, content knowledge, and personal growth. We found examples of these in the literature and arranged them around existing highly-regarded teaching methods (active learning, co-production of knowledge, place-based education, and feedback). In this figure, activities, skills, or other attributes involved in field trips are listed inside the bubbles associated with specific pedagogies. However, these attributes can be associated with multiple pedagogies, fitting in the overlaps of multiple bubbles. Due to their multiple associations, these attributes could be arranged within the diagram in numerous ways, of which we have provided one example.

Figure 2. Field trips can incorporate four main pedagogical attributes: active learning, knowledge co-production or co-construction, feedback (between peers and between the

instructor and the students), and place-based learning. These four attributes are transferable to classroom activities when field trips are not possible.

Figure 1

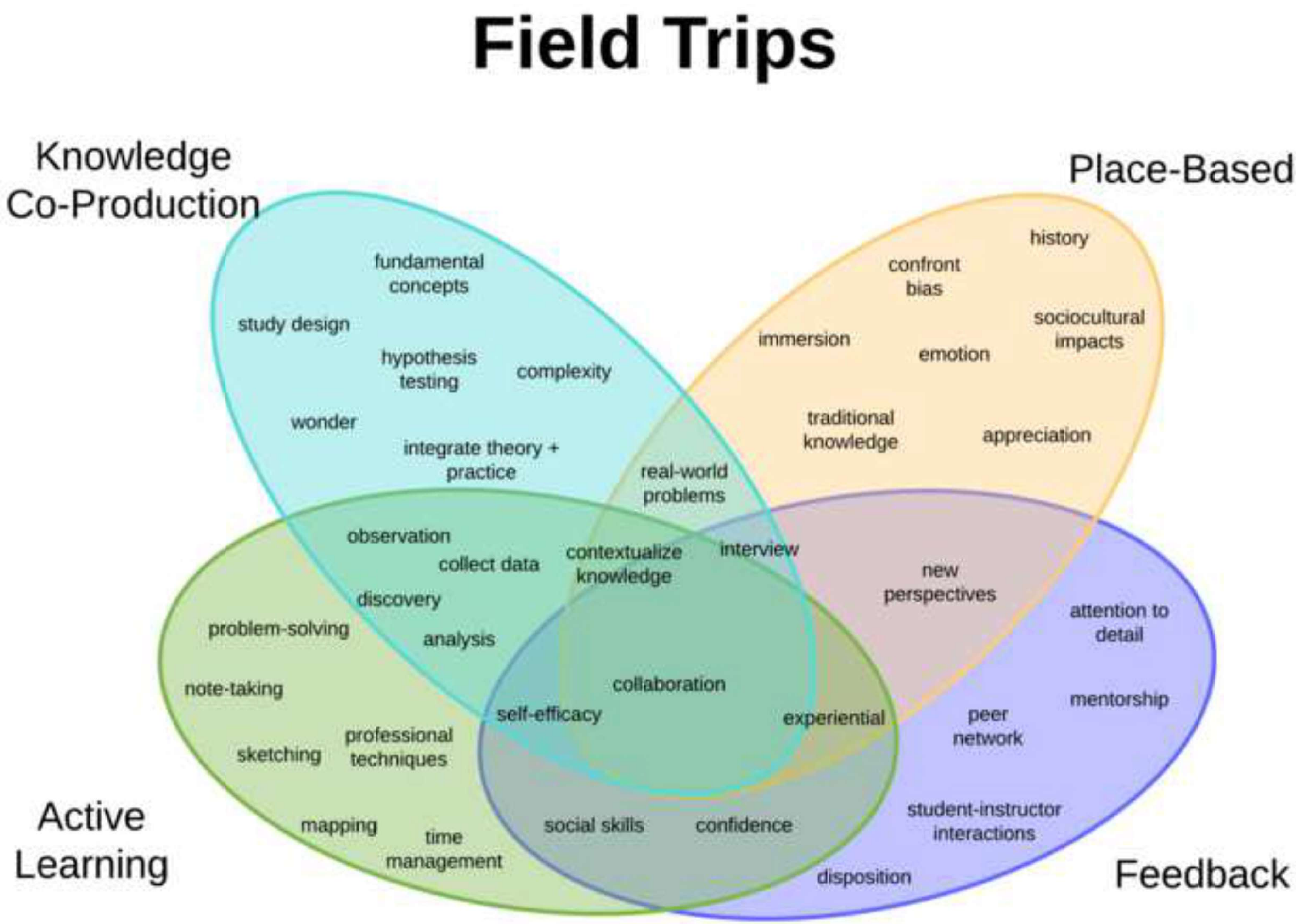
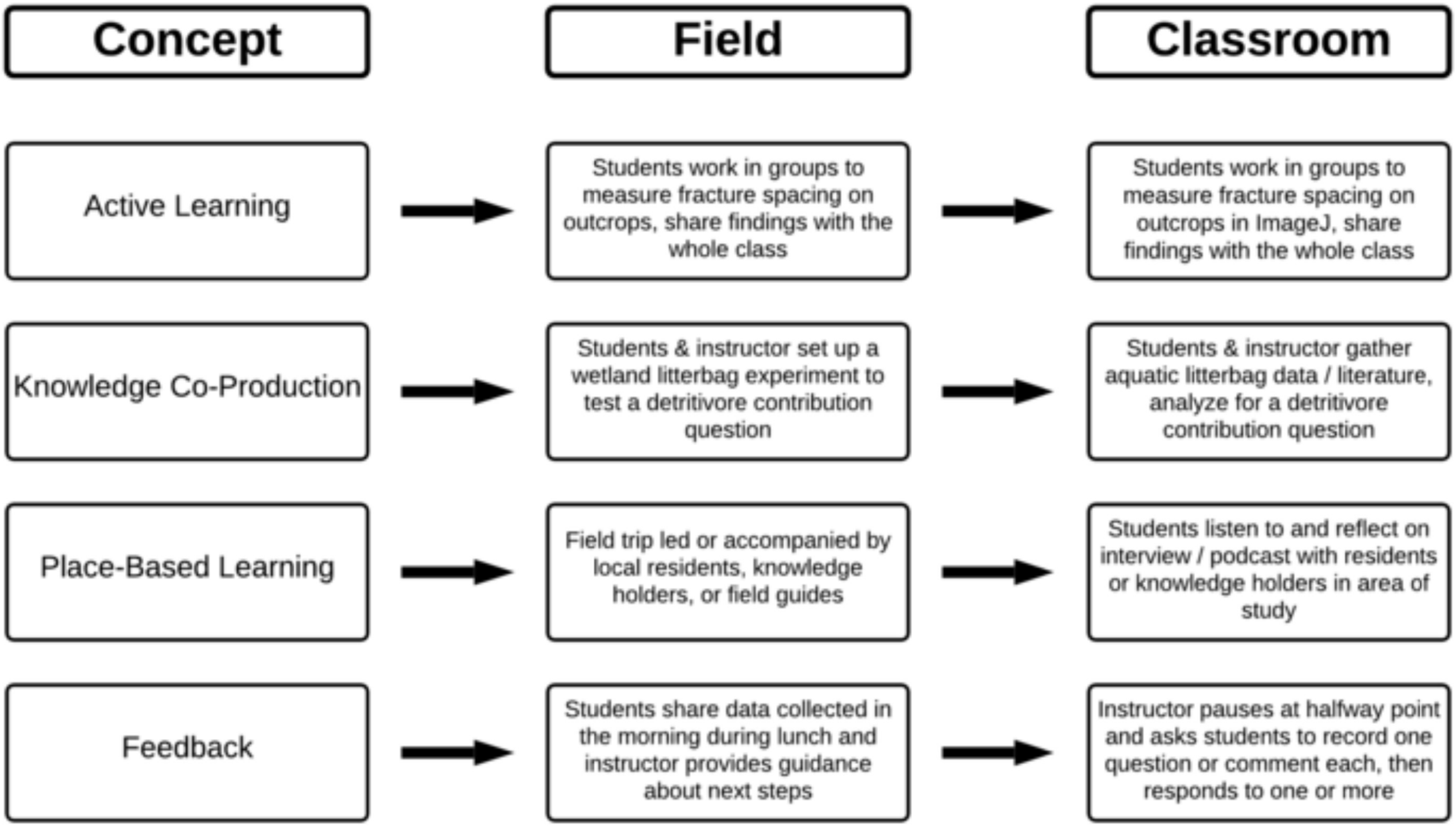

Field Trips
Knowledge Co-Production
Place-Based
Active Learning
Feedback
fundamental concepts
study design
hypothesis testing
complexity
wonder
integrate theory + practice
history
confront bias
sociocultural impacts
immersion
emotion
traditional knowledge
appreciation
real-world problems
observation
collect data
contextualize knowledge
interview
discovery
new perspectives
attention to detail
problem-solving
analysis
note-taking
collaboration
mentorship
self-efficacy
experiential
peer network
professional techniques
sketching
mapping
time management
social skills
confidence
student-instructor interactions
disposition

Figure 2



Concept
Field
Classroom
Active Learning
Students work in groups to measure fracture spacing on outcrops, share findings with the whole class
Students work in groups to measure fracture spacing on outcrops in ImageJ, share findings with the whole class
Knowledge Co-Production
Students & instructor set up a wetland litterbag experiment to test a detritivore contribution question
Students & instructor gather aquatic litterbag data / literature, analyze for a detritivore contribution question
Place-Based Learning
Field trip led or accompanied by local residents, knowledge holders, or field guides
Students listen to and reflect on interview / podcast with residents or knowledge holders in area of study
Feedback
Students share data collected in the morning during lunch and instructor provides guidance about next steps
Instructor pauses at halfway point and asks students to record one question or comment each, then responds to one or more

Table

Inclusion Issue	Recommendations	Sources
Accessibility: students with mobility impairments may not be able to access remote field sites; students with visual and hearing impairments may require accommodation	**Design for accessibility:** Select field sites that are accessible (road cuts, parks with walkways, etc.), pair students with disabilities with students who do not have a disability, implement Universal Design for Learning, create tactile versions of diagrams, captions for those with hearing impairment	Atchison et al., 2019; Carabajal et al., 2017; The International Association for Geoscience Diversity (https://theiagd.org/)
Sexual Harassment: biases based on perceived and self-identified gender can lead to self-doubt and withdrawal, as well as harassment or assault from peers or strangers	**Prioritize safety and allyship:** departmental safety policy, signed behavior agreement, gender-neutral language, implement an ethic of care, diverse class leadership	Clancy et al., 2014; Hill et al., 2021; John & Khan, 2018 Sexton et al., 2016; Warren et al., 2018
Racialization of the outdoors: students of color may be uncomfortable or unsafe entering predominantly white spaces	**Prioritize student safety:** faculty bystander and antidiscrimination training, identify risks before going to the field, discuss risks/apprehension with students, address problems when they occur	Anadu et al., 2020; Demery & Pipkin, 2021; Giles et al., 2020; Hughes, 2016
Racialization of access to green space: socioeconomic and racial inequality determine access to green spaces, level of landscaping, and biodiversity	**Strength in a diversity of observations:** in asynchronous settings, design learning objectives that can be met in a variety of settings, explicit discussion of spatial patterns/inequality	Kinzig et al., 2005; Lerman & Warren, 2011; Melles, 2005; Schell et al., 2020; Washko, 2021
Financial burdens for students of lower socioeconomic status: extra costs for field courses and trips, cost of outdoor gear	**Ease student financial burden:** scholarships, include costs in course fees for financial aid, consider weather conditions, have a departmental gear closet, alumni funding/gear drives	Anadu et al., 2020; Giles et al., 2020; Núñez et al., 2020; Zavaleta et al., 2020