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From Grand Canyon to Yosemite:
Lessons learned from the development and assessment of digital geoscience field trips for mobile smart devices

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Geoscience educators have long considered field trips to be the best way of drawing students into the discipline (e.g., Orion and Hofstein 1994; Tal 2001; Fuller 2006; Kastens et al. 2009; Mogk and Goodwin 2012). However, field trips often are not possible in high-enrollment introductory geoscience courses (e.g., McGreen and Sanchez 2005; Cook et al. 2006; Bandiera et al. 2010; Whitmeyer and Mogk 2013). With advances in mobile technology over the past two decades, educators have found that a variety of learners can benefit by visually and even physically interacting with virtual representations of the real world (Stainfield et al. 2000). In the last decade, these types of interactive virtual or augmented reality experiences have been increasing in abundance and quality within STEM (science, technology, engineering, mathematics) fields (e.g., Spicer and Stratford 2001; Liarokapis et al. 2004; Stumpf et al. 2008; Yuen et al. 2011; Pringle 2013; Bursztyn, Shelton et al. 2017; Bursztyn, Walker et al. 2017).

Based on my experience teaching introductory geology courses at various types and sizes of postsecondary institutions since 2001, the impact of a field trip on student learning comes from the opportunity for students to apply their classroom content learning to the real world by observing rocks and geologic structures *in situ*. The motivation for my foray into digital learning tools a decade later was twofold: (1) to facilitate the field trip experience for my future self and for other instructors facing the "big class challenge" (university classes with enrollment of 100–500 students), and (2) to embrace, rather than ban, the use of smartphones in my classes.

Grand Canyon Expedition (GCX) was launched in 2012 as a series of three smart-device apps to teach introductory geoscience concepts through augmented reality field trips. After their launch, we assessed these apps for their impact on student engagement (Bursztyn, Shelton et al. 2017) and on student learning (Bursztyn, Walker et al. 2017). The testing phase alone initially resulted in introducing GCX as a learning tool to nearly 1,000 students (and their respective instructors) at four institutions in different states. Following the publication

Community college geology field trip to the Mojave Desert, California, circa 2008. Two students "getting a taste for" geology as they lick their freshly collected sample of salt crust from a dry lake bed.

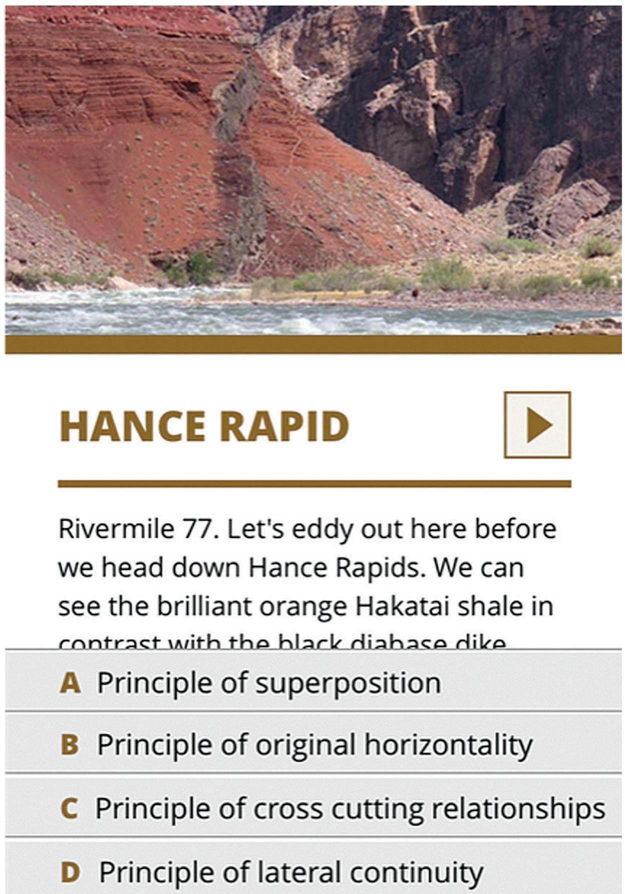
and presentations of the results in journals and at conferences, several other instructors at additional institutions began using these apps in their classes as well. Having noticed students struggling to observe geologic features pointed out to them, even while on a field trip, formed part of my initiative for collecting student free-response feedback from their digital experience. This work led to a chapter titled “I Felt Like a Scientist” in *America’s Largest Classroom* that explores qualities of mobile learning and the potential for using it for place-based education (Bursztyn et al. 2020).

When the apps were first developed, we thought about them from the perspective of assessing their educational value, not the longevity of the product, consequently our budget did not include funding for the app maintenance that is required with operating system updates over time. Thus, seven

Community college geology field trip to the San Andreas Fault, California, circa 2006. Three students showcase the “sticking power” of what they learned about porous Earth materials.

Community college students walking the soccer field with cell phones in hand. All students are playing GCX.

University students standing, walking, and biking the quad with cell phones in hand. Some students are playing GCX (can you identify which? I can’t).



Screenshot of the GCX app on Geologic Time showing the format of the screen. Upper third: playable imagery with audio narration from Grand Canyon. Middle third: written script of the narration along with a question the student has to answer related to that material. Lower third: multiple-choice-answer buttons the student must choose from to respond.

years after the initial release, GCX no longer can be hosted by the Apple App Store or Google Play until critical software compatibility updates are made. This, of course, requires additional funding. I am not sure of the exact number of users beyond GCX's testing phase, but when the series was removed from the app stores, the number of inquiries regarding the app in my email inbox suggested that it was more than double the number of geoscience instructors I knew were using them—each educating a significant number of geoscience students.

Lesson 1: In the fast-paced world of digital applications, think about the future, and budget accordingly.

Within the context of the studies, three main findings emerged from our research. First, the implementation of the GCX apps within an introductory geoscience course resulted in increased student engagement. Second, there were distinct patterns of positive experiences within student feedback in the context of playing GCX. We derived this second finding from applying the learning framework qualities of personalization, collaboration, and authenticity to student free-response feedback. This framework helped to uncover evidence that students became involved in the activity in a personal, competitive, and collaborative ways. These were, unexpectedly, quite different from the ways they operated within traditional group-work lab activities. This difference in experience (GCX interaction over traditional lab) seems to have made the material more important to them. The following are example quotes from students:

> "Walking around and discovering landmarks with fitting questions really gave it an immersive feel."
>
> "Real life application of geology was fun."
>
> "I had fun inspecting the walls of the canyon and investigating like a geologist."
>
> "The best part for me was actually getting out of the classroom and interacting with all my peers. The whole virtual experience was great and we got to learn in a different way."

Finally, disappointingly—but consistent with other research in this field (e.g., Ebner and Holzinger 2007; Stumpf et al. 2008; Jacobson et al. 2009)—there was no statistically significant evidence of learning gains that resulted from the inclusion of the apps in course curriculum.

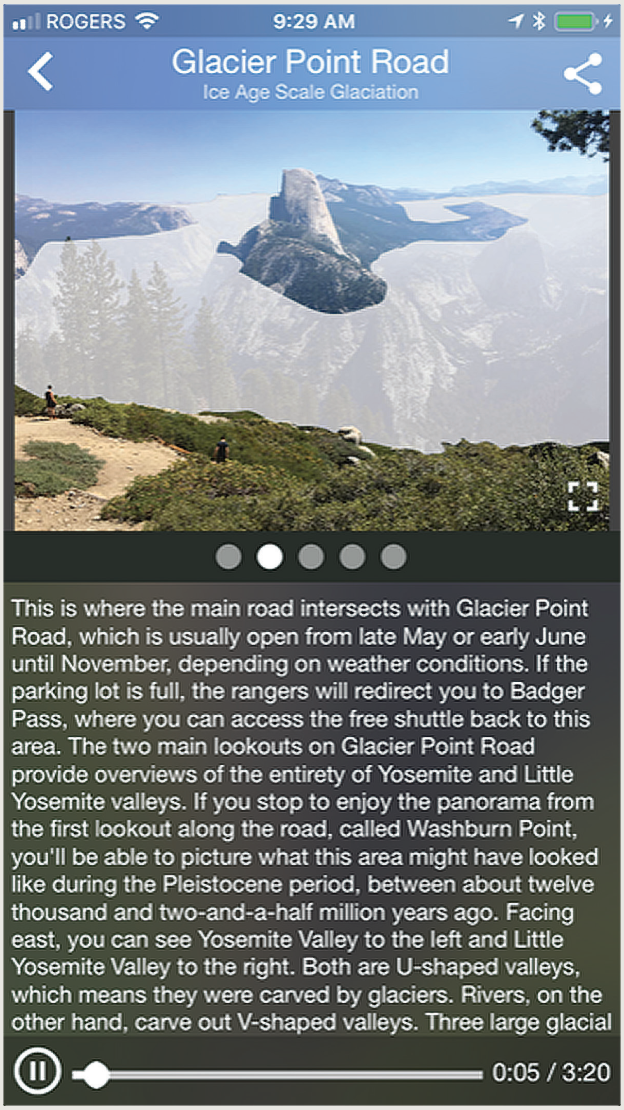
Lesson 2: There is a lot more to digital learning than we understand at the moment, and it needs to be explored further.

In 2016, the National Park Service (NPS) celebrated its centennial. As a part of its education mission, NPS set a "go digital" goal to help it broaden its reach with new audiences by using digital platforms. It struck me that some of the student engagement gains that we were seeing with GCX might be a good launching pad for learning gains *if the learners were already engaged*. With this in mind, I started the Yosemite: A Story of Fire and Ice (YFI) project. YFI started with two shifts in project direction. The first was in target audience, from formal university education to informal public education; the second was in product objective, from class engagement to making a roadside geology educational tour for visitors in Yosemite National Park. Since tourists are visiting places they are already curious about, YFI was designed to digitally apply geoscience content to these natural spaces and showcase rock textures and features that are important for geologic interpretation. YFI went live in 2019 and takes advantage of an existing platform and app developer that will take care of updates and maintenance.

"I had fun inspecting the walls of the canyon and investigating like a geologist."

Lesson 3: The objective of assessing and reflecting on one's work is to improve upon and learn from it.

As with many STEM practitioners, geoscientists have made use of digital technology advances in recent decades, and have found applications for these tools within our field. However, the application and development of such technologies for geoscience education and outreach has happened much



Screenshot of the YFI app showing the format of the screen. Upper half is a slideshow of images of the location—all with either overlays or cartoons that illustrate the geologic past of the area. Lower half is accompanying written narrative that also plays as audio.

more slowly. Furthermore, geoscience learners everywhere are constrained by geography—from glaciated plains in Iowa and overgrown marshlands in South Carolina to the confines of a car on a road trip. The GCX and YFI example apps, described in this essay, demonstrate the power of digital technologies to affordably and effectively transmit the concepts of geology as well as that of *changes throughout geologic time* to learners anywhere. Thus, we view this type of digital experience as the accessible open window, in both formal and informal spaces, to learning how to see the world more like a geoscientist—and, to get excited about it.

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