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Using Virtual Reality to Augment Museum-Based Field Trips in a Preservice Elementary Science Methods Course

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Positioned in the context of experiential learning, this paper reports findings of a virtual reality field trip (VRFT) in conjunction with an in-person field trip involving preservice teachers in an elementary science methods course to a local natural history museum. Findings included that virtual reality (VR) is best used after a field trip to encourage student recall of the experience, but only when done for a limited time to avoid VR fatigue. The types of experiences that preservice teachers thought VR would be good for in their science classrooms included the ability to visit either inaccessible or unsafe locations, to explore scales of size that are either too big or too small, and to witness different eras or events at varying temporal scales. Furthermore, this study uncovered potential equity issues related to VRFTs being seen as a viable alternative if students could not afford to go on field trips. Further research needs to be conducted to better understand the impact of VRFTs on student learning outcomes and take advantage of recent improvements in VR technology.

Museum-based field trips are a form of experiential learning with roots that date back to educational pioneers such as John Dewey (1900). Yet, despite being a mainstay in education, the number of field trip visitors to museums has substantially declined over the past decade, largely due to the lasting impact of budget cuts from the Great Recession (Ellerson, 2015). For example, in 2010 field trips accounted for 195,000 visitors to The Field Museum of Natural History in Chicago (The Field Museum, 2012), down from an annual peak of over 300,000 (Greene, Kisida, & Bowen, 2014). Although the broader economy had since recovered, attendance further declined to 160,000 field trip visitors in 2017 (Galaboff, personal communication, May 26, 2018).

This trend toward fewer museum-based field trips is taking place nationally, as demonstrated by a 2015-16 report from the American Association of School Administrators which found that only 12% of administrators surveyed were implementing field trips at prerecession levels (Ellerson, 2015). The decline in field trips has also been attributed to the shifting of financial and time resources toward high-stakes testing (Behrendt & Franklin, 2014; Whitesell, 2016) and the increasingly complex logistics of planning such trips (Adedokun et al., 2012). As a result, many students are being denied these museum-based field trips as part of their formal educational experience.

Field trips to science museums and museums of natural history have been shown to increase students' interest, motivation, and attitudes toward science (Potvin & Hasni, 2014), positively affect students' science test scores and proficiency (Whitesell, 2016), and provide social learning experiences that students find enjoyable (Gutwill & Allen, 2012; Sample McMeeking, Weinberg, Boyd, & Balgopal, 2016).

Furthermore, participation in self-paced education programs at science museums have been shown to enhance K-12 students' motivation and program-related content knowledge when compared using pre/posttest design (e.g., health awareness in a medical science museum; (Martin, Durksen, Williamson, Kiss, & Ginns, 2016). In contrast to the decline of field trips, evidence remains strong that science museum-based experiences are beneficial tools to enhance student learning.

Researchers have been seeking alternative solutions to recapture these benefits of museum-based field trips within the budget, time, and high-stakes testing constraints of the current educational environment. One possible solution has been to implement virtual field trips (VFTs) in the classroom (e.g., Adedokun, Liu, Parker, & Burgess, 2015; McKnight et al., 2016; Morgan, 2015). Enabled by increased access to multimedia-rich technologies, such as laptops, tablets, and smartphones, VFTs allow students to interact with text, audio, images, video, and/or immersive 3D environments while exploring real-world locations. More recent advances in technology have made it possible to use mobile devices, such as smartphones, for virtual reality (VR) as a means of going on VFTs.

Rather than using VR as a replacement for in-person, physical field trips, we were interested to investigate VRFT experiences as a means of enhancing and amplifying existing field trips. VR holds promise as a cognitive tool for improving student learning while on field trips.

Consistent with the cognitive load theory of learning (Sweller, 1994), VR may ameliorate the effects of novelty (Falk, Martin, & Balling, 1978) when students enter the museum and view its collections for the first time. It may also reduce the burden of logistics by helping to familiarize students and teachers with the layout and physical features of the museum (Anderson & Lucas, 1997). By diminishing procedural impacts of an initial visit, VR may enhance opportunities for student learning. VR may also serve to enhance recall by extending the opportunities for students to be fully immersed with the field trip experience without having to physically revisit the destination.

In this paper, we report findings of a study using student mobile devices for a virtual reality field trip (VRFT), that is a VFT that uses VR, in conjunction with a separate in-person field trip to a museum of natural history as part of a preservice elementary science method course.

Literature Review

The following section is a review of the literature related to field trip experiences in preservice science method courses, the implementation of VFTs in science courses, and the use of student mobile devices for VR in the K-12 classroom.

Field Trip Experiences in Preservice Elementary Science Method Courses

Preservice teachers are generally not taught how to orchestrate and implement field trips as part of their pedagogical training (Behrendt & Franklin, 2014). As a result, inexperienced teachers may not be aware that students benefit from contextual learning that takes place before, during, and after the field trip (Falk & Dierking, 2016).

This before-during-after pedagogical sequence is important since it allows the teacher to scaffold a field trip so it is rooted in students' prior experiences, interest, and knowledge. Without appropriate planning, students can be overwhelmed by the novelty of the new experience, leading to heavy cognitive load and a reduction in desired learning outcomes (Falk et al., 1978). During the field trip, student learning can be enhanced through the guidance of a *docent* (i.e., a museum volunteer, employee, or teacher who acts as a guide) and through interactions with displays, exhibits, and kiosks (Metz, 2005). Furthermore, after the visit, the teacher can help reinforce the experience and enhance recall by engaging students in discussion, activities, readings, and videos (Behrendt & Franklin, 2014).

Implementing field trips as part of a preservice elementary science method course provides an opportunity to engage in contextual learning while also modeling the before-during-after pedagogical sequence. Preservice elementary teachers often lack confidence in their science teaching abilities (Howitt, 2007), but elementary science method courses have been shown to have a positive outcome toward developing preservice teachers' beliefs, attitudes, and self-efficacy towards science (Kazempour & Sadler, 2015).

These courses introduce preservice teachers to science pedagogy while also exposing them to activities that extend beyond the walls of the classrooms, including workshops, family days, and field trips (Kisiel, 2013). During these trips students can develop their conceptual understanding of scientific concepts, while also assessing the advantages and disadvantages of museum-based field trips (Morentin & Guisasola, 2015).

Even with this pedagogical training, however, the advantages of these visits may never be realized if the teacher goes on to teach in a school where time, budget, and testing constraints make the field trips impossible. The possibility of virtual field trips adds a new dimension to teacher field trip preparation. Thus, we turn our attention to VFTs, their affordances and constraints, and how other researchers have studied them in the classroom.

Virtual Field Trips

Limited research has been done with the incorporation of VFTs as part of a preservice science education program. One possible reason is the reliance on technology needed to make VFTs possible. Preservice teacher programs typically lack the time, experience, and materials to effectively implement technology in their own courses (e.g., Banerjee, Xu, Jiang, & Waxman, 2017; Yuksel, Soner, & Zahide, 2009).

Even once teachers get into the classroom, challenges remain with helping newly inducted teachers develop lesson plans that effectively integrate technology. Pringle, Dawson, and Ritzhaupt (2015) studied a yearlong intervention that aimed to enact technological, pedagogical, and content practices in science lessons. They found that their intervention increased device use and the frequency of some technology-mediated classroom activities, such as simulations of science experiments. However, after collecting 525 lessons they found no instances of VFTs. Access to technology alone is not the only barrier when introducing new pedagogical practices to the classroom. Rather, as technology usage increases in the classroom, the need for effective pedagogical practices becomes even more important (Philip & Garcia, 2013).

VFT experiences vary in their depth of immersion and interactions with the learning environment (see Table 1). This variation is partially due to the lack of an agreed-upon definition of what constitutes a VFT and partially due to the advancement of technology over the past 2 decades. For example, Spicer and Stratford (2001) conducted a study using VFTs to explore ocean tidepools using text, images, video, and interactive two-dimensional simulations stored on a CD-ROM. While students both enjoyed and learned from the experience, they unanimously agreed that the VFT did not substitute for an actual field experience. Unlike actual field trips, where students are usually provided with time to roam and explore, VFTs can be less effective since students are able to experience only what has been included by the designers of the media (Behrendt & Franklin, 2014).

Table 1
Levels of Immersion for Virtual Field Trips

Examples	**Research or Application**
Low	
Text, images, and interactive 2D simulations on a CD-ROM	Spicer & Stratford (2001)
Gathering of text and images on the World Wide Web	Tuthill & Klemm (2002)
Partial	
Prerecorded video broadcasts of scientists' field work with live video	Adedokum et al. (2012)
Q&A Controllable 3D avatar, third-person view	Tutwiler, Lin, & Chang (2013); Jones & Alba (2016)
Full	
VR first-person with smartphone, or stand-alone headsets (e.g., Oculus Rift / HTC Vive)	Howard (2016); Apollo 11 VR; Titanic VR

One way to overcome this limitation is by having students curate their own resources from the Internet, allowing them to personalize their experience and visit more locations than they could in person (Tuthill & Klemm, 2002). This idea of personalization can apply to more than learning about physical locations. For example, VFTs have also been used to help middle school students explore STEM-related professions. Through the use of interactive video broadcasts, students were able to hear about actual research being conducted by scientists and see how they conducted their research in the field without having to travel to remote sites (Adedokun et al., 2015).

While video can be effective in exposing students to a wide variety of current scientific work, it does not provide much room for the student to explore and make their own discoveries. More recently, VFTs have started to include partially immersive 3D environments where students can explore using virtual avatars, similar to the online virtual world Second Life (https://secondlife.com/).

This approach has proven to be effective when the location is too far away, such as a museum in a different country (Jones & Alba, 2016), or if the climate or terrain is unsafe for children, such as the mountains of Taiwan (Tutwiler, Lin, & Chang, 2013). These VFTs are typically done with students working on computers in partners or small groups and controlling their avatar with the arrow keys on the keyboard.

While these 3D experiences with controllable avatars are much more immersive than images and multimedia on a CD-ROM, they do not represent a fully immersive experience where the student has the feeling of presence in the virtual environment (Steuer, 1992). However, recent advancements in mobile technology combined with student ownership of smartphones has made it possible to implement fully immersive VR experiences in the classroom.

Virtual Reality and Student Smartphones

The introduction of VR to the K-12 classroom was reported by the 2017 edition of the *NMC/CoSN Horizon Reports for K-12* as a technology with a time-to-adoption of 2-3 years (Freeman, Adams Becker, Cummins, Davis, & Giesinger Hall, 2017). The industry leaders in commercial VR headsets include Oculus Rift, HTC Vive, and PlayStation VR.

In a primary school context, these technologies are prohibitively expensive, because they require specialized high-end hardware and are limited to one user at a time. Affordable alternatives, such as Google Cardboard (https://www.google.com/get/cardboard/), provide a more equitable method of bringing VR technology to the classroom. Based on low-tech solutions, Google Cardboard uses a cardboard box with lenses to transform smartphones into a virtual reality headset (Brown & Green, 2016).

This feature allows users to have three-degrees of freedom (looking up/down, left/right, and tilting side-to-side) in a virtual space. Students also have the ability to interact with their environment by pressing a button on the top of the box, which is covered with conductive foam to simulate a finger touching the smartphone screen.

As smartphone ownership has become widespread, the possibility of engaging all students in educational VR experiences has become increasingly possible. According to an EDUCAUSE (2016) student survey, 96% of college students own a smartphone, with 79% of respondents reporting to have used their smartphone in at least one college course for class-related activities. Unfortunately, smartphones may also serve as distraction devices in higher education classrooms: sending text messages, composing e-mails, viewing social media, surfing the web, and playing games (McCoy, 2016).

Similar concerns have been raised in K-12, where some teachers view digital devices as distractions (Cho & Littenberg-Tobias, 2016). While one option is to simply ban the device, other educators have found ways to take advantage of these devices to help students engage in scientific exploitation (Cartwright, 2016; Kamarainen et al., 2013). We propose that smartphones have a great deal of untapped potential in the classroom, particularly when used for VRFTs.

Compared to students on college campuses, fewer K-12 students have access to smartphones. According to a Pearson (2015) survey, about 35% of elementary, 61% of middle school, and 81% of high school students have their own smartphone. As prices continue to fall for mobile devices, however, districts have been able to afford entire class sets that can be shared among schools, such as with the Google Expeditions program (https://edu.google.com/expeditions).

Google Expeditions allows teachers to take students on guided field trips to over 200 locations (Howard, 2016), including exploring sunken ships at Pearl Harbor (Yap, 2016). Google Expeditions has drawbacks, though. It requires specific applications to be installed on each device, limits students to a passive viewing experience that is controlled by the teacher, and supports only limited availability of local destinations that could be visited as part of a traditional field trip. In addition, teachers who use such experiences may not be following the before-during-after pedagogical sequence of traditional field trips or may simply be exposing students to VR for the novelty of the experience.

Purpose of the Study

With these limitations in mind, we wanted to create an experience where college students in a preservice science methods course could be introduced to both traditional museum-based field trips and VFTs/VRFTs. As part of the study, we were trying to develop new and innovative ways to use technology in elementary science classrooms, specifically around science museum field trips. The VRFT was introduced as a way for preservice teachers to gain experience with advanced technologies and be exposed to their challenges and benefits in a real-world context.

Using a museum of natural history at a research university in the southwestern United States, we developed a VR museum tour using 360-degree photospheres, Google Cardboard, and the students' own personal mobile devices for viewing (Harron, Petrosino, & Jenevein, 2017). Students were introduced to best practices for museum visits, focusing on before-during-after pedagogies from Falk and Dierking (2016). So as not to bias students' responses on later open-ended tasks, no details specific to VR pedagogy were given, so we could capture the participants' firsthand experiences with VR.

Research was guided by the following questions:

1. What are the differences in how participants explored a museum using VR before and after they visited the physical museum in person?
2. How do preservice science teachers think VR could be used to teach science in their elementary science classroom?
3. What do preservice science teachers perceive as the affordances and constraints of using mobile devices for VR in the classroom?

Research Design

Theoretical Perspectives

We drew upon two distinct theoretical perspectives in the design of this study. First, interactive virtual environments can provide a powerful source of data to assess how student learning takes place. Unlike a traditional classroom activity, where it can be difficult to track all participants, virtual environments allow researchers to continuously log data about user interactions. By utilizing learning analytics we are able generate intuitive data visualizations, such as heatmaps, which can be used to display either the amount of time or frequency that a user visits a specific location in the virtual environment (Dede, Grotzer, Kamarainen, & Metcalf, 2017; Serrano-Laguna, Torrente, Moreno-Ger, & Fernández-Manjón, 2014). As such, more can be learned at both the individual and group level about interactions within the virtual environment.

Second, while learning analytics are powerful for learning about user interactions, they fail to capture how the user perceives the experience. Taking an interpretivist perspective (Koro-Ljungberg, Yendol-Hoppey, Smith, & Hayes, 2009), we believe that as individuals experience and act within the world they make sense of it in relation to their past knowledge, beliefs, and experiences. These perspectives are important to account for since preservice teachers bring with them their own perspectives regarding how technological, pedagogical, and content knowledge could be implemented in their science teaching (Koehler & Mishra, 2009).

Participants

Participants in this study were preservice elementary teachers (n = 27) enrolled in two class sections of an elementary science methods course at a large research university in the southwestern United States. This methods course is required for all undergraduate students who are seeking to earn their EC-6 generalist teaching certificate. Each section had its own instructor, which included both the third author and a graduate student with a science teaching background.

Convenience sampling was used to recruit the participants. The participants included 15 Hispanic women (56%), seven white women (26%), two Asian women (7%), and three Hispanic males (11%). The gender distribution reflected the common gender gap in elementary teacher preparation programs (Sparks, 2012). Participants ranged from low- to high-SES. Multiple students were bilingual and spoke English as a second language after either Spanish, in the majority of cases, or Mandarin, in the case of one international student.

The elementary science methods course met once a week for 3 hours. All participants had their own smartphones, and we provided a Google Cardboard headset to each participant for the VRFT portion of the study. We had additional smartphones available for any participants who experienced technical issues with their personal device, such as a dead battery or trouble connecting to the wireless Internet. One participant declined to use the Google Cardboard due to past nausea, but was able to participate in the VRFT experience using a browser-based version of the tour on a laptop computer that could be controlled via touchpad.

Methods

The in-person field trip and VRFT were of a natural history museum located at the participants' university campus. Prior to conducting the study, all four floors of the museum were captured using a Ricoh Theta S 360-degree camera. We designed a custom VR tour of the museum **(Authors, 2017)** where participants could move through the museum by looking at arrows and pressing the button on the top of their Google Cardboard (see Figure 1.) This study took place over a period of 3 weeks, with each week representing one portion of the before-during-after field trip sequence (see Table 2).

Figure 1. *Stereoscopic view of the virtual reality field trip as displayed in Google Cardboard.*

Table 2
Timeline of Study

Week 1 - Before	Week 2 - During	Week 3 - After
Discuss the importance of learning outside of school and benefits of field trips.	Students met on main floor (2nd) and went down to 1st floor for guided tour.	Class discussion about trip.
Pre-assessment titled “Museum Trip Survey.”	Guided tour by instructor for 1 hour and 45 minutes.	Other half of the class (n = 15) taken to conference room for VR experience.
About half of participants (n = 12) taken to conference room for VR experiences.	45 minutes of unstructured time to explore.	Students return to class and all participants complete post-assessment.

Before the trip. The week before the trip, the instructors gave students general background information about the local natural history museum, an overview of the trip itinerary, and a description of the goals for the trip, which included (a) the importance of learning outside of the school, (b) benefits of informal science programs, and (c) benefits of field trips. In addition, the instructor shared a recorded lecture on the role of outside of school learning to prepare students for the field trip.

All students were given the preassessment, titled "Museum Trip Survey," which included open-ended and sorting questions to assess their current knowledge of sedimentary rock and fossils, as well as open-ended general questions about using museum field trips, other field experiences, and VR when teaching science. This assessment took approximately 15 minutes to complete.

After completing the survey, one randomly selected half of the participants was taken to a conference room to try a VR tour of the museum in order to capture their interactions prior to physically visiting the museum. The other half stayed in the classroom to discuss class material unrelated to the field trip and would later receive the virtual experience after the museum field trip. This process was repeated for the second sections of the course.

Premuseum virtual reality field trip. The VRFT was conducted in a conference room around a large conference table with rotating chairs. Participants connected their phones to the campus Wi-Fi and were given a Google Cardboard to insert their phone. We provided a URL for the virtual tour and assisted with participants who were having technical problems. During the first few minutes participants were given time to orient themselves in the virtual environment by exploring the third floor of the museum, which they had not visited as part of their in-person trip to the museum. This provided us with time to deal with technical issues, gave participants time to get familiar with the one-button interface, and served as a control for the novelty of the VR experience. Once everybody was familiar with the interface, instructions were given to unveil a hidden menu that allowed participants to move to the first floor of the museum.

As participants explored the virtual museum, their virtual movement was captured in a database that recorded participant ID, current photosphere being viewed, and duration in seconds. Participants were free to explore the VRFT for as long as they liked. Immediately following their virtual experience each participant was given a survey about the experience and was encouraged to write additional comments on the back.

Museum field trip. Participants met their instructor on the main floor (level 2) of the natural history museum. Any participants who arrived early were free to explore the glass cases and exhibits on the main floor while they waited for the rest of the class. Once all participants had arrived, the instructor handed out printed packets ("My trip to the museum," a K-3 guide designed for elementary students who visit the museum) and gave a brief introduction to the museum (e.g., its history, floor plan, where bathrooms were located, and how the trip would proceed).

The instructor led a tour of the first floor, and students completed an activity with the associate director of the museum about interpreting fossil dinosaur tracks. Students had to calculate the stride length of two different dinosaurs in order to figure out if the dinosaurs were running or walking. After the activity, participants were free to explore the remaining parts of the first floor of museum by themselves to complete the packets.

The third author served as the docent for the field trip, leading students through the first floor as a "tour of geological time" – pointing out key events in the timeline of geologic history represented by the artifacts at the museum, such as the variety of body plans after the Cambrian explosion and the end-Permian and end-Cretaceous extinctions. The main focus was on fossils, specifically the different kinds of fossils, where fossils are most likely to be found, and what fossils reveal about past life on Earth. In total, students spent 150 minutes at the museum, with 45 minutes to explore the museum on their own.

Postmuseum virtual reality field trip. The week following the museum visit was held in their regular classroom. The other half of the class who had not tried the VR museum field trip was brought to a conference room to experience the VRFT. Participants completed surveys about the VRFT, and we captured field notes of their conversations. Following the VRFT, these participants rejoined the rest of the class in their regular classroom.

In addition to the postmuseum VRFT, the entire class debriefed with the instructor about what they thought of the museum, what were their favorite parts of the museum, and what science content they had learned. In addition, the instructor also asked about their impressions of the VR experience and how it might be used in their teaching. After the discussion, all participants completed the postassessment of the Museum Trip Survey.

Data Analysis

The information captured in our database was used to generate heatmaps using Heatmap.JS, which was layered on top of a map from the museum website. Based on the guidelines for creating heatmaps by Bojko (2009), frequency of visiting each photosphere was used instead of duration in order to account for users who were idle, such as setting down the headset to write a comment on their survey.

The use of frequency also makes it easier to identify locations that were popular with multiple users, since in a duration heatmap one user visiting a location for 60 seconds has the same cumulative time as six users visiting for 10 seconds. To account for the larger n of the postmuseum group (n = 12 versus n = 15), each frequency was given 80% of the weight in the postmuseum visualizations to provide a normalized representation between the pre- and postmuseum groups.

We performed an analysis of the pre- and postassessment open-ended question ("How might you use virtual reality experiences when teaching science?") and any comments that participants wrote on the back of their VR experience survey. First, one researcher coded the responses using open-thematic coding with constant comparison (Creswell, 2014; Strauss & Corbin, 1990). This initial coding generated 17 codes related to types of VR experiences.

A second researcher then checked these coded responses, and the codes were verified and modified until agreement was achieved. These codes were then refined through axial coding to identify four broader themes. Through the coding of the open-ended question and additional comments on the back of the VR experience survey, two additional codes emerged related to VR fatigue and equity issues related to using VR in the classroom.

Findings

In the following section the findings from the data collected from students using the VR experience are described, as well as the surveys completed immediately after the VR experience and the open-ended assessment questions.

Exploration Patterns of the Virtual Reality Experience

In an effort to reduce the novelty effect of using VR, all participants started on the third floor of the museum (which they had not visited during their trip). Usage patterns of the before and after groups were similar during this orientation period, with participants mostly staying one or two photospheres from their starting point or exploring only the main hallway (see Figure 2 and Table 3). Both the before and after groups spent about 5 minutes getting oriented before they were instructed to use a hidden menu to change to the first floor of the museum.

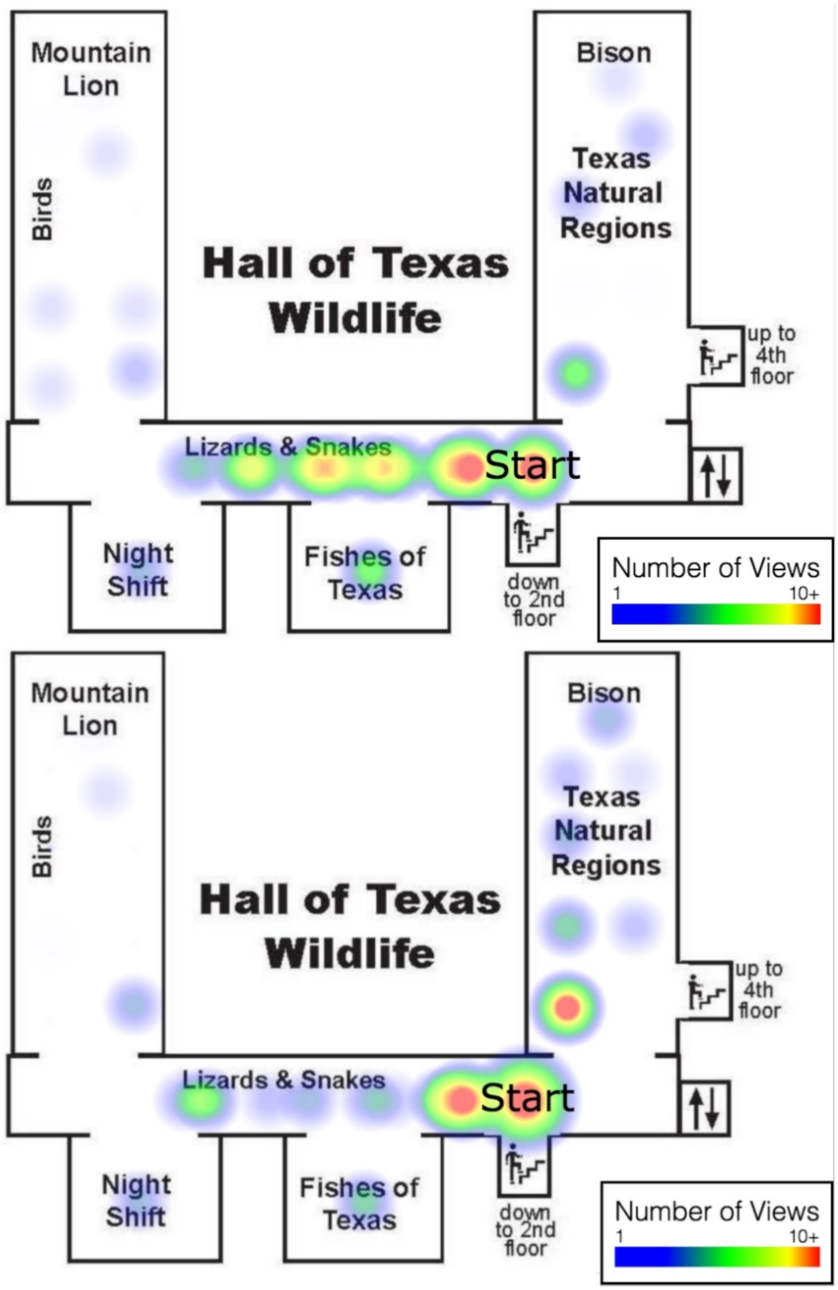


Figure 2. *Heatmap of the before (top) and after (bottom) virtual reality field trip groups during their orientation period (third floor of the museum.)*

Table 3
Length of Time and Number of Photospheres Viewed on Virtual Reality Field Trip

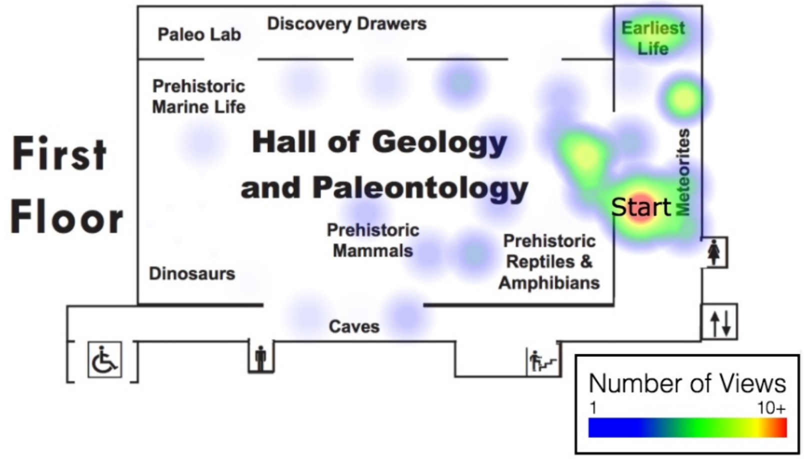
Variable	Premuseum (n = 12)	Postmuseum (n = 15)
Average time on first floor	5 min 40 sec	6 min 8 sec
Average number of photospheres viewed	18.8	23.4
Average time per photosphere	18.1 sec	15.6 sec
Note. min = minutes; sec = seconds		

The group who had never visited the museum focused on the room where they started the VR field trip. This usage pattern shared similarities with the limited exploration of both groups during their orientation period. Students were often attracted to a large blue prehistoric fish exhibit that was in the field of view when they arrived on the first floor. Of the 12 participants, only three ventured more than one photosphere outside of the starting room, with seven stopping one picture into the main hall, and two participants never leaving the starting room.

Students commented that the signs in the museum were difficult or impossible to read due to the resolution of the images. The average premuseum participant engaged in the VR tour for 5 minutes and 40 seconds, which was less time than we had anticipated.

The postmuseum group exhibited a completely different usage pattern when compared to the before-museum group (see Figure 3). To our knowledge, this is the first study to report such a finding. First, participants immediately engaged in recall of the exhibits. Students could be heard discussing elements they remembered from the trip, such as, “There is the meteorite,” or “I’m going to go find the mosasaurs.” In the after-museum group, 14 of the 15 participants left the starting room, with eight of the participants specially seeking out the dinosaur exhibit, which was at the opposite end of the museum from their starting point. Participants in the after-museum group spent an average of 6 minutes and 8 seconds in VR.

After discovering that the hidden menu allowed them to travel to any floor of the museum, one participant asked whether she could go to the fourth floor. After receiving permission, the participant chose to engage in self-exploration of this additional part of the museum that was not intended for the study. Following suit, three other participants in the post group also engaged self-exploration on the fourth virtual floor of the museum.



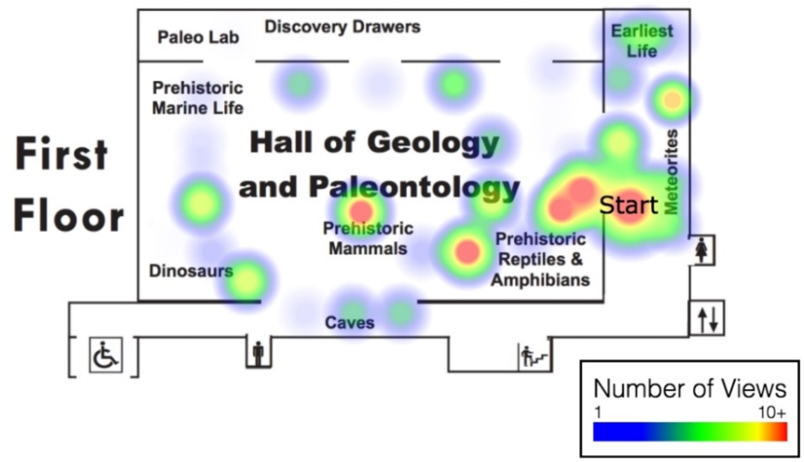


Figure 3. *Heatmap of the before (top) and after (bottom) virtual reality field trip groups exploring the portion of the museum they visited in person.*

Types of Virtual Reality Experiences

Participants reported four broad categories when describing the types of experiences that they might use VR for when teaching science (see Table 4.) First, the most commonly described experience was based on locations that were *inaccessible*, or those that were seen as "too far" or "far away." Specific examples including visiting the first cave drawings in Spain, along with several examples of types of habitats such as mountains, beaches/tides, deserts, and rain forests. The second category included experiences that were viewed as *unsafe* to visit in person. These included heat-intense events such as an active volcano, as well as dangerous weather like tornadoes.

Third, *scale of size* was a determining factoring when selecting where to visit. This category included scales that were far too small to see in person, such as atoms, molecules, and chemical reactions so that students could "see abstract concepts" or "something that is hard to represent and explain." Participants were also interested in scales that were too large to experience in a classroom, such as weather systems and the solar system.

Finally, participants described *scale of time* to experience VR in science teaching. This category included being able to visit different eras, such as walking with the dinosaurs or living in a different century. Participants also expressed interest in exploring time longitudinally, such as observing evolution over time or watching the sedimentary rock layers form.

Table 4
Types of Virtual Reality Experiences When Teaching Science

Type of Experience	Examples
Inaccessible	Visit "Far away" Cave Drawings in Spain Mountains Beaches / Tides Deserts Rainforest
Unsafe	Active Volcano Tornado
Scale of Size	
Too Small	Atoms Molecules Chemical Reactions
Too Big	Weather System Solar System
Scale of Time	
Past Era	Extinct Animals (e.g. Dinosaurs) Travel Back in Time
Longitudinal	Evolution Rock Formation

Virtual Reality Fatigue

While the in-person visit to the museum took place over the period of 2.5 hours, we found that students actively engaged in the VRFT for far less time. In our study, both the pre- and postmuseum VR groups explored the space for about 10 minutes, including their orientation time. After that 10-minute period the majority of participants began to experience VR fatigue. Multiple participants commented about eye-strain and feelings of dizziness. The majority of the Google Cardboards used in this study had lenses that could be adjusted to change the pupil distance, which may have contributed to some eye-strain if the lenses were not properly adjusted by the participant.

The relatively brief time participants were able to tolerate the physical strains of the Google Cardboard VR experience are recognized as a constraint of the study design. However, the brevity of the VR experience did not interfere with the goal of assessing students' feelings about VR and ideas about how to use VR to enhance in-person field trip experiences. Students quickly formed attitudes toward VR based on only a few minutes of exposure to the VR environment. In addition, the VR experience prompted lively discussion between students about what they were looking at in the Google Cardboard.

Virtual Reality Field Trips as an Alternative

In the analysis of open-ended survey questions, many participants mentioned VR could be an alternative for those who do not have the financial means to go on in-person field trips. Some comments showed recognition of some of the barriers teachers face when it comes to in-person field trips, such as, "In case you can't afford to leave the classroom due to time or financial limitations..."

Although the majority of comments were about the general lack of time and funds, some participants specifically mentioned low-income students. For example, one participant wrote, "With low income students this can help students have a virtual tour of a museum, or another place the class can't go." Despite the wide variety of experiences the participants said they were interested in trying in VR, they indicated a preference for in-person field trips.

Discussion

The findings described in this section are specifically related to the sequencing of pre- versus post-VRFTs with in-person museum field trips, the use of local experiences, recommendations to reduce VR fatigue, and emerging equity issues related to VRFTs.

Sequencing of In-Person and Virtual Field Trips

Based on the findings of this study, VRFTs are best used for recall of the experience after an in-person field trip. The before museum field trip group exhibited less exploration, possibly due to being unfamiliar with the environment – a finding that aligns with the novelty effect identified by Falk et al. (1978). Participants in the postmuseum VRFT group showed higher levels of recall from their in-person field trip, particularly when seeking out their favorite exhibits. In addition, participants in the postmuseum group more freely explored the space and sought to explore parts of the museum they had not seen on the trip, such as the fourth floor. As such, the ways local and virtual field trip experiences can be used to complement each other may need to be reconsidered.

Opportunity to Rethink the Local Field Trip Experience.

Although participants in this study visited a local museum, VR was still perceived as a way to visit "far away" rather than as a supplementary tool to enhance local field trips. Further work needs to be done so the posttrip benefits of VR can be fully utilized in the classroom with more museums, zoos, and other popular field trip destinations.

Numerous user-friendly advances have occurred since the custom software for this study was developed. First, many locations have already been captured as 360-degree photospheres and can be viewed in VR using the Google Street View App on both Android and iOS devices. While VR in Street View was not an option when we conducted our study, it has since opened the door to Google's vast image collection to be used in VRFTs.

A second solution could include students using 360-degree cameras to capture their own 360-degree photos or video while they are on the field trip. The photos or video can be viewed after the field trip using the application included with the camera. This strategy would provide an opportunity to give students authorship over their virtual experience.

Scaffolding to Reduce Virtual Reality Fatigue

After only about 10 minutes of using low-cost VR technologies, VR fatigue begins to set in. As such, educators should consider how they plan to implement the virtual experience in the classroom. Given that 10 minutes is not long enough to explore larger destinations, such as a four-story museum of natural history, teachers may need to scaffold the virtual experience with periodic small-group and whole-class discussion to reduce eye-strain and dizziness. For example, students could locate their favorite exhibit and describe what they recall about it to a classmate. Alternatively, the teacher could send the students on a virtual scavenger hunt to find multiple exhibits throughout the museum, which may aide in the recall of the in-person experience.

Equity Issues Related to Virtual Reality Field Trips

Fewer students are having the opportunity to participate in field trips as part of their K-12 experience due to financial and time constraints. In this study, many participants perceived VRFTs as an alternative for those who could not go on in-person field trips, including low-income students. This circumstance raises two important questions: Could the use of VRFTs reproduce educational inequities that are already present in the system? Furthermore, could the use of VRFTs unintentionally justify the lack of access to in-person field trips, particularly with low-income populations?

At the moment, the cost of implementing VRFTs with an entire class continues to be high when compared to in-person field trips. As increased student ownership of smartphones and affordable class sets of devices become more available, however, VRFTs may become more common in the education system. Moving forward proactive steps should be taken to ensure that this technology is not used to justify, replicate, and widen existing gaps between high- and low-income populations. As such, we reiterate that this study used VRFTs in conjunction with an in-person field trip experience, not as a replacement.

Further Research

Additional research needs to be conducted to replicate the findings of this study. While evidence is strong that student recall took place when using VR after the museum visit, we do not have evidence whether it contributed to their understanding of the concepts learned during their actual field trip. Studies with a control group and validated pre- and postassessments need to be conducted before any claims can be made about student learning outcomes.

Such studies could help further our understanding of what can be learned from the physical versus the virtual learning environment. This research could play an important role when developing methods to integrate VR with physical field trips in terms of both sequencing and choice of content.

This study relied on the first generation of 360-degree cameras, which had a limited resolution. While these cameras were simple to use, their resolution was too low to capture fine details such as small text on signs and plaques next to exhibits. As such, students often commented that they could not read the text. As imaging capturing technology continues to improve, additional research needs to be conducted with higher resolution images to improve the VRFT experience. In addition, further research may choose to augment the virtual experience with pop-up textboxes when looking at an exhibit as a way of overcoming the resolution limitations.

As suggested in our discussion, students could capture 360-degree photos and videos while on an in-person field trip. Further research could explore whether students capturing their own VR photos as part of a field trip have a positive or negative impact on their recall of the experience and associated learning outcomes.

Furthermore, the role of the docent or tour guide remained unexplored in this study. Further research could explore the use of both physical and virtual docents to help guide participants through their museum experience and the effect on learning outcomes.

Limitations

This study makes no claims about whether VRFTs could be used as a substitute for actual field trips. Rather, our research focused on the virtual experience being used in conjunction with an actual field trip involving preservice teachers in an elementary science methods course. This study relied on convenience sampling since there was a limited pool of students enrolled in elementary science methods in any given semester. We did not control for participants who may have visited the natural history museum prior to the start of the study. As such, the premuseum VR group may have had at least one participant who was already familiar with the museum. All participants in this study were elementary preservice teachers; thus, we cannot make any claims about whether the outcomes are generalizable to K-12 students.

Conclusion

In this study we implemented a VRFT in conjunction with an in-person field trip involving preservice teachers in an elementary science methods undergraduate course to a local natural history museum. Our findings included that VR is best used after a field trip to encourage student recall of the experience, but only when done for a limited time to avoid VR fatigue. The types of experiences that preservice teachers thought VR would be good for in their science classrooms includes the ability to visit either inaccessible or unsafe locations, explore scales of size that are either too big or too small, and to witness different eras or events at varying temporal scales.

Furthermore, this study revealed potential equity issues related to VRFTs being seen as a viable alternative if students could not afford to go on field trips. Further research needs to be conducted to better understand the impact of VRFTs on student learning outcomes and take advantage of recent improvements in VR technology.

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