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Natural Sciences Education

SPECIAL SECTION: COVID-19 FORCED RAPID CHANGES IN EDUCATION, BUT WHICH CHANGES SHOULD WE KEEP?

# Hybrid classroom approach: Virtual and live field data integration

**William E. Schlosser** | **Aidan J. Aumell** | **Madison M. Kilkenny**

School of the Environment, Washington State University, Pullman, Washington, USA

**Correspondence**
William E. Schlosser, Washington State University, Pullman, WA, USA.
Email: Schlosser@wsu.edu

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**Abstract**

University students stepped into synchronous remote learning as the COVID-19 pandemic arrived in spring 2020. Temporal limitations of the live field trip-based paradigm in teaching ecology have been complicated by remote learning. To meet the challenge, we have designed and deployed an immersive virtual ecology platform with associated field explorations and data analysis using a 360˚ video apparatus and software applications augmented with wildlife camera trap videos and aerial drone images at Washington State University in an undergraduate Natural Resource Ecology class. Throughout four semesters (fall 2020 to spring 2022) of synchronous online instruction, students have been using the virtual platform simulating the natural landscape at Kamiak Butte County Park. The immersive virtual ecology platform provides students with (1) access to broader learning comprehension of abiotic and biotic landscapes; (2) ability to collect and analyze tree data to describe differential woodland site characteristics; (3) visualization of native wildlife habitat uses; and (4) guidance through virtual field instruction tasks. With softening of pandemic restrictions in 2022, we designed the immersive virtual ecology platform in conjunction with in-person learning. This proof-of-concept article briefly summarizes the steps followed in creating this blended delivery curriculum using a hybrid field trip experience in combining virtual data discovery with live field trips and classroom events.

## 1 | INTRODUCTION

On March 13, 2020, Washington State University (WSU) converted all instruction to an online synchronous learning format in response to the COVID-19 pandemic, a move taken by educational communities worldwide (Rapanta et al., 2020). Some instructors were better prepared for the online-only teaching conversion, and others were challenged to accommodate student needs through synchronous distance learning (Singh & Matthees, 2021). Conversion from live, face-to-face classes to synchronous online teaching introduced additional challenges for natural resource science classes.

A shift in environmental teaching modality had to take place. Cancelation of class field trips and field-based

**Abbreviations:** DBH, diameter at breast height; GPS, Global Positioning System; SoE, School of the Environment; UDLF, Universal Design for Learning Framework; VR, virtual reality; VRP, variable radius plot; WSU, Washington State University.

instruction mandated by social-distancing requirements prompted faculty and students to adapt to this change in all areas of instruction and student learning (Barton, 2020). This was particularly problematic for natural resource science courses due to the traditional importance of field-based learning in these disciplines (Fleischner et al., 2017). Some instructors integrated digital technologies into their lesson plans to successfully implement field-based learning into their online classrooms (Barton, 2020).

At WSU, the School of the Environment (SoE) offers a variety of courses involving field trips and field-based learning activities. SoE-300, Natural Resources Ecology, an undergraduate course, requires a field trip to the woodland area of Kamiak Butte County Park (Whitman County Parks and Recreation, 2022; WSU Virtual Ecology, 2022a). Accessing the park, located 12-miles north of the WSU Pullman campus, was prevented for field trips by social-distancing needs (Bailenson, 2021; Ramachandran, 2021). The instructor for this course established a flipped classroom design (Butt, 2014) prior to the pandemic. The idea of the flipped classroom implies that students watch lecture videos, created by the instructor, before attending live class sessions as well as read textbook materials. Synchronous lectures are conducted three times a week using virtual tools described in this article (Singh et al., 2021).

In spring semester 2020, the SoE-300 class conducted the field trip series to Kamiak Butte, completing all field trips on the last day of live-class instructions (March 13). Synchronous online class sessions were successfully filtered into a Zoom-mode of instruction (https://explore.zoom.us/en/industry/education/) for the remainder of the spring 2020 semester, for fall 2020, spring and fall 2021, and spring 2022. Live field trips resumed in fall 2021, though WSU accommodated students were allowed to treat field trip attendance as an optional event. The physical field trip participation in fall 2021 hosted 29% of registered students. The same attendance protocols were applied in spring 2022 when 78% of class students participated in the physical field trip events.

Since the fall 2020 semester, all class participants have interacted in immersive virtual field trip exercises as a matter of class expectations. Since fall 2021, students have been involved in the blended experience of virtual and physical field trip events. The immersive virtual ecology platform is an effective instructional tool for this teaching space.

During the process, students gain hands-on experience in field technology deployment which becomes a basis for active learning practices.

## 2 | DESIGNING THE VIRTUAL ECOLOGY EXPERIENCE

Universal Design for Learning Framework (UDLF) is proposed by the Center for Special Technology (CAST, 2018; Rose & Meyer, 2002). Meyer et al. (2014) stated that UDLF "drew upon neuroscience and educational research to leverage the flexibility of digital technology to design learning environments that from the outset offered options for diverse learners needs" (p. 3). UDLF was included in the Higher Education Act of 2008 as a framework to help guide educational practice for higher education institutions (Gordon et al., 2009). The UDLF guidelines are made up of three guiding principles (1) provide multiple means of engagement, (2) provide multiple means of representation, and (3) provide multiple means of action and expression (CAST, 2018).

**Core Ideas**

- An immersive virtual field trip format was defined using technological devices applied across the physical site.
- Virtual interactive 360° tours were recorded as immersive videos to deliver teaching content.
- Camera trap devices were placed to record wildlife and plant interactions traditionally hidden from view.
- Drones were flown to do video recordings to broaden visuals from nontraditional angles.

### 2.1 | Engaging virtual goals

We have started looking for ways to realize virtual reality (VR) options. One of the key components of the SoE-300 course curriculum is a field trip involving data collection, analysis of plant and wildlife interactions, evaluation of climatic, and geologic conditions to formulate examples of abiotic and biotic relationships at Kamiak Butte County Park. Setting up a 360° camera portal is the way we chose to collect site data to create the immersive virtual experience in a hybrid learning experience.

This approach stimulates inquiry-based teaching to enrich students with relevant and captivating learning experiences, contributing to enhanced student engagement. Faced with an online work environment, students are learning to apply innovative technological solutions making unexpected discoveries along the way. The visual content, integrated into the course, provides students with additional resources as they engage in an online learning space.

### 2.2 | Managing the pandemic teaching space

The immersive virtual field trip involves 360° tour (3DVista, https://www.3dvista.com/en/) camera trap image

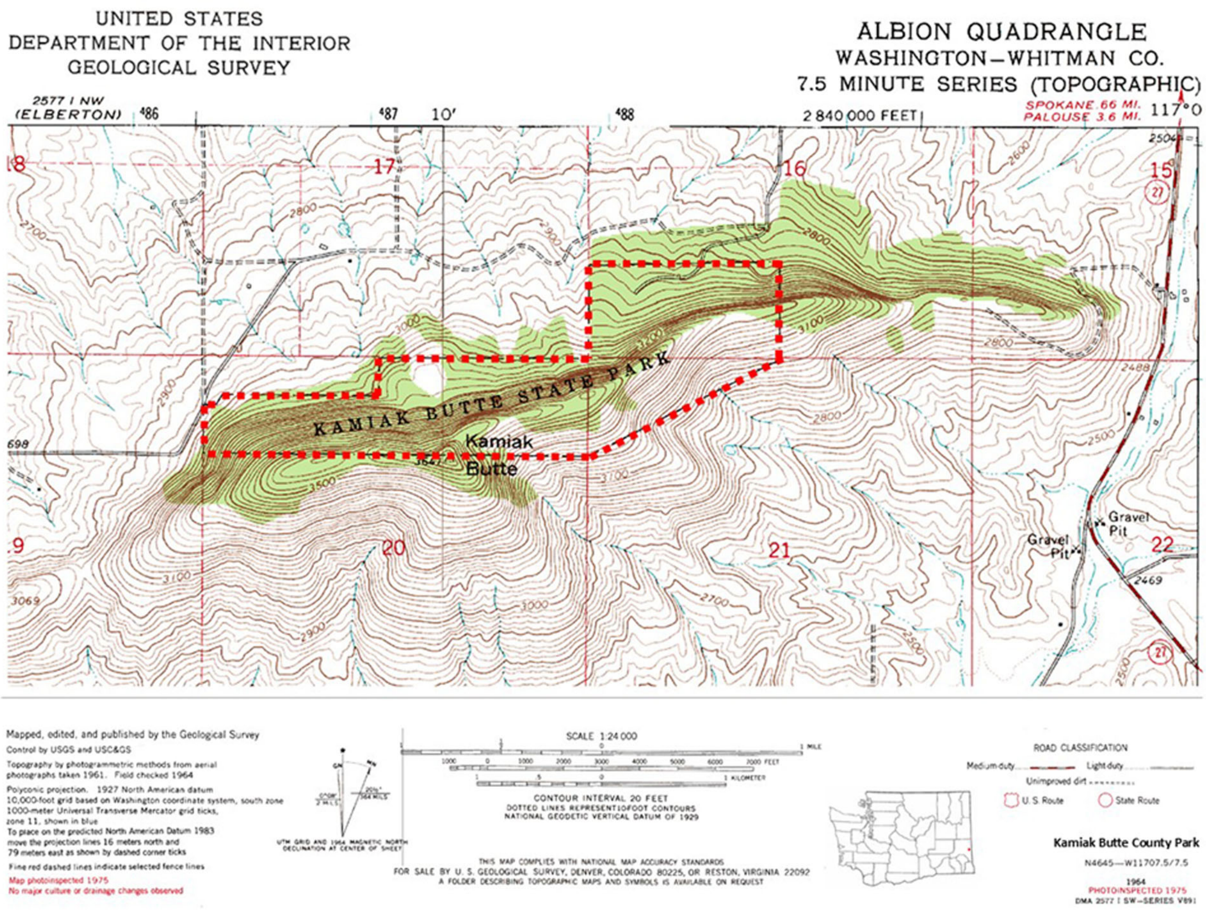


**FIGURE 1** Kamiak Butte County Park locator map (USGS, 2012)

**FIGURE 2** Google Cardboard units provided to all class students

(T85 Wifi trail camera, CamPark) and drone flight views (Mavic 2, DJI) with recent abiotic landscape and weather pattern displays. Within the immersive virtual field trip platform, students access an interactive 360° tour of the park on their computer, mobile device, or a VR headset. The goals are (1) to provide simulation of abiotic and biotic conditions at selected field sites, (2) to teach students to collect and analyze tree data describing differential woodland site characteristics, (3) to create visuals of native wildlife habitat use, and (4) to guide students through virtual field instruction.

The immersive virtual field trip diversifies resources and opportunities of the live field trip experience. At this point, it makes sense to describe how the instructor has crossed the bridge stepping from teaching methods used in the online instruction style to transform it into a hybrid post-pandemic model.

## 2.3 | Resource engagement

Virtual field trips have been used by educators in natural sciences both before and during the COVID-19 pandemic. Several educators have exercised instructional practices in alignment with the UDLF principle of representation and engagement. Culber (2021) used 360° videos and non-panoramic videos to virtually recreate an 8-day long field course taught in the forestry department at University of British Columbia, Canada. This study showed videos improved course material understanding and was appropriate given the context of online instruction. Schulze et al. (2021) provided undergraduate students in a soil science course at Purdue University with a virtual field trip which included text, 360° images, videos, Google Maps, and images to provide an alternative to live class field trips. Students preferred both


FIGURE 3 Kamiak Butte microsite vegetation differences shown for north- and south-facing aspects (Google Earth Pro, 2015 )

in-person field trips and virtual field trips presented in combination, with a stronger preference for virtual field trips over in-person field trips alone (Schulze et al., 2021).

Augmented reality is used to support teaching undergraduate students in ecology and environmental science course field trips (Kamarainen et al., 2018). Klippel et al. (2019a) investigated the application of VR field trips in an undergraduate geoscience course in preparation for in-person field trips. They compare student perceptions who used VR prior to the field trip with those who did not. Klippel et al. (2019b) found that students self-reported higher learning gains and more positive experiences while using VR for a virtual field trip compared to students who only experienced in-person field trips. This confirmation correlates with results from a literature review among virtual and in-person field instruction experiences where Cliffe (2017) proposed that virtual field guides can be beneficial for students as they prepare for in-person field trip events.

## 2.4 | Natural resource ecology course overview

The SoE at WSU is located within an administrative structure of the College of Agricultural, Human, and Natural Resource Sciences and of the College of Arts & Sciences. The SoE (https://environment.wsu.edu/) focuses on topics in global ecology, ecosystem science, and environmental sustainability. The purpose of the SoE-300 course is to teach students scientific principles of ecology and how they are employed for conservation policies and management of renewable natural resources. Students develop understanding of human interactions and their influence on the natural world. Relationships between organisms and their environments give exposure to variety and complexity of interactions. This class emphasizes critical thinking and problem solving within an ecological framework. This is accomplished by using natural system models and physical site investigations with the goal of teaching students to describe concepts using ecological data. The course is taught with expectation that students acquire basic comprehension of environmental science and become able to operate software on their computer device.

SoE-300 learning objectives integrate classroom instruction with investigations of Kamiak Butte County Park (Figure 1). The park includes 298-acres of natural ecosystems offering students examples of dissimilar geology, diverse plant populations, and abundant animal species. The field trip serves as an important component to the course curriculum as field instructions enhance student understanding of ecology (Kamarainen et al., 2013).

**FIGURE 4** GoPro MAX on tripod mount used for the initial immersive virtual ecology platform at permanent plot no. 1

**FIGURE 5** Insta360 Pro 2, 360° camera on carbon fiber 3-section tripod

# 3 | MATERIALS AND METHODS

## 3.1 | Immersive virtual ecology platform

In this paper, we define "immersive virtual ecology platform" as an online module created using physical and virtual tools to access physical site characteristics data, which students access during the course. This platform serves as a bridge connecting temporal limitations of live field trip experiences with the benefits of additional virtual content.

Klippel et al. (2019b) defined virtual experiences, analogs to the immersive virtual field trip, as interfaces where students can interact with simulated content using a VR headset to navigate in the emulated environment. Students access the immersive virtual ecology platform using a desktop computer, laptop, tablet, or mobile device. Within the context of this approach, students can use their personal mobile phone (iPhone or Android) with Google Cardboard VR headset (Figure 2), or an Oculus to access platform imagery. We provide Google Cardboard headsets to all registered class members for use with their personal mobile phone device.

Virtual site data are further processed into coherent panoramic videos with and without narration. Interactive imagery contains such data as tree diameter at breast height (DBH), tree height, and tree species names, physical site characteristics (elevation, slope, Global Positioning System [GPS] coordinates, aspect, tree canopy closure, wildlife species) presented as a constellation of anchor site locations.

Physical site descriptions within the platform allow student interactions on a higher level of comprehension through merging their physical field trip observations with the immersive virtual experience. In the context of UDLF and inquiry-based learning, students enhance their experiences via multiple means of representation and engagement (CAST, 2018; Petersen et al., 2020).

## 3.2 | Field trip approach: Pre-pandemic

The instructor's teaching style utilizes a flipped classroom approach mentioned earlier (Enfield, 2013; Lage et al., 2000; Pearson, 2012). This combined synchronous and asynchronous method appeals to a variety of learners (Goedhart et al., 2019). Live class session expectations include students reading textbook materials and viewing lecture videos before the class opens, where discussions, breakout sessions, peer-learning classroom activities, and topical scenarios are discussed. Each lecture is accompanied by videos of vetted topical presentations available through licensed access within Panopto or as publicly available YouTube videos. All class lectures are created and narrated by the course instructor and

FIGURE 6 Camera trap mounted for remote den site ingress and egress video capture


FIGURE 7 Bull Shiras moose (*Alces alces shirasi*) captured on a trail camera trap at Kamiak Butte


**FIGURE 8** White-tailed deer (*Odocoileus virginianus*) doe and fawns captured on snowy night camera trap at Kamiak Butte

**FIGURE 9** CamPark Wi-Fi camera with solar panel apparatus designed for elevated bird nest video capture

are updated periodically (https://youtube.com/playlist?list=PLP-gm6C-TAEPc1EXWaeKJy4FhZ5YMd41x). Class lecture videos are 20–60 minutes each with embedded subtitles as required by the Americans with Disabilities Act (https://www.ada.gov/law-and-regs/ada/).

Integrative classroom teaching (Aelterman et al., 2019), as applied here, includes field trip investigations, weekly on-line quizzes, bi-monthly written assignment tasks, and a four-part term report. Students coalesce their final term report into a YouTube video presentation lasting from 6 to 12 min. Term report videos are posted to a class Discussion Board in Canvas where students view and comment on the videos made by at least five other students.

### 3.2.1 | Teaching space tactics

Learning objectives capture topics of ecology, beginning in the abiotic realm with discussions and activities of the region's geologic genesis where the WSU Pullman campus and the subject property (Kamiak Butte) are located (Figure 1). All discussions and presentations focus on interactivity of energy, nutrients, and abiotic features to reveal biotic plant and animal interactions. Photographic and video examples derived from the immersive virtual ecology platform are an available resource for all class participants.

### 3.2.2 | Field trip integration in live classes

Prior to the global COVID-19 pandemic, students participating in the physical field trip formed teams to conduct tree investigations through a variable radius plot (VRP) sample. Students established location of plot center measuring the distance to the closest four to seven trees, recorded tree species names, tree distance from plot center, DBH, and total tree heights within the plot. Each student team conducted this procedure for two randomly located VRP locations at Kamiak Butte: north- and south-facing aspects.


**FIGURE 10** Great horned owl (*Bubo virginianus*) nest bag being mounted by an undergraduate teaching assistant (image captured by camera trap device)

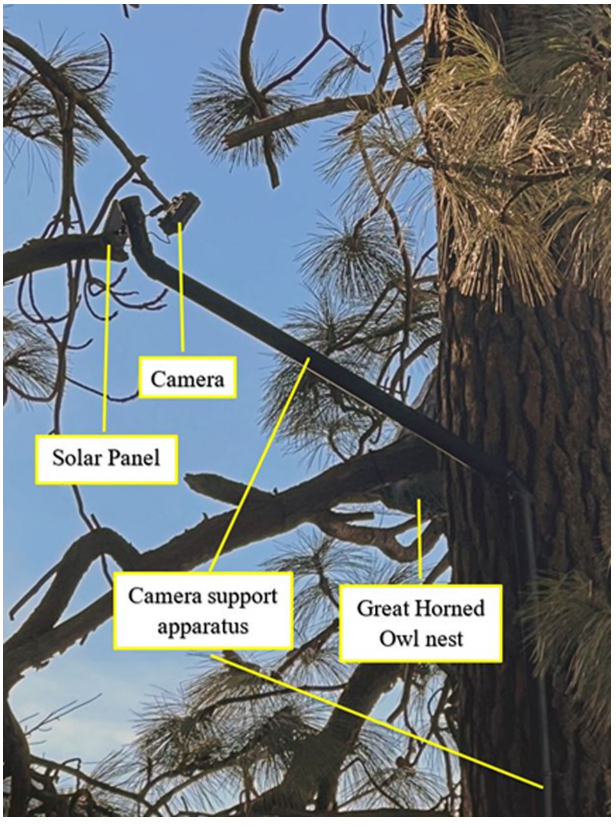


**FIGURE 11** Great horned owl nest viewing camera trap at 20 ft above ground

Generally, students possess differing skills while making woodland site observations, as there are no class prerequisites. Without completing a dendrology class, most students fail to accurately identify tree species. Students typically cannot operate a diameter tape to determine DBH, or measure and calculate accurate tree heights without the instructor's assistance. They also lack skills or instruments to record their randomly placed plot center GPS coordinates.

**FIGURE 12** DJI Mavic 2 drone vehicle with Insta360 ONE X2 360° camera

Limited field-trip time curtails the instructor's ability for catering to the needs of every student while verifying accuracy of collected data. Later discovered, the VR component of the field trip aids to overcome this challenge.

## 3.3 | Field trip approach: During the pandemic

Two SoE-300 students approached the class instructor (this report's lead author) early in the spring 2020 semester

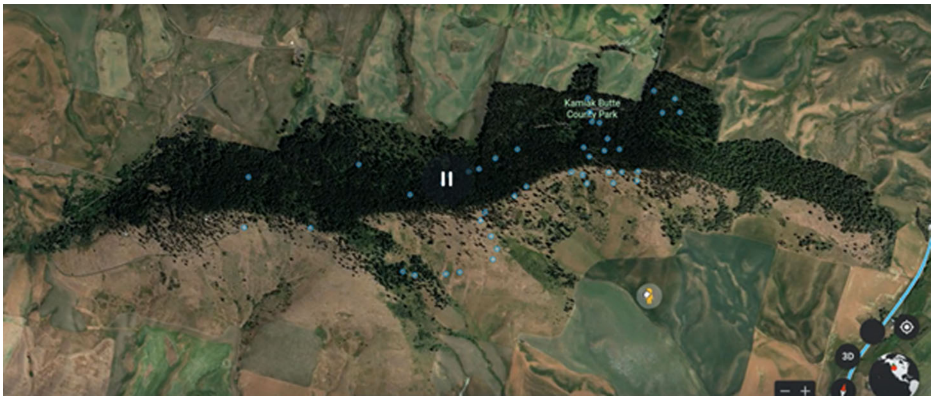


**FIGURE 13** Google Earth site hot spots at Kamiak Butte


**FIGURE 14** Immersive virtual ecology platform interface

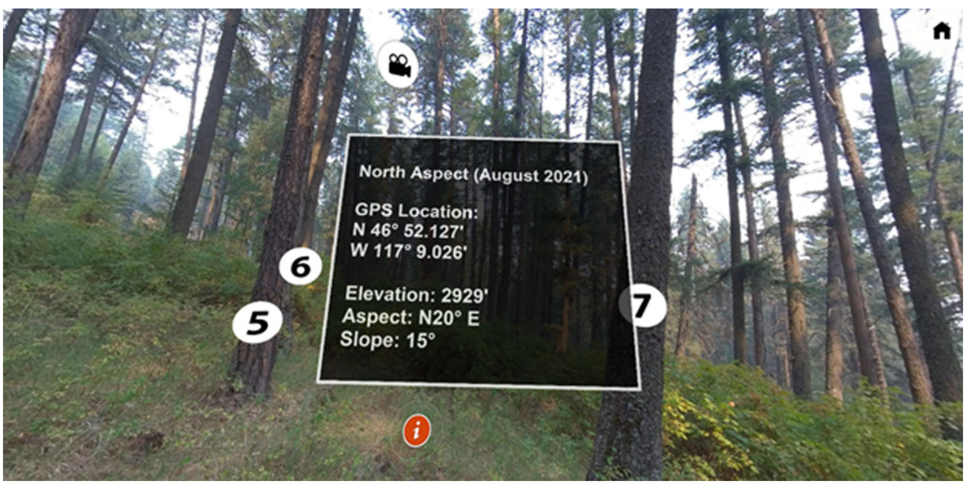


**FIGURE 15** Characteristics of the first permanent woodland plot on the north-facing aspect

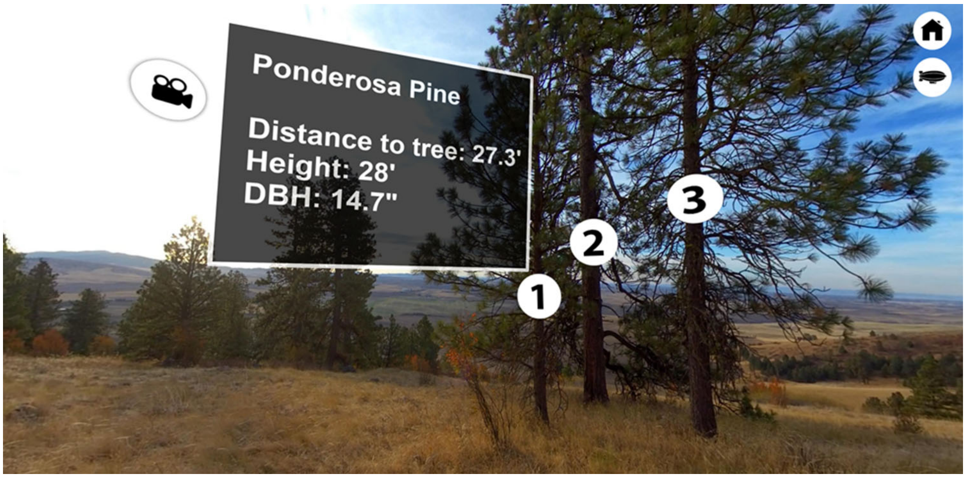


**FIGURE 16** South-facing aspect permanent plot: tree no. 1

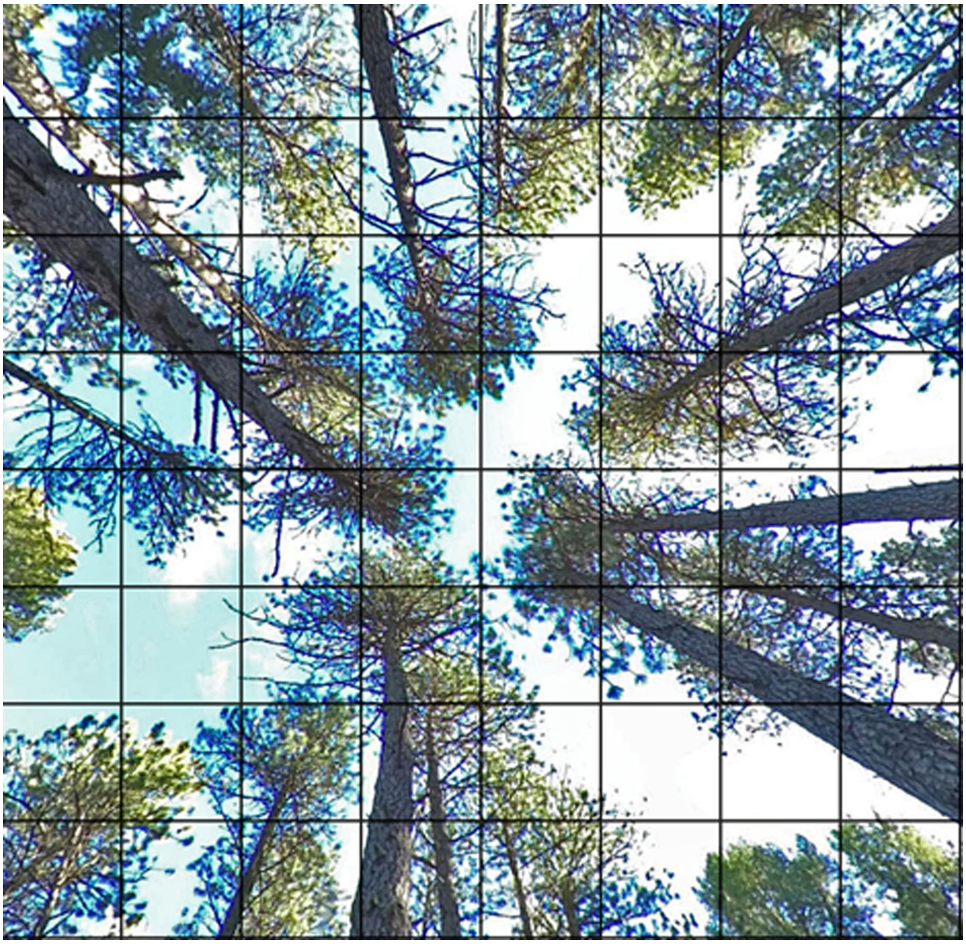

**FIGURE 17** 360˚ camera view rotation to heuristically determine canopy coverage

to discuss the concept of the immersive virtual ecology platform. They coauthored this article. The realization of the concept became possible through joint efforts by the instructor, students, and teaching assistants volunteering their time. The WSU Virtual Ecology web domain (https://environment.wsu.edu/virtual-ecology/) was developed as a launching point accompanied by the WSU Virtual Ecology YouTube channel (https://www.youtube.com/channel/UCA23Q4I2W8GQxBaz-ofd7_w) where videos in the immersive virtual ecology platform are housed.

**FIGURE 18** Understory vegetation heuristic plant coverage assessment


**FIGURE 19** Seasonal change 360° video with teleport keys to months of the year

We have started by creating a general design of the immersive virtual field trip to supplement the physical field trip event as an obvious priority. Later, additional opportunities such as camera traps, 360° camera recordings, and aerial drone imagery were added.

A WSU Student Technology Fee grant was won by the team in 2021 and again in 2022, allotting means to purchase technologies and make field deployable resources. Six (6) fundamental class learning segments of the immersive virtual field trip were identified.

1. Permanent plot tree measurements:
   a. Variable Radius Plot (VRP)
   b. Quadratic Mean Diameter (QMD)
   c. Tree cover density (Densiometer)
   d. Understory vegetation type (grass, fern, moss, and shrub) and density
2. Weather conditions at microsites:
   a. 360° camera imagery recorded monthly at permanent plots,
   b. Linkage of climate data (PRISM Climate Group, 2021) captured in class to align with panoramic imagery recorded by date,
   c. Plant growth status based on visual indicators linked to temperature and precipitation.
3. Plant and wildlife activity as recorded by remote camera traps.
4. Geological substrate documentation:
   a. Google Earth street view uploads,
   b. On-site geologic views through 360° camera imagery with narration.

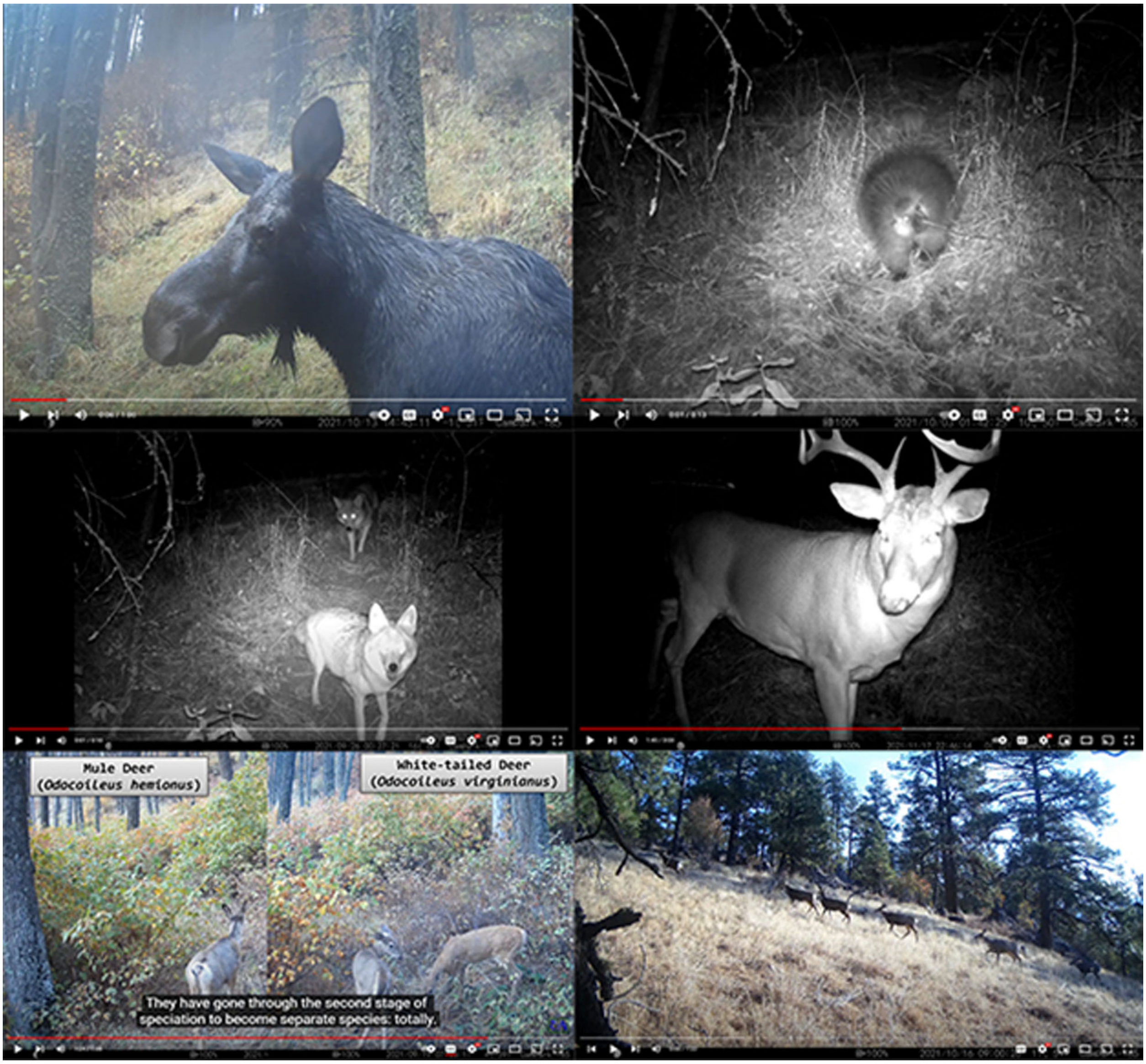


**FIGURE 20** Wildlife displayed in a teleport array

5. Drone flights with subtitles and verbal narration about the significance of observed scenes.
6. Bird audio captured at Kamiak Butte by date, location, species identified, and photographic evidence.

## 3.4 | COVID-19 pandemic with live teaching

Use of the immersive virtual ecology platform as an educational tool has proved to be critical for student learning during the initial COVID-19 pandemic period with social-distancing restrictions in place. At a later stage of the pandemic, the virtual field trips realized through the immersive virtual ecology platform were combined with physical field trips to shape the hybrid field trip model in its existing form.

Through the hybrid model, students experience components of the virtual field trip model the same way as during the initial phase of the pandemic. They complete the six priorities described earlier. Once exposed to the virtual field trip, students also attend the in-person field trip. Students physically enter Kamiak Butte woodland area where two unique microsites are located on adjacent aspects (Figure 3), separated by a 20 min hike. Physical site attributes, viewed earlier through the virtual interface lens, become easily recognizable to viewers who observe differences and similarities between virtual and physical realities of the site.

VR data creation presents new learning opportunities for students involved. In natural resource science classes, teaching students how to consistently describe physical site characteristics has long been a challenging effort (Shernoff

**FIGURE 21** Quartzite substrate in the immersive virtual ecology platform


**FIGURE 22** Aviary species documented at Kamiak Butte

**FIGURE 23** Parabolic microphone and field audio recorder used at Kamiak Butte

et al., 2016). We encourage students during their live site experience to strategize additional data needs, learn how to collect data, find research solutions, and present their findings.

### 3.4.1 | 360° Video production

Initially, we have utilized GoPro MAX (GoPro, Inc.) and Amazon Basics tripod (Amazon) to capture 360° videos at the field sites to start building the immersive virtual ecology platform (Figure 4). The lead field collection analyst has recorded imagery data at two permanent plot locations on the Kamiak Butte north- and south-facing aspects every month for 2 years (2020–2022), which we later have changed to use a GoPro MAX and Adobe Premiere Pro (Adobe). These image arrays captured seasonal changes of plant composition and precipitation.

Successful grant awards facilitated purchases of new equipment in July 2021, including the Insta360 Pro 2 (Insta360) a professional grade 360˚ video camera which records 8K 3-D 360˚ videos. The camera is equipped with a GPS unit to report spatially specific data (Figure 5).

Insta360 Pro application and Adobe Premiere Pro are used to edit and publish video content. The 360˚-video camera enables consistent presentation of monthly scene imagery to capture panoramic views.

### 3.4.2 | Camera trap image processing

We placed 20 remote camera traps at Kamiak Butte County Park (Figure 3) beginning in the summer of 2020: some of them intended to catch ground-based animal movement, others to record potential cougar den activity, and four to observe bird nesting events. Class students and teaching assistants collaborated with the instructor to find collection sites. Students deployed all camera traps and revisited them to collect captured imagery.

*Ground-based animal camera traps*

Ground-based camera traps are placed in anticipated high animal traffic areas, especially for white-tailed deer (*Odocoileus virginianus*), mule deer (*Odocoileus hemionus hemionus*), Rocky Mountain elk (*Cervus canadensis nelsonii*), Shiras moose (*Alces alces shirasi*), coyotes (*Canis latrans*), Cascade red fox (*Vulpes vulpes cascadensis*), and other animals. One camera trap is posted to capture activity at a cougar (*Puma concolor*) den site (Figure 6).

All cameras (CamPark) record 3-min video/audio clips when activated by movement (Figure 7), and all are solar powered with battery backups. Nighttime infrared image records animal movement as colorless video (Figure 8).

*Bird nesting camera traps*

Bird nesting camera traps, designed and built by the instructor and students, represent a camera apparatus (Figure 9) supporting the tree-mounted trail camera and a solar panel, while securing connecting wires from access by birds and rodents. Great horned owl (*Bubo virginianus*) nest bag (Cornell Lab of Ornithology, 2022) is mounted in forested areas of the butte's north-facing aspect (Figure 3) by student volunteers (Figure 10). The apparatus is secured to trees with nest bags about 20 ft above the ground (Figure 11). The combined nesting sites with remote viewing camera traps are further enhanced by Wi-Fi image retrieval without disturbing nesting birds.

Camera trap videos are reviewed before posting to the WSU Virtual Ecology YouTube channel. The instructor for SoE-300 uses these recordings for lecture videos, and they are available for students to integrate into their class term report presentations.

### 3.4.3 | Aerial drone videos

Imagery from aerial drones presents a visually engaging and compelling view. Drone videos naturally appeal to all course participants who embrace creating virtually accessible data of natural landscapes.

A professional grade aerial drone (Mavic 2) used for this effort is augmented with a 360˚ camera (Insta360) mounted under the aircraft (Figure 12). A WSU doctoral student volunteers to pilot the drone and assist others involved.

Aerial videos taken from a bird's-eye view are compelling to watch, engaging student active participation in using modern technology advanced information delivery in Natural Resource Ecology. Drones can be used to evaluate various ways interactions of energy, moisture, and temperature influence interspecies competition on these sites.

Students identify desired flight paths and analyze the imagery collected. Several students have voiced the desire to receive a drone pilot license from the Federal Aviation Administration (FAA, 2022). All drone flight videos with the mounted 360˚ camera are posted to the WSU Virtual Ecology YouTube channel (WSU Virtual Ecology, 2022c) for students to use in their analysis, reports, and presentations.

### 3.4.4 | Google street view production

Using the Insta360 Pro 2 panoramic camera, we upload Google Street View imagery to Google Maps and Google Earth platforms to provide students with visualization across the sites of study. Students reference field sites as they analyze the subject property. As of May 2022, 90 panoramic images from Kamiak Butte have been uploaded on Google Maps or Google Earth (Figure 13).

### 3.4.5 | Anthropogenic influences on Kamiak Butte environment

The local area news media periodically present articles with the stories covering the last 170 years (WSU Virtual Ecology, 2022d) of history, and the influence local Indians have made on the landscape (Yakama, Nez Perce, and Palus people). The coauthor of this manuscript did some research in local archives concerning Kamiak Butte since

1890. All references to these articles are presented, with publisher approval, on the WSU Virtual Ecology web domain.

### 3.4.6 | Immersive virtual ecology platform interface

Through the interface page of the platform (Figure 14), students select different pathways in the virtual environment. The tours in the menu (https://storage.googleapis.com/kamiakbutte/ecology/index.htm) guide student interactions with focus on specific aspects of Kamiak Butte County Park's ecology labeled as "tree populations," "seasonal change," "wildlife populations," "geologic foundations," "bird populations," and "Chief Kamiakin." Each pathway presents a lesson plan deliverable for the SoE-300 class.

*Tree populations*

Students visit north- and south-facing aspect permanent plots to explore woodland site characteristics. Each plot has GPS location, elevation, and slope (Figure 15). These parameters serve as anchor points in accurate descriptions of various woodland type areas for plot sampling. Students virtually collect and record tree data (DBH, height, species, and distance from plot center) to calculate a VRP sample at each plot (Figure 16).

Each plot location is displayed in 360° high resolution imagery. Students record tree data on plot sample forms. This way students grasp the idea of the VRP concept and its significance in multiple sample tree data collection. These calculations allow students to make accurate determination of the total basal area of each specific woodland type. The immersive virtual ecology platform makes accurate assessments possible.

Having completed these calculations, students rotate the virtual image to look up at the tree crowns to heuristically estimate canopy coverage simulating the use of a densiometer (Figure 17). In the same manner, they observe understory vegetation to make assessments about shrub coverage (Figure 18). Learners can use the high-quality imagery to snip vegetation pictures in the close-up scene and submit it to iNaturalist (https://www.inaturalist.org/) to confirm plant identification.

*Seasonal change*

The seasonal change tour contains monthly captured 360° images (Figure 19) at each permanent plot. During the tour, students click on hotspots to teleport to different months throughout the year to view how monthly weather conditions influence the environment. Hotspots trigger the presentation of 2-D photos to display changes. Although a live field trip is conducted each semester, the immersive virtual ecology platform allows students to visualize site transformations due to seasonal weather changes each month in 360° views.

*Wildlife populations*

The wildlife tour guides students through videos and images of native wildlife of Kamiak Butte County Park. Students teleport to the virtual location of the wildlife cameras and click on hotspot icons to trigger wildlife video and still images (Figure 20) which include species name (Latin and common). Each video displays the time and date of recording.

We use OpenShot video editor (OpenShot Studios) to digitally trim and combine video segments (e.g., https://youtu.be/BtQ_R9RrTD4). These shows are linked on the WSU Virtual Ecology YouTube channel. Americans with Disabilities Act compliant subtitles are integrated into narrated videos.

*Geology tour*

The geology tour contains 360° images of quartzite substrate materials overtopped by loess soils (Figure 21). Students teleport to various locations to view quartzite rock terrains and click on hotspots to display instructional videos and images (WSU Virtual Ecology, 2022b), This interface provides interesting details about Kamiak Butte geology.

*Bird Populations*

In the bird tour, students visit bird habitats at Kamiak Butte (Figure 22). Class demonstrations show how to use the iNaturalist app for bird species identification. Students view bird imagery while reading captions to learn each Latin name (genus species) and common name. Audio recordings of bird calls accompany the imagery.

Student volunteers have collected high-quality audio recordings to represent nuances in bird sounds and, with reference to specific bird species, to identify bird calls throughout the year. Field audio recordings are made using a Mono Parabolic Microphone (Figure 23), MixPre 2, Rode NTG2 Shotgun Condenser Mic, and studio headphone (RØDE).

*Chief Kamiakin*

WSU's Pullman campus and Kamiak Butte County Park are located on the ancestral homelands of the Nimíipuu (Nez Perce) Tribe and the Palus band. Their presence spans time immemorial as represented by continuing connection to the land, water, and their ancestors. Kamiakin (1800–1877) was the leader of the Yakama, Palouse, and Klickitat peoples east of the Cascade Mountains from 1840 through 1855 (Saluskin, 1989; Scheuerman & Finley, 2008).

Kamiak Butte, named in honor of Chief Kamiakin, is part of his homeland. A drone flight video narrates an introduction to the Virtual Ecology platform and tells the story of Chief Kamiakin's life and tribal experiences (https://youtu.be/4Yb7Y9UHqmM). Tribal long-time presence in this area is well pronounced throughout the Kamiak Butte environment having shaped regional abiotic and biotic features the way we see it today.

### 3.4.7 | Hybrid field trip

In their anonymous reviews, students describe the physical field trip as the focal point of the entire SoE-300 class with many course concepts demonstrated in real life situations. However, the time available to the instructor on site is limited in terms of its educational content delivered to students. With the creation of the immersive virtual ecology platform, we have transformed the teaching/learning paradigm. Benefits of the live field trip, amplified by the virtual platform, have enriched student learning experience via diversified technological applications to a more challenging and at the same educationally more meaningful content.

## 4 | RESULTS AND DISCUSSION

According to the instructor's heuristic evaluation of SoE-300 student performance metrics, based on quizzes, examinations, report writing, and assignments, their learning has remained at acceptable levels during both the pre-pandemic and pandemic periods.

Students using the immersive virtual ecology platform, built around a simulated field trip, have improved data-solution engagement during synchronous online learning. The hybrid model of instruction, as described here, expands classroom and field-based student learning outcomes.

The flipped classroom approach, augmented with the use of VR concepts, guides learners to more effective educational outcomes. In the opinion of the instructor, student final term reports and video production quality have undergone improvement in terms of content, organization, and level of comprehension. Furthermore, within the context of UDLF, the hybrid learning model may benefit students as they have access to additional ways of representation and engagement at the field site.

## 5 | CONCLUSIONS

To conclude the discussion, several points need to be emphasized. The flipped classroom approach, with its reliance on a passive virtual component (watching videos prepared by the instructor prior to class lecture), can be considered an introductory step. It was followed by creation of the virtual platform built around its field trip focal point, which became impossible at the onset of the pandemic. This module transformed the idea of a live field trip into an interactive learning paradigm for students who can develop new data collection and processing skills. Those created step-by-step teaching/learning innovations have paved the way for introducing an interactive learning avenue. Thus, the visual aspect of the course content becomes amplified when students rely in their learning process on diversity of visual presentations. What we visualize leaves a deeper imprint in our memory (Stangor & Walinga, 2014).

With the immersive virtual ecology platform in place, we have succeeded in combining 'the best of both worlds': live experience on site with technological benefits of virtuosity. Data analysis conducted on a simulated site becomes the focal point of discussions at live lectures focused on a variety of characteristics on specific woodland plots, thus accentuating the value of stratified random sampling in forestry, as one of the examples. Students acquire a valuable skill of navigating between the two study environments building their experience in handling real-world tasks to formulate scientifically justified conclusions while using virtually collected evidence. At the end of semester, students write a final report fully integrating new skills, thus proving the conceptual validity of this two-world scientific symbiosis made possible by technological advances.

## AUTHOR CONTRIBUTIONS

**William Schlosser**: Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Supervision; Validation; Visualization; Writing – original draft; Writing – review & editing. **Aidan J. Aumell**: Conceptualization; Investigation; Project administration; Resources; Software; Writing – original draft. **Madison M. Kilkenny**: Conceptualization; Investigation; Methodology; Writing – review & editing.

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## CONFLICT OF INTEREST

The authors declare no conflict of interest.

## ORCID

*William E. Schlosser* https://orcid.org/0000-0002-3843-4213

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