A Novel Course-Based Experience to Promote Ecological Field Skills During the COVID-19 Pandemic

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Abstract

Providing safe access to functional field experiences during the early stages of the COVID-19 pandemic was a distinct challenge. However, these experiences are critical to train students in ecological methods and provide an opportunity for open-ended, authentic research. Here, we report on a multi-week lab designed for an introductory ecology course, which was adapted for hybrid instruction during the pandemic. In the lab sequence, students independently surveyed basic phenological, population, and community dynamics of easily identifiable, cosmopolitan plant species in the genus *Plantago*. Students used this crowd-sourced dataset to develop, analyze, and report on unique research questions regarding interactions between *Plantago* and the local environment. The new lab sequence effectively met course learning objectives in experimental design, field methods, statistics, and science communication, while being accessible to both in-person and online learners. We conclude by discussing the evolution of this design for other audiences.

Introduction

Course-based undergraduate research experiences (CUREs) promote early and expanded student engagement in scientific research that improves science literacy, analytical skills, and inclusivity within STEM majors (e.g., Bangera & Brownell, 2014; Olimpo et al., 2018). Incorporating academic research interests and novel pedagogies benefits both student and faculty development (Shortlidge et al., 2016). However, the transition to online education during the COVID-19 pandemic posed many challenges to the implementation of such lab experiences (Tsang et al., 2021).

Institutions adopted myriad strategies for course delivery early in the pandemic, including distanced labs, hybrid formats, and asynchronous learning. Purely online simulations or recordings of experiments did not maintain student engagement and led to a superficial understanding of lab methodology or purpose (Sansom, 2020). Several methods to promote active participation in remote labs were later adopted, including computer simulations and ecological field research (Abriata, 2022; Creech & Shriner 2020), although it was important to ensure equal accessibility for all students using hands-on modalities (Jawad et al., 2021; Kelley, 2020). These rapid shifts to new modalities and implementation of new technologies induced anxiety and revealed inequity among students (Tsang et al., 2021). Feelings of isolation were common, making it difficult for students to establish a routine and remain motivated from home (Feldman, 2020). The pandemic also triggered emotional stressors caused by direct illness, grief, financial instability, and loneliness and led to physical and mental health issues including disordered eating and depression (Flaudias et al., 2020; Mushquash & Grassia, 2020). Within a semester of teaching during COVID-19, it became clear that pedagogical modalities should acknowledge and accommodate evolving student needs.

Independent field experiences using cosmopolitan organisms are one option to combat accessibility and equity issues associated with remote learning. Organisms that are easy to find and identify can be used by students to crowd-source data collection, address ecological research questions, and connect to their local community (Penczykowski & Sieg, 2021). Having students or community members assist in the collection of observational data can generate robust datasets while promoting bioliteracy and data management skills in participants (Hitchcock et al., 2021; Jones et al., 2021; Putman et al., 2021). Hands-on exposure also tackles "plant awareness disparity" and "biodiversity naivety" problems (Niemiller et al., 2021; Parsley, 2020; Wandersee & Schussler, 1999), whereby students fail to recognize the identities or functions of floral and faunal community members (Schuttler et al., 2018; Soga & Gaston, 2016). Engaging in field work may also lead to greater student retention or interest in ecological careers.

In approaching our first hybrid academic year (2020-2021), we recognized that traditional labs would be rendered non-functional due to social distancing procedures, safety concerns, and unpredictable attendance. Many labs were reconfigured or condensed to accommodate these challenges, but we wanted to maintain a field experience despite the challenges with hybrid instruction. We elected to build a new experience based on an accessible plant genus (*Plantago* spp.) that could be observed by both in-person and remote students while promoting skills in experimental design, data management, statistics, and science communication. In this report, we outline the pilot project and preliminary outcomes, discuss its limitations within our changing institutional curriculum, and describe how the fundamentals of this project have led to "second-generation" projects for other audiences on campus.

Methodology

The Institution and Course

Truman State University is a rural public liberal arts university of under 4,000 undergraduate students located in Kirksville, MO. During this study (2020), Truman State had a 72% acceptance rate, the gender identity at Truman was 40:60 identifying male:female, and approximately 80% were white, in-state, and received financial aid. Truman has a long-standing reputation in the Midwest as an affordable, quality public college option. As at many universities across the United States, enrollment has been steadily declining at Truman; undergraduate enrollment is down approximately 35% in the past five years. Biology is a consistently popular major that accounts for 12% of incoming freshmen, but enrollment has declined more than 50% since 2017. Recently, the Biology department implemented a new curriculum for the major. Biology majors who started before fall 2019 were required to take Introduction to Ecology (BIOL 301);

TABLE 1. General Comparison of Course Delivery Components During Fall 2019 (In-Person)

FALL 2019 (PRE-COVID)	FALL 2020 (COVID)
No weekly quizzes	**Weekly reading quizzes posted on learning management software**
No discussion boards	**Weekly discussion boards alternating between course concepts and student wellness / metacognition**
Lectures delivered in person	**Weekly asynchronous, recorded lectures**
Sporadic case studies and active learning during lecture	**Weekly synchronous "in-Zoom" case studies and activities**
Three physical problem sets (individual, smaller point value)	**Two online problem sets (completed in pairs, larger point value)**
In-person exams (1 hr 20 min)	**Online exams accessed on learning management software (2-hr timer)**
Sporadic email contact as needed to update students	**Consistently formatted weekly updates depicting upcoming tasks and deadlines**
EcoPhoto (local): Student blogs of ecological observations on campus	**EcoPhoto (community): sharing and commenting on blogs with peers at three different institutions (UT, MO, NY)**
Field experiences to quantify stream biodiversity or human demography	**Analysis of pre-collected data on these topics to accommodate distancing**
Written grant proposal and analysis of national water quality datasets	**No change from fall 2019**
Multiple disjointed single week lab activities	***Plantago* survey CURE**

after the curriculum change, BIOL 301 was one of four organismal biology course options. With many Truman students pursuing careers in medicine or healthcare, microbiology has proven more popular than ecology or the other two organismal courses (evolutionary biology and eukaryotic diversity). Since the new curriculum has been implemented, student demand for ecology has steadily decreased from six 24-seat sections per year in 2017 to a single section in 2022.

Course Structure Amidst the Pandemic

At the onset of the COVID-19 pandemic, Truman transitioned to a fully remote modality to conclude the spring 2020 semester. During the 2020–2021 academic year, faculty could select from several delivery options, including fully asynchronous, online, or hybrid instruction. Four hybrid sections of BIOL 301 were offered during fall 2020, with two asynchronous recorded lectures and one synchronous Zoom activity per week. Lab sections were split into three groups (two in-person sections, one virtual) that each met for 50 minutes of the nearly three-hour period to accommodate social distancing. Excluding the new *Plantago* project, labs were modified from established protocols used in previous semesters.

Course instructors (Drew Sieg and Joanna Hubbard, hereafter RDS and JKH) collaborated extensively to develop materials for this model; they restructured the learning management system, co-developed asynchronous recorded lectures and lecture activities, and held weekly meetings to discuss how the hybrid course was supporting student success and wellness. A full comparison of course changes to accommodate a hybrid delivery are listed in Table 1. Pre- and post-surveys evaluating student skills in science communication, statistics, and graphical interpretation were issued, but IRB approval was not established until after implementation of this project. Thus, evaluative feedback on this study is limited to voluntary course evaluations administered for all Truman courses and reflects the pedagogy of the course as a whole, rather than just the new lab experience. As both instructors taught sections in 2019 and 2020, comparisons between years were made to evaluate changes in student perceptions due to both COVID-19 and the intervention.

Experimental Study System

In pre-COVID semesters, BIOL 301 students would survey water quality and macroinvertebrate diversity from local streams to acquire field experience (modified from Doherty et al., 2011). Sampling sites were located up to 30 minutes from campus, which required university transportation and longer lab periods, neither of which were feasible using a hybrid model. For the new field experience, we expanded on a survey protocol for *Plantago lanceolata* and *P. rugelii* used by Rachel Penczykowski (RMP) to train students in the Tyson Undergraduate Fellows program at Washington University in St. Louis. *Plantago* are short-lived perennials commonly found in human-disturbed habitats, including lawns, parks, paths, and pastures. The geographic distributions of these species span gradients in latitude, elevation, urbanization, and other environmental factors. They are easy to find and identify, are regionally abundant, of low conservation concern, and extremely accessible (Penczykowski & Sieg, 2021). They are suitable for addressing research questions at the population or community level, due to their distinct phenological stages and easily recognizable evidence of interactions with both herbivores and fungal pathogens (Penczykowski & Sieg, 2021).

Project Outline

Three labs interspersed throughout the semester were developed to encompass the *Plantago* field experience. In addition to the instructional goal of providing an effective hybrid learning experience, student outcomes from the experience included the ability to

- quantify the abundance and status of local plants to combat plant awareness disparity,
- develop novel research questions regarding local variation in *Plantago* dynamics, and
- analyze data, address challenges with crowd-sourcing data, and practice visual science communication.

Activities and assessments for each lab session are summarized below and in Table 2.

Lab 1: Introducing the Study System and Tackling Plant Awareness Disparity

The first lab established the utility of *Plantago* as a model organism for ecological research. Students watched a 13-minute recorded video by RMP discussing how the species can be used to address questions at multiple spatial scales across varying environment types. Connections to climate change and urban development were stressed, along with the use of cosmopolitan *Plantago* species in

TABLE 2. Activity Summary for *Plantago* Survey CURE

Lab	Learning Objective	In-Lab Activity	Assessments
1	Outline utility of *Plantago* to address ecological interactions	Introductory video about *Plantago* study system	Upload photo of focal species from local environment
1	Differentiate between plants exposed to ecological threats	Training on species ID, phenology, infection, herbivory	Worksheet with sample images to confirm ability to ID species characteristics
2	Explain best practices in data management	Discussion on data management in Excel	Critique example datasets to develop rules for management
2	Conduct an ecological field survey	Training on survey protocol	Independently conduct *Plantago* surveys
2	ID mechanisms to manage crowd-sourced datasets	Build consensus on data management strategy	Upload survey data to learning management software
3	Generate a novel ecological question	Group discussions to develop research questions	Outline null and alternative hypotheses and justify research question
3	Conduct statistical analyses on crowd-sourced data	Training in statistical analysis methods	Upload formatted dataset containing analyzed data
3	Communicate scientific findings in visual formats	Discussions on effective use of design in science communication	Create graphical abstract and post to Padlet; post feedback on peer abstracts

global collaborations including PlantPopNet and HerbVar. This video also emphasized the value of community science engagement and collaborative research across universities.

Following the video, students were trained to identify focal species, their flowering status, types of herbivory damage, and evidence of infection by a fungal pathogen (powdery mildew). These skills were practiced as a group for in-person students, followed by an individual homework assignment. Remote students participated in the training, but practiced individually. Example images were provided via PowerPoint, so that students could participate in synchronous group work in person or via Zoom. Groups also brainstormed research questions and hypotheses, generally focusing on variation in herbivory or infection between species or survey locations.

TABLE 3. Parameters Reported to Course-Wide Dataset for Each Surveyed Plant (N=60 Plants per Student)

Parameter Measured	Options
Date	Mid-September 2020
Latitude / longitude	Determined via Google Maps or equivalent
Location type	Campus, yard, road, sidewalk, farm, state park, city park, other
Location image	Google Earth screenshot at 50-ft altitude
Species	*P. lanceolata, P. rugelii*
Light status	Sun, shade
Flowering phenology	None, budding, flowering, seeds immature, seeds mature, seeds dispersed
Evidence of powdery mildew infection	Yes, no
Evidence / type of herbivory	None, chewing, leaf mining, multiple
Evidence of mowing damage	Yes, *no*
# of conspecifics in 1.5-m radius	0, 1-10, 11-50, 51-100, 100+
# of infected conspecifics in 1.5-m radius	0, 1-10, 11-50, 51-100, 100+

Lab 2: Field Surveys

After completing a series of guided online tutorials and discussing a paper on common issues in data management (Broman & Woo, 2018), each student independently conducted a field survey of *P. lanceolata and P. rugelii* using a modified line transect protocol. Students identified a local site containing both *Plantago* species, noted environmental conditions, and then recorded observations regarding flowering phenology, neighbor density, and evidence of community interactions for a single *Plantago* individual (summarized in Table 3). Students advanced 2 m to another individual *Plantago* and repeated the process a total of 30 times for each focal species.

Students could complete surveys at any accessible site in their vicinity on their own schedule within a one-week window. Most surveys were conducted in parks or neighborhoods in Kirksville, but remote students provided data from across Missouri. Students recorded data on a data collection sheet provided by the instructor, entered handwritten data into a spreadsheet, and uploaded the file as a homework assignment. A teaching assistant compiled each unedited dataset into a master "crowd-sourced" spreadsheet for use in lab 3.

Lab 3: Experimental Design, Analysis, and Reporting

For the final lab activity, students accessed the master spreadsheet and worked in teams either in person or via Zoom to analyze their research questions. Tutorials on statistics were provided, and each group framed questions as testable hypotheses with their instructor prior to analysis. Groups worked over two weeks to organize their data set, conduct analyses, and synthesize their findings into a graphical abstract. A major component of this assignment was recognizing the amount of time and effort associated with organizing large datasets.

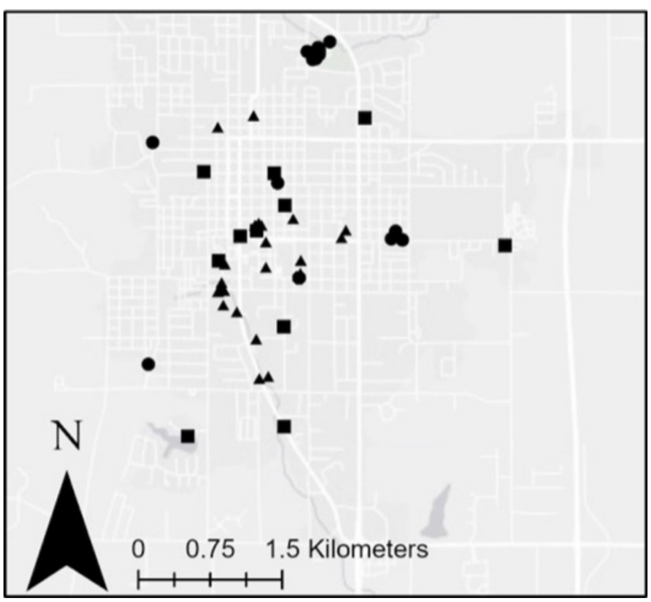
Graphical abstracts were a novel concept for most students. Therefore, the class initially evaluated examples from scientific journals and discussed their use in comparison to written abstracts. Instructors then provided a tutorial on building graphical abstracts in PowerPoint. Student products were posted to Padlet (padlet.com), which allowed students to asynchronously provide and receive feedback on their research questions, analyses, and abstract designs. In practice, most products took on a form resembling a research poster, probably because students had greater familiarity with that medium and a fear of leaving information out.

Results and Discussion

Novel Research Outcomes from the Lab Activity

Via this lab activity, 3360 plants were surveyed by 55 students, primarily in Kirksville. A map displaying *Plantago* distributions in the city was generated from these data (Figure 1), which has subsequently been used by independent research students to conduct follow-up studies on *Plantago* community dynamics. Survey locations were clustered around Truman State, as it is primarily a residential campus. The majority of student-generated questions and hypotheses focused on comparisons of herbivory and/or fungal infection across plant species, sunny vs. shaded microhabitats, or location types (e.g., roadsides vs. parks). Primary findings included a significantly higher likelihood of infection on *P. rugelii* than *P. lanceolata*, particularly in shaded habitats, while infection frequency was not affected by mowing or herbivory.

FIGURE 1. Transect Sites Within Kirksville, MO City Limits



Note: Circles represent parks, squares represent roadsides, and triangles represent yards. Each icon represents 60 plants surveyed.

Undergraduate research students (Madison Williard and Zachary Dwyer) working with RDS independently evaluated the dataset and confirmed these patterns, presenting their research at Truman State's Student Research Conference (Dwyer et al., 2021).

Due to restrictions on social gatherings, students in the course did not disseminate their findings in the broader Kirksville community. However, this pilot study demonstrated that data collection within the *Plantago* system is tractable for novices. Elements of this project have been incorporated into submitted research proposals that incorporate community science, public outreach, and civic engagement as broader impact objectives (RDS & RMP, personal communication).

Student Responses to the Course

Beyond the *Plantago* project, other activities were implemented to promote an active classroom amidst a hybrid redesign. These included weekly interactive case studies using Zoom and Google Docs, a semester-long "EcoPhoto" project on Flickr to document local ecological interactions, discussion board prompts that pushed students to reflect on their wellness or creatively discuss course concepts (such as a knockoff of "Dear Abby" called "Dear Ecology"), a month-long lab that used EPA datasets to estimate water quality in wadable streams (modified from Nuding & Hampton, 2012), and team-based problem sets instead of virtually proctored traditional exams. We communicated with students through consistently formatted weekly announcements on our course management software and email, aiming to keep students on track without bombarding them with disparate notices. Collectively, these activities made our redesign distinct from previous versions of BIOL 301, but also from other hybrid courses at Truman.

Evaluative Likert-scale data and representative free responses reported in Table 4 pertain to the fall 2020 hybrid course redesign, including the *Plantago* CURE. While some outcomes are likely driven by the *Plantago* experience, we acknowledge that other elements of our redesign influenced student perceptions of the course. Total responses to the course survey (n=48) represent approximately 85% of the class. Since submissions were anonymous, we cannot directly compare different demographic responses to the redesign, but we can assume that the makeup of students roughly matches that of Truman State as described in the methodology section.

Students valued the applicability of the course, with more than 97% of respondents agreeing that the course related concepts to real-world issues or everyday life (Table 4). Informally, students noted that they found themselves spotting *Plantago* between classes, and felt a sense of pride that they could better identify the plants around them. Extended engagement and sense of familiarity with focal plants is a key component to combat plant awareness disparity (Krosnick et al., 2018; Niemiller et al., 2021); thus this new lab experience appears to have promoted greater bioliteracy and plant awareness.

The general organization, approach, and transparency regarding expectations in BIOL 301 was viewed by students as exemplary in comparison to other courses that transitioned to hybrid instruction (Table 4). Whether the new approach led to long-term positive feelings about ecology is less clear, as 29% of respondents indicated that they would not want to take additional ecology courses (Table 4). This may be a product of the hybrid design: students viewed asynchronous assignments (quizzes, readings, discussion boards) as busy work. Hybrid courses require a distinct mindset from both the instructor and the student in order to be effective (Shea et al., 2015), and most of our students took hybrid courses out of necessity rather than desire. Animosity towards materials used to maintain asynchronous engagement makes sense considering the rapid transition to online modalities. However, lessons learned from similar experiences are leading to new evaluations of best practices in hybrid or online instruction in a post-COVID era (e.g., Singh et al., 2021).

Using course evaluations, we also statistically compared student responses to these questions in fall 2019 (the pre-pandemic version of the Plantago project) and fall 2020 (during the pandemic, with the hybrid changes

TABLE 4. Introduction to Ecology Course Evaluation Data (N=48 Respondents).

Survey Question	Disagree	Agree	Strongly Agree	Representative Free Responses
I can relate topics in this class to my everyday life.	1	27	20	I [am] more conscious of my environment and surroundings. I never thought of ecology as something that is always around me. I look at what happens around me differently now.
The instructor demonstrated the relevance of course material to real-world issues.	0	14	34	I learned a lot about animal and plant interactions … and the environment in general, which has already been useful when talking to my friends about environmental issues. I feel that I have a more in-depth, new perspective when it comes to evaluating biological interactions. I have a better appreciation for how wide the field of Biology is.
This course challenged students intellectually.	4	31	13	I liked that reading scientific literature and statistics were consistently reinforced. Those skills are valuable. I relearned a lot of statistics which I found incredibly helpful. I really did not know anything about Ecology outside of food webs, so I came out of this course having learnt a lot.
Reasonable changes to instruction and assignments were made [for hybrid instruction in the pandemic].	2	15	26	The instructor was able to understand … COVID restrictions and make appropriate adjustments. The class was delivered as well as it could be virtually. Expectations were clearly organized. Organization and communication were the best of any [course] I've taken by a mile. It was so helpful.
As a result of this class, I would be interested in taking more courses in the subject.	14	18	15	Sometimes assignments did not seem beneficial and took up a lot of time that I didn't have. There were assignments that felt like busy work … to keep students engaged [in] distance learning but did not contribute to my learning.

Note: The options "disagree" and "strongly disagree" have been collapsed into a single column due to small reported numbers in these categories.

described in this study; Table 5). However, there are extrinsic factors that should be accounted for, such as general stress and COVID fatigue, which make direct comparisons between these two student populations tenuous.

For three of four questions, no significant difference between semesters was seen (Table 5), suggesting that students perceived equal course rigor and relevance with the traditional in-person delivery and hybrid instruction. It is encouraging that objectives related to real-world application of ecology were maintained in the hybrid delivery, despite the new format and disruptions to instruction during the pandemic. We also take this to mean that the course structure and activities were seen as equivalent to a non-disrupted semester by upper division students who had taken college courses both before and during the pandemic.

In contrast, there was a significant increase in student willingness to take other courses in ecology (Table 5, p=0.020). The new lab module, coupled with accommodations made for hybrid instruction, may have made ecology a more tangible sub-discipline for students relative to the traditional mechanism of instruction. As a result, several of the activities used to improve the use of learning management software, communicate with students, and check in on student wellness have been continued by RDS and JKH in other courses, and have been formally presented to other university faculty.

TABLE 5. Student Perceptions of the Course Before (2019) and During (2020) the COVID-19 Pandemic

Survey Question	Fall 2019 (Pre-COVID) n=89-90	Fall 2020 (During COVID) n=48	P-value
I can relate topics in this class to my everyday life.	3.29 +/- 0.59	3.40 +/- 0.54	0.31
The instructor demonstrated the relevance of course material to real-world issues.	3.72 +/- 0.45	3.71 +/- 0.46	0.90
This course challenged students intellectually.	3.26 +/- 0.64	3.15 +/- 0.68	0.33
As a result of this class, I would be interested in taking more courses in the subject.	2.59 +/- 0.93	2.98 +/- 0.91	0.02

Note: Averages based on 4-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree). Comparisons between years conducted via 2-tailed t-test; error represents +/- one standard deviation.

Current and Future Status of the Project

Despite the effort to restructure BIOL 301 as a hybrid course, reduced student enrollment, curricular changes, and interest in the topic remains low, such that the department now offers only a single, in-person section per year. That section is not scheduled to be taught by RDS or JKH in the near future, and thus many changes are not trackable beyond the pilot implementation. The *Plantago* field experiment continues to be offered by the current BIOL 301 instructor, but a lower number of participants reduces the crowd-sourcing project elements. Since our pilot delivery, the project has been conducted two more times, with minimal changes to the established protocol. The instructor has considered widening the project to tackle other core skills in ecology related to estimating other population dynamics.

We had previously used social media (e.g., Flickr) in observational ecology projects to connect our students with peers enrolled in similar courses across the country (RDS and JKH, personal communication) and intended to build out a similar network with this project that would allow students to compare *Plantago* demographics across wider urban-rural, latitudinal, climatic, or temporal gradients. While we encourage interested parties to reach out if the modules would fit their course needs, the restructuring of BIOL 301 has limited our ability to further develop broader community engagement aspects of this project.

We recognized the benefit of using open-ended projects to promote observational and data management skills in students majoring in biology at

Truman, and we have since modified the *Plantago* project for an introductory biology course (BIOL 104) that RDS and JKH regularly teach. Introductory courses are a wise target for open-ended inquiry, as it introduces bioliteracy, statistics, and communication skills needed to succeed academically and in STEM-related careers. Early exposure to authentic research eliminates "cookie-cutter" experiences that do not accurately reflect the challenges associated with research (Wood, 2009), providing students with a better representation of the scientific process.

In the new introductory biology module, students mine iNaturalist (inaturalist.org) to quantify global images of infection or herbivory on *Plantago* and address questions that are thematically similar to those emphasized in BIOL 301. The pilot implementation of this version of the project occurred in spring 2022, resulting in 13,700 images processed by 105 students (RDS, personal communication). This new initiative has the potential to be expanded both at Truman and in the wider community and has been a core component of new grant proposals written by RDS and RMP. We intend to build this database annually and embrace iNaturalist as a tool for community science, while tracking student perceptions of effective science communication and assessing challenges associated with community-sourced data (e.g., Dickinson et al., 2010). Ultimately, this introductory version of the *Plantago* project is likely to be a more impactful initiative than the original pilot project outlined in this manuscript.

Conclusions

The transition to online learning due to the COVID-19 pandemic was difficult for students and faculty alike, and we are now assessing which instructional approaches are most effective. The adjustments we made to maintain an accessible and rigorous field experience were largely successful within a hybrid undergraduate course. The pilot implementation of this project has evolved into a more robust project that targets new biology majors.

About the Authors

Drew Sieg is an assistant professor of biology at Truman State University. He is a SENCER Leadership Fellow whose traditional research examines chemically mediated ecological interactions among plants, fungi, algae, and herbivores. He is also involved in educational research, particularly examining how authentic research experiences and other novel pedagogies affect student engagement in STEM.

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