

ARTICLE

Eco-Education

Going remote: Recommendations for normalizing virtual internships

Amy M. Hruska  | Alison Cawood  | Katrina M. Pagenkopp Lohan  |
Matthew B. Ogburn  | Kimberly J. Komatsu 

Smithsonian Environmental Research
Center, Edgewater, Maryland, USA

Correspondence

Amy M. Hruska

Email: hruskaa@si.edu

Funding information

Bryn Mawr College; Chesapeake Student
Recruitment, Early Advisement, and
Mentoring (C-StREAM); National Science
Foundation, Research Experience for
Undergraduates, Grant/Award Numbers:
NSF REU DBI 1659668, NSF REU DBI
1950656, NSF REU DBI 2031880;
University of Chicago; Wabash College

Handling Editor: Jenny Dauer

Abstract

Research internships provide students with invaluable experience conducting independent research, contributing to larger research programs, and embedding in a professional scientific setting. These experiences increase student persistence in ecology and other science, technology, engineering, and mathematics (STEM) fields and promote the inclusion of students who lack opportunities at their home institutions and/or are from groups that are underrepresented in STEM. While many ecology internship programs were canceled during the 2020 COVID-19 pandemic, others successfully adapted to offer virtual internships for the first time. Though different from what many researchers and students envision when they think of internships, virtual ecology internship programs can create more accessible opportunities and be just as valuable as in-person opportunities when research programs and advisors develop virtual internships with intention and planning. Here, we highlight six ways to structure a virtual intern project, spanning a spectrum from purely computer-based opportunities (e.g., digital data gathering, data analysis, or synthesis) to fully hands-on research (e.g., sample processing or home-based experiments). We illustrate examples of these virtual projects through a case study of the Smithsonian Environmental Research Center's 2020 Virtual Internship Program. Next, we provide 10 recommendations for effectively developing a virtual internship program. Finally, we end with ways that virtual internships can avoid the limitations of in-person internships, as well as possible solutions to perceived pitfalls of virtual internships. While virtual internships became a necessity in 2020 due to COVID-19, the development and continuation of virtual internships in future can be a valuable tool to add to the suite of existing internship opportunities, possibly further promoting diversity, equity, and inclusion in ecology and STEM.

KEYWORDS

diversity, equity, inclusivity, and accessibility, research internships, science, technology, engineering, and mathematics, undergraduate research experiences, undergraduate training, underrepresented minorities, virtual learning

This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

© 2022 The Authors. *Ecosphere* published by Wiley Periodicals LLC on behalf of The Ecological Society of America. This article has been contributed to by US Government employees and their work is in the public domain in the USA.

BACKGROUND

Research internships—opportunities to conduct independent research within a larger research program—provide students the opportunity to build upon foundational knowledge learned in the classroom. In ecology, research internships primarily take place in-person, with students traveling to universities, research institutes, and field stations for the experience. These opportunities are one of the primary ways high school and undergraduate students and recent graduates gain experience working with a research team and conducting independent research prior to starting graduate school or entering the workforce.

The goals of typical internships are for students to gain experience with the scientific process and acquire important technical, networking, and values-based (e.g., confidence, teamwork, and independent learning) skills for their career. Research interns often develop independent projects related to a laboratory's ongoing research program, conduct laboratory- and/or field-based experiments or surveys, and engage with a community of scientists and staff at their host institution. However, internships are variable in funding, timing, and training. Depending on funding, interns may be hosted by a specific research laboratory or as part of a larger internship program run at the department or institution level. Additionally, an intern's direct advisor may be a laboratory's principal investigator or another member, such as a laboratory manager, technician, graduate student, or postdoc.

Internships are critical for promoting diversity, equity, and inclusion in ecology. Internship experience increases student retention, particularly for first-generation college students and groups that have been traditionally underrepresented in science, technology, engineering, and mathematics (STEM) fields (Graham et al., 2013; Grineski et al., 2018; Hernandez et al., 2018; Pender et al., 2010). After completing internships, students report growth in skills critical to conducting and communicating research, as well as developing clear career goals (Lopatto, 2007). Students from underrepresented groups report higher learning gains from undergraduate research experiences compared to peers (Pender et al., 2010). Many also develop relationships with a peer group that provides support as members of the group advance in their careers. As a result, research internship programs are commonly encouraged to prioritize students without access to research experiences at their current universities and/or from underrepresented groups. For example, the National Science Foundation's Research Experience for Undergraduates (NSF REU) program is one of the longest running federal programs for undergraduate internships in the United States and an

important source of funding for many institutions, with more than \$270 million in funding from 2014 to 2020 (NSF, 2020a, 2020b). NSF REU goals include "increasing the numbers of women, underrepresented minorities, and persons with disabilities in research", as well as "veterans of the US Armed Services and first-generation college students" (NSF REU solicitation).

During 2020, many research internships were dramatically impacted due to the COVID-19 pandemic. In the United States, extended quarantines began in the spring—a critical time for summer position decisions. This resulted in the cancelation of many internship programs, substantially reducing the number and type of opportunities offered for students. For instance, the number of sites that hosted NSF REU students in biology was reduced to a fifth of typical years, from 124 sites in 2019 to 25 sites in 2020 (NSF BIO-REU program report). The few internship programs that did run, both within and outside of NSF REU, adapted to accommodate institutional, state, and federal public health recommendations by offering an unprecedented number of virtual opportunities, many of which had never been virtual before (Scott Price et al., 2020).

Before COVID-19, virtual internships, particularly in ecology, were uncommon. Indeed, NSF REU experiences in biology were required to occur in-person prior to 2020. However, there is growing support that postsecondary online learning and mentoring opportunities do not yield differential learning gains and provide more accessible opportunities (Armstrong et al., 2020; Faulconer et al., 2019; Jeske & Linehan, 2020; Jose et al., 2019; Pei & Wu, 2019; Scanlon et al., 2015). Compared to STEM fields, virtual internship opportunities in business enterprises have been increasing globally. Psychological and social research support that virtual opportunities can be as valuable as in-person opportunities and provide interdisciplinary recommendations for implementing virtual internships (Jeske, 2019; Jeske & Linehan, 2020).

The success of virtual opportunities in 2020 highlights the viability of these novel internship formats, which could increase the accessibility of science. Offering virtual or hybrid internships—opportunities that combine virtual internships with some in-person experiences—could increase the participation of underrepresented groups and nontraditional students who, even during non-pandemic years, cannot travel to participate in-person. For example, nontraditional students with family obligations that require their physical presence could work from home and develop a flexible schedule that meets their needs. Virtual internships could also benefit students with health conditions that require regular medical consultation (e.g., ongoing therapies and scheduled procedures) that would limit the time a student could spend away from

BOX 1 Moving virtual—Smithsonian Environmental Research Center as a case study

Since 1971, the Smithsonian Environmental Research Center (SERC) has had an active internship program focusing on global change ecology, including student projects on topics including climate change, biological invasions, ecosystem restoration, and sustainable management practices. Recently, SERC has hosted 30–40 interns per year, with most internships occurring over the summer. All SERC interns receive stipends, with funds coming from NSF BIO-REU grants (since 2001), university partnerships, grants to individual SERC researchers, and donations. In line with the goals of the BIO-REU program, our summer intern recruitment focuses on students from groups that have been historically underrepresented in STEM (defined by the BIO-REU program as women, Black, Latinx, American Indians, Alaska Natives, Native Hawaiians and other Pacific Islanders, veterans, and students with disabilities), as well as students who have limited research opportunities at their home institutions, such as community college students. Typically, interns live in on-site housing on SERC's 10.72 km² research campus located on the Chesapeake Bay. Nearly all intern projects include field work on SERC's campus, which includes forest, wetland, and estuarine habitats, as well as greenhouse, common garden, and wet laboratory research facilities.

In summer 2020, the commitment of SERC's staff scientists to provide opportunities for students, especially those who have had less access to those opportunities, provided strong incentive to shift the program from in-person to virtual internships. Originally, all planned projects required extensive field and/or laboratory components. However, mentors were able to either adapt the original project idea to focus on existing data or developed new projects that fit within the scope of both the laboratory's and intern's interests, and that could be conducted remotely. This was particularly important for laboratories that had already completed intern application review and made offers to students. Some of the advisors were initially hesitant about the idea of virtual internships. However, as internships progressed, mentors reported that they were able to provide valuable learning experiences for interns, even if those were very different experiences and required the interns to learn different skills than had been initially planned.

SERC hosted 27 interns (two master's students, 19 undergraduates, and six high school students) during summer 2020. Similar to previous years, all SERC interns completed independent research projects that they developed with the support of a research mentor over the course of their 10- to 12-week internship. To ensure virtual accessibility, we offered to provide access to any technology that the students would need to complete their internships (e.g., computer and Internet access), but in this case, all students were able to provide their own. All SERC interns are provided with Smithsonian network accounts, which allowed them access to virtual meeting and communication tools, cloud storage, a broad array of data analysis software, and internal Smithsonian networks that house data and images. While these network accounts and resources are available to interns in all years, they were particularly vital for virtual internships. These platforms allowed interns and mentors to have video conferences and online messaging, share resources, co-edit documents, and for students to interact with one another.

In 2020, most of our intern projects were based on the analysis of existing data from SERC projects, or gathering and analysis of publicly available digital data (Table 1). However, there were several cases where interns were engaged in new data collection (Table 1). One group of interns and their advisors designed and conducted an experiment related to plant growth and nutrient uptake by growing potted plants in their yards. In this case, all students were in the Washington, DC region, and the mentor was able to safely deliver plants and supplies to the three participating interns' homes. In another case, two students worked with high school teacher externs to determine the feasibility of crowd-sourcing the measurement of crab images through the Zooniverse citizen science platform. The teachers measured the physical preserved crab specimens, and the interns processed images of the crabs to determine the best axes to measure to reduce digital measurement error. In a third case, the advisor shipped plant samples and equipment to the intern's home, where the intern was able to sort, weigh, and classify samples for future DNA extraction.

In addition to conducting independent research projects, SERC interns participate in a series of mini-courses to develop skills that are valuable across a range of STEM professions. These courses cover a wide variety of topics, including science communication, research ethics, diversity and inclusion in STEM, introduction to programming in R, and STEM career exploration. In 2020, we were able to conduct all mini-courses virtually. Virtual mini-courses had a few advantages, including easier scheduling and the ability to bring in presenters from across the country (including a panel of former SERC interns). At the end of their internships, each SERC

intern gave a formal research presentation about their project and created a short (3-min) video for a public audience. Presentations and video premieres occurred through a virtual meeting platform, which provided the additional benefit that family members, friends, and professors from their home institutions were able to view the presentations, in addition to the SERC staff.

Through exit interviews, SERC's 2020 interns reported feeling a high degree of ownership over their projects and appreciated the amount of independence they had in developing and implementing their research. Interns also reported feeling well supported and mentored overall by their advisors and that they were integrated into their laboratory groups. Advisors reported high levels of satisfaction with the experience, and many enjoyed the opportunity to teach parts of the research process that they tend to spend less time on during in-person internships (e.g., programming, data management and analysis, writing). Because the projects were all virtual and no relocation costs were accrued, we were able to extend the appointments of five interns into the fall, allowing the funding for them to continue working on their projects part-time, including preparing manuscripts for publication. Based on summer 2020, SERC plans to continue to offer virtual and hybrid internships when possible and appropriate to accommodate the needs and goals of students and advisors.

home by allowing them to work virtually for part of an internship (Maestre, 2019; Nash, 2021). Shifting to a virtual internship may be a successful strategy when an intern cannot complete an ongoing internship in-person due to an emergency or other outstanding circumstance (Jose et al., 2019). While virtual internships certainly cannot and should not entirely replace in-person experiences, and challenges remain in ensuring access to computers and other resources needed to participate in virtual internships, regularly offering virtual experiences as part of existing programs could promote diversity and inclusivity in science and expose students from all backgrounds to additional parts of the research processes (e.g., Jose et al., 2019; Nocco et al., 2021; Scanlon et al., 2015).

The five authors of this paper hosted virtual interns for the first time during summer 2020 with the Smithsonian Environmental Research Center (SERC) (Box 1). Although these opportunities arose due to a global pandemic, our experiences highlight that virtual internships are not only possible, but that offering virtual or hybrid internships in future could increase the accessibility of STEM training for all students. Reflecting on the success of our collective experiences, we present an in-depth look at six types of virtual internship projects, provide our top 10 recommendations for conducting virtual internships, and provide possible solutions for some commonly perceived pitfalls and limitations to internships. Our hope is that internship programs and funding organizations will create more flexible policies to continue virtual and hybrid opportunities in future.

TYPES OF VIRTUAL INTERNSHIPS

In large part, internships are structured to expose students to the scientific process and to give them

experience conducting independent research; however, it is rare that an intern gets in-depth practice with each step of the scientific process during a single internship. In ecology, these experiences often focus on gaining practice with technical field- and laboratory-based techniques. While these experiences are worthwhile, virtual internships highlight other worthwhile project types previously underrepresented across internships. While it can be difficult to conceive of how typical intern projects can be moved to a virtual setting, there are opportunities throughout the scientific process to complete remote tasks (Figure 1). Thus, it is possible for advisors to work with interns to develop research questions that can be answered remotely and engage interns in every stage of the scientific process, even if they never come to the host institution in person. Based on our collective experiences, we identified six types of projects that can occur within a virtual internship and span the entire range of the scientific process. Examples of five of these six types of projects are described in detail in Table 1.

At-home experiment

Advisors can work with interns to develop experiments that can be conducted either at home or at a site local to the intern. Working at a site local to the intern may only be feasible if the intern lives near an existing field site and/or collaborator. In contrast, at-home experiments may be feasible anywhere; however, indoor/outdoor space requirements and the safety of the intern and their household are critical considerations for any at-home experiment. The necessary equipment and supplies can be shipped to the intern's home during the initial phase of the internship, and any samples generated can be shipped back to the host institution for archiving if desired. Advisors should work with interns to determine

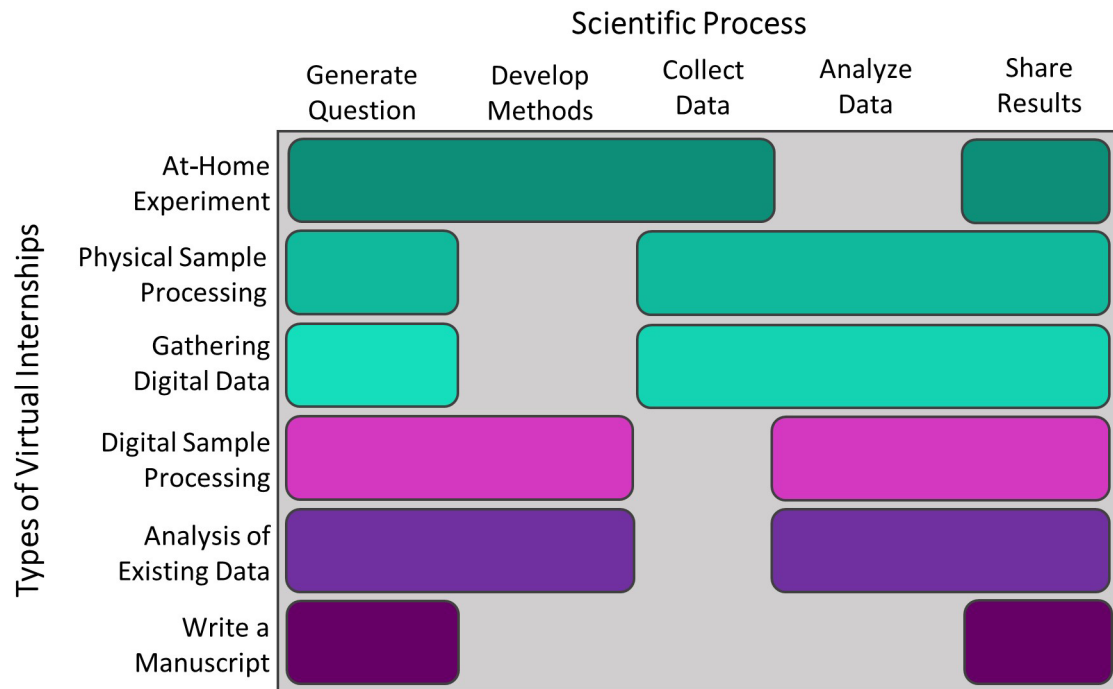


FIGURE 1 The parts of the scientific process that interns focus on within each of six different types of virtual internships. Importantly, all different types of independent projects should involve the generation of scientific questions and sharing of results

the feasibility of remote experiments prior to the beginning of the internship. At-home experiments are well suited for interns that seek to gain experience in experimental design, setup, and maintenance.

At-home physical sample processing

Advisors and interns can design research questions around previously collected samples that can be shipped to the intern's home for processing. Necessary equipment and supplies could also be shipped or loaned from institutions or collaborators near the student's home. Again, space and safety requirements must be considered in the planning phase for these types of projects. These projects would be well suited for interns that seek experience with a particular methodological technique that can be learned and performed from home, or how to process samples to create data and prepare for analysis.

Gathering digital data

Interns can create new datasets from existing information pulled either from large online databases or from other digital sources (e.g., existing surveys, online informatics, and literature reviews for quantitative meta-analyses). While these projects focus on existing digital data, they

move beyond pure data processing and analysis to include the data gathering step. These projects can be particularly valuable for students who are interested in meta-analyses, big data, and large-scale synthesis efforts.

Digital sample processing and methods development

Digital samples are becoming increasingly common in ecology, including acoustic, video, or image files from which meaningful information can be extracted. Interns can be provided access to these digital samples either through a cloud service or remote access to their host institution's network for processing. Further, interns can be tasked with developing protocols for the processing of these digital samples if one does not already exist. These projects can be well suited for interns who are interested in working with digital samples to address unique scientific questions.

Analysis of existing data

Interns can use existing datasets to develop and address research questions of interest. Tasks related to these projects can include power analyses, outlier analyses and data cleaning, and statistical analysis. These projects can

TABLE 1 An overview of the Smithsonian Environmental Research Center's (SERC's) virtual internship program, indicating the type of virtual project, the number of projects and interns, and project examples

Project type	Number of projects and interns from SERC summer 2020 program	Example projects from SERC summer 2020 program
At-home experiment	Two projects, four interns	• <i>Examining the effects of plant species diversity on the uptake of nitrogen runoff from residential yards.</i> An advisor dropped off supplies at the interns' homes, and three interns ran the same experiment, with each home serving as a replicate. • <i>Examining the impacts of algal shading on oyster restoration projects.</i> An intern and an advisor were able to deploy materials at sites near their homes, and collect data using the same experimental design in two different coastal locations.
At-home physical sample processing	Two projects, three interns	• <i>Determining the impacts of environmental change on host/parasite dynamics.</i> An advisor dropped off mud crab samples, which were measured, sexed, and checked for parasites. • <i>Analyzing the impact of nitrogen enrichment on saltmarsh ecosystems.</i> The intern was able to borrow equipment from a local university to weigh and measure plant samples that had been mailed by the advisor.
Gathering digital data	Two projects, three interns	• <i>Determining public perceptions of invasive species to develop recommendations for media coverage of invasion science.</i> Interns used Google Analytics and existing public databases to characterize how the media portrays invasive plant species and the consequences for public perceptions. • <i>Analyzing the media framing of climate change solutions in marine habitats.</i> An intern conducted key word searches and sentiment analysis on articles obtained from journalism databases.
Digital sample processing and methods development	Six projects, nine interns	• <i>Analyzing the game camera footage to assess the utility of river otters as sentinel species.</i> An intern developed methods for analyzing video and photographic images from game cameras to determine presence, abundance, and categorize behaviors of river otters. • <i>Determining the impact of drought on vessel formation in deciduous trees.</i> An intern used images of slices from tree microcores to develop a method for identifying and measuring xylem vessels.
Analysis of existing data	Eight projects, eight interns	• <i>Determining the efficacy and interoperability of coastal carbonate chemistry methods.</i> An intern used existing data about coastal carbonate chemistry measurements to compare collection methods and model the accuracy of different data collection scenarios. • <i>Tracking changes in the stock of Summer Flounder in Chesapeake Bay.</i> An intern conducted a time series analysis of summer flounder catches and relevant environmental variables.

Note: A sixth project type (writing-based internship) is not included in the table, as no interns conducted this type of project within our 2020 virtual internship program.

be valuable for interns who are interested in learning new statistical techniques or improving their data analysis and/or coding skills.

Write a manuscript

Interns can focus on writing through the development of either a perspectives piece or a literature review on a topic of interest for a peer-reviewed journal. This type of internship may be particularly useful for more advanced interns who have either previously completed an internship on a similar topic or with an in-depth understanding of the topic through coursework. These projects would be most valuable for interns later in their career seeking to improve their writing skills and understanding of the peer-reviewed process.

RECOMMENDATIONS FOR CONDUCTING VIRTUAL INTERNSHIPS

As the ability to conduct work virtually and collaborate globally becomes increasingly feasible, so does the discussion around how to effectively work virtually. Most of the discussion about virtual work in STEM fields has been focused around creating productive environments for individuals and collaborations (Frassl et al., 2018; Frater & Sullivan, 2018), with increasing attention to how to virtually mentor postdocs and early career researchers (Burgio et al., 2020; Kumar & Coe, 2017; Nash, 2021; Payne, 2018). Here, we build on Burgio et al.'s (2020) 10 recommendations for remote postdocs to develop 10 recommendations for conducting successful virtual internships (Figure 2).

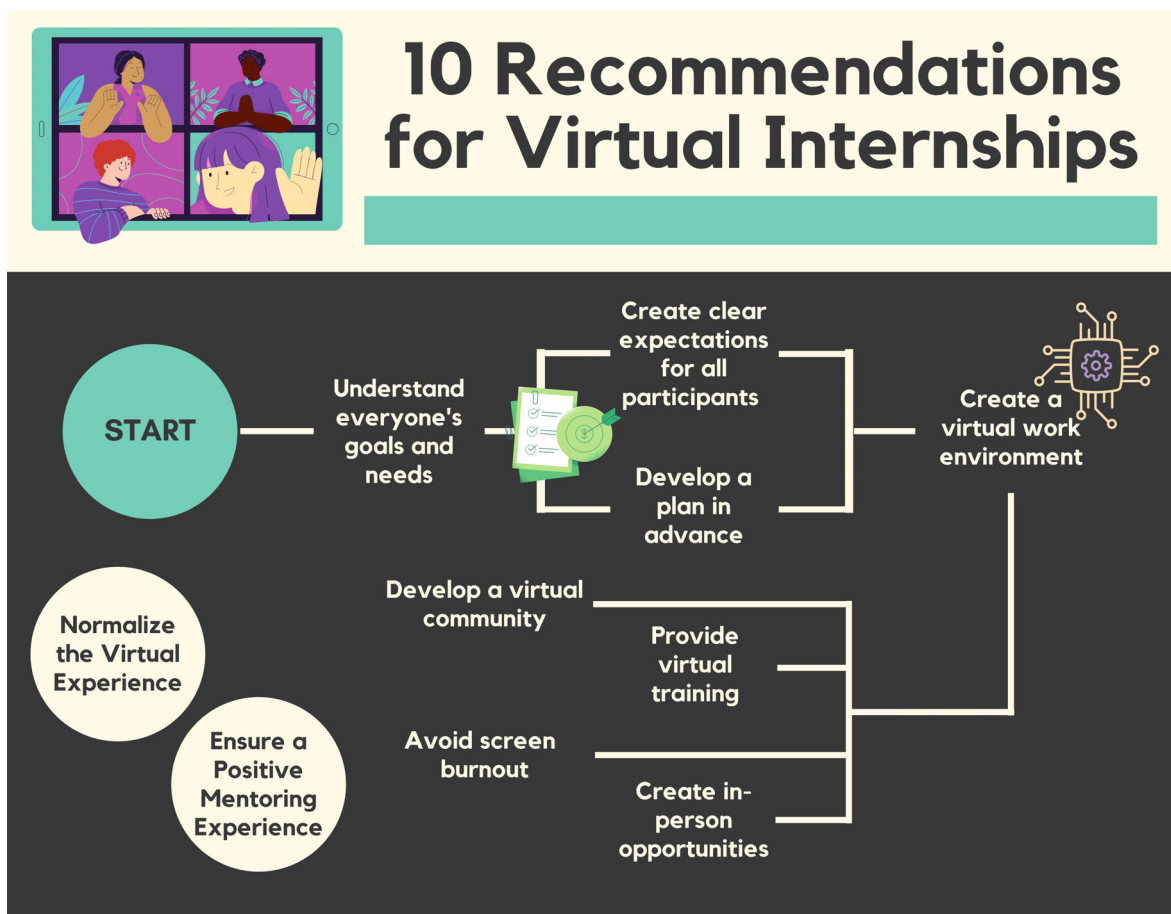


FIGURE 2 Ten recommendations for conducting a successful virtual internship program. First, the goals and needs of all participants must be identified. Second, clear expectations and a plan of action should be developed and communicated to all participants, leading to the creation of a shared virtual work environment. The virtual work environment should provide a platform for activities such as virtual community-building activities and virtual training, while allowing space for off-screen activities to avoid screen burnout and in-person opportunities when possible. All of these steps require intentional mentoring and together serve to normalize the virtual internship experience

Understand everyone's goals and needs

A critical first step in designing a successful virtual internship experience is understanding the goals and needs of the intern. This is best done through virtual discussions with the intern prior to the start of their internship, ideally occurring as part of the selection process. This involves discussing whether the intern requires or prefers a virtual internship in order to participate in the program. Importantly, advisors should also go into the experience with a firm understanding of their own needs and what kind of experience they can feasibly provide. Advisors should inventory existing research questions, projects, data, and supplies in their lab. This will highlight opportunities that pair well with intern goals, while also contributing to their larger research program. As with any internship, advisors should also consider the time commitment involved in a virtual program (particularly when the program is first being developed) and how best to incorporate this commitment given their other responsibilities. Although virtual interns are not physically present at the host institution, that does not mean that virtual internships require less time or investment on the part of advisors (DiBiase, 2000). By matching the needs of the interns with what can feasibly be offered by the advisors, a more fulfilling experience can be created for all participants. For example, laboratories that can offer supplies for conducting a backyard experiment (Box 1) would be well matched with students who seek to gain experience in experimental design, setup, and maintenance. Similarly, laboratories that can offer an existing dataset for analysis (Box 1) would be well matched with students who seek to improve their analytical skills. Finding students whose goals pair well with what the laboratory can offer will not only lead to the best virtual experience, but will also go the furthest toward advancing the student's career aspirations by training them in the technical skills they aim to develop. Once advisors and interns have discussed their goals and needs, the advisor can develop and share expectations for the virtual internship.

Create clear expectations for all participants

Having clearly defined expectations for all individuals participating in the virtual internship is imperative. These individuals include the laboratory's principal investigator(s), additional advisor(s) such as postdoctoral fellows or graduate students, and the interns. These expectations should be comprehensive. The advisor should clearly state the research expectations and

deliverables for the intern project. In addition, the advisor should be clear about the following: (1) the number of hours the intern is expected to work; (2) the frequency of formal advisor–intern check-ins (e.g., weekly); (3) the times that both the intern and advisor are available for quick consultations (e.g., working hours only or additional times outside of working hours); (4) the preferred communication platforms (e.g., virtual meeting, phone call, text, email, and chat); and (5) departmental or institutional resources available to the intern (e.g., accessibility services, conflict resolution, and reporting misconduct). The expectations should also note what the intern can expect from the advisor, such as their standard working hours and contact information. We strongly recommend that these expectations be written out clearly and concisely, and saved in a central location accessible by the intern and advisors for the duration of the internship. This is often done through an internship or professional training agreement (Zimeri, 2015). Finally, these expectations should be discussed at the very first meeting between the advisor and intern, and modified as needed to ensure the needs of both parties are met. Creating and discussing expectations at the start of the internship creates a clear path forward and provides the baseline for a positive workspace.

Develop a clear plan for virtual projects in advance

Based on the agreed upon project and expectations, advisors should develop a clear project plan prior to the start of the internship. Importantly, a schedule of project deadlines should be developed with the interns at the beginning of the internship. For example, when should an intern be expected to settle on a research question? Determined the methods they will employ? Have finished data collection and/or analysis? Will the interns be required to give a final presentation or write up a report, and if so when would the advisor expect to see a first draft? The schedule of broader program events and trainings should be factored into the project timeline to ensure that the interns have the proper support to meet their scheduled deadlines. Advisors should also consider their own schedules, and the time commitment they are making to assist the intern in achieving their goals and deadlines, such as packaging and mailing supplies, training interns in various tasks, or reviewing practice presentations or draft reports. Furthermore, advisors should also be aware of broader institutional requirements of the virtual internships, such as various bureaucratic steps necessary to properly fund virtual internships or ensure supplies can be shipped to the interns' homes. Once the advisors and interns have developed a clear plan for the virtual project,

advisors can focus on mentoring and producing a worthwhile experience for the interns.

Ensure a positive mentoring experience

Mentoring is perhaps the most critical aspect of all internship programs. Students rely on their advisors to mentor them through the process of conducting independent research and navigating the professional culture of science. Strong, positive mentorship is increasingly important in a virtual setting as mentorship yields a greater number of learning opportunities and development gains for interns, particularly in relation to communication, teamwork, scientific ethics, and problem-solving (Jeske & Linehan, 2020). Although mentoring needs differ among individuals, successful mentor-mentee relationships are based on respect and trust. In-person, these relationships can be built through regular meetings, open-door policies, casual conversations, and working together to design and complete independent research projects. Moving virtual, advisors must be more intentional in building mentoring relationships with their interns. Advisors should not only clearly communicate goals, expectations, and deadlines to interns, but they should also conduct themselves in a reliable and trustworthy manner. As there is an inherent power dynamic in mentor-mentee relationships, mentors set the tone for how the relationship will evolve through the virtual internship. Advisors should promote an open and friendly research environment by providing clear explanations of the scientific process, giving context to tasks that would normally be observed in person, and encouraging comments and questions from the intern. These conversations might feel forced early on but can become more natural through regular and frequent meetings, particularly early in the internship. Advisors should also promote their accessibility to their interns to address any questions that arise. Early on, advisors may want to schedule frequent meetings (e.g., daily) to check-in with interns, while the intern learns an advisor's working and communication style. By building a strong bond early, the mentoring relationship can extend well beyond the course of the internship and provide lasting benefit to both the intern and the advisor.

Create a virtual work environment

A critical component of defining expectations and developing a project plan (see Recommendations 2 and 3) is establishing methods of access and availability across all parties in a way that both provide the

required accessibility while simultaneously setting the necessary boundaries for workplace relationships. Developing a virtual work environment takes upfront effort and organization, but once established can promote productivity and collaborations beyond the virtual internship period, as is critical for establishing a sense of community (see Recommendation 6). A virtual work environment can be created through the variety of virtual platforms now available, including virtual meeting spaces, cloud document sharing and storage, and messaging applications (Rillig et al., 2020). Different platforms offer different services, and those services are rapidly improving; advisor or internship program directors should be mindful of this changing landscape and choose platforms that meet their needs and complement one another. Within the virtual work environment, advisors, interns, and collaborators can share important documents, create schedules, and meet virtually. Virtual work environments differ substantially from in-person in that both advisors and interns may miss out on physical cues from one another, like noticing when people are available or how projects are progressing. Thus, a critical part of the virtual work environment is keeping lines of communication open and intentionally discussing potential challenges and important considerations that may be self-evident or easily addressed during in-person internships. Within the virtual work environment, it is important for advisors to follow the protocols established in their expectations to build the reliability and trust required for successful mentoring (Recommendations 2 and 3). Developing organized and functional work environments is not only important for the intern's success, but also important for facilitating a virtual community for interns.

Develop a virtual community

Communities form the backbone of scientific endeavors and are another critical component of research-based internships. Many relationships make up communities, such as between peers or collaborators. Overall, a healthy research community can create a positive work and learning environment for interns by promoting motivation, accountability, and collaboration, while simultaneously decreasing isolation, loneliness, and academic struggles (Rillig et al., 2020). In a European study about students' perceptions of virtual internships, students identified clear, regular communications as an important factor in maintaining a positive and productive virtual internship and lack of social interactions as a possible disadvantage to in-person opportunities (Medeiros

et al., 2015). While building a virtual sense of community can be more difficult initially, social ties formed through virtual experiences have been shown to be more lasting in some instances (Francescato et al., 2007; Miltiadou & Yu, 2000). To promote peer-to-peer relationships, advisors may design opportunities for interns to work together on research projects while answering independent questions, either within or across laboratory groups. For example, interns may work with an advisor to develop a shared experimental design that can be used to answer multiple research questions. Alternatively, interns may work together to develop science communication materials related to their independent projects or major laboratory themes. Additionally, institutional or departmental internship programs may create opportunities for peers to work together to achieve learning outcomes, such as collaborative short courses or projects (Litchfield et al., 2010). Advisors may also encourage students to reach out to other laboratory members to answer questions that align with their interests and research projects. These opportunities provide the following two benefits: (1) they provide a line of communication to additional persons the intern can approach if their advisor is unavailable, and (2) they expand the intern's scientific network. Regularly scheduled virtual laboratory meetings also go a long way toward fostering a sense of community within the laboratory group, by allowing for more informal conversations while exposing interns to research topics and scientific approaches that extend beyond their specific project. Timing and topics of these meetings may vary, but the goals and timing should be communicated and agreed upon early on (see Recommendations 2 and 3). To encourage relationships among students and other principal investigators within a department or institution, internship programs could develop a seminar series that includes short presentations or panel discussions from different laboratory groups. Furthermore, a benefit of a virtual community is that it is not restricted to one host institution. Advisors and internship program directors can develop programs that include virtual speakers at different institutions—such as intern alumni, distant collaborators, or research specialists—or that span internship programs across multiple institutions. Across all these types of interactions, if there are a mix of in-person and virtual interns, those in-person may be encouraged or required to take part in virtual events to prevent a sense of isolation or exclusion among the virtual participants. Finally, a sense of community can be further encouraged by scheduling time for unstructured, casual conversation either into existing meetings (e.g., extended hellos at the start of a meeting) or as separate events (e.g., virtual lunch or coffee hours). Unstructured conversation can be facilitated using

icebreaker questions or discussing hobbies or activities that interns are involved in outside of their internship. Advisors should also participate in these activities where relevant to further build trust and community. Overall, while developing a virtual community requires intentional effort and may take more time to develop compared to in-person opportunities, it provides many benefits for all participants in the program, including relationships that can last longer than those developed in-person (Francescato et al., 2007; Miltiadou & Yu, 2000). Thus, a virtual community should be fostered at every opportunity.

Provide virtual training

As with traditional in-person internships, a primary goal of virtual internships is training and skill development. However, many of the spontaneous, informal training opportunities that occur during in-person internships require intentional effort and planning to provide virtual interns with the necessary experiences to develop skills related to their projects and interests. These opportunities may include virtual demonstrations of the techniques that interns need to complete their projects, an organized reading group to discuss scientific theory and demonstrate how to read literature, or scenario simulations (Rock et al., 2016). For project-specific training, advisors should consider the best methods to provide interns with the learning experiences necessary to develop and master a given skill (e.g., one-on-one virtual meeting, prerecorded materials, and written protocols). Additionally, professional development training, such as science communication or CV/resume building, may be incorporated into laboratory meetings or cohort training at the program level. These broader professional development trainings can serve the dual purpose of developing intern skills, while also nurturing a sense of community (see Recommendation 6). Additionally, maximizing the number of trainings that occur within virtual work environments can further enhance opportunities for in-person and virtual interns to interact and build relationships.

Avoid screen burnout

Repeating any task for hours on end can lead to physical and emotional fatigue, and this is particularly true for screen time. Interns should be encouraged to step away from the screen frequently to participate in non-screen-related research, educational, or training activities where possible. For interns whose virtual experiences focus on hands-on activities, such as backyard experiments or at-

home processing of physical samples (Table 1), avoiding screen burnout should be relatively straightforward. However, nonscreen activities can be incorporated as a side project into even screen-heavy virtual experiences. For example, interns whose primary research project involves analyzing plant or animal data might be encouraged to take walks around their neighborhood or in local natural areas to record species observations on apps such as iNaturalist or eBird. These interns would not only benefit from time away from the computer, but would also be contributing to valuable global databases that are used in scientific research. At a minimum, scheduled stretch

breaks should be incorporated into any screen time, and the laboratory culture should encourage these breaks for all members.

Create in-person opportunities when possible

The value of virtual internship experiences can be enhanced by supplementing with in-person opportunities when possible. This could take the form of one to several days of in-person activities at the advisor's field site or

TABLE 2 Possible pitfalls and limitations to virtual internships and potential solutions for avoiding or alleviating each example

Possible internship pitfalls and limitations	Internship format	Potential solutions
An intern may not be able to travel for their internship for personal reasons (e.g., family obligations, medical needs)	In-person	A virtual internship may be an excellent solution to provide an opportunity for an intern who cannot participate in person.
An intern's financial situation may require them to maintain a job during the internship.	Both	Provide a living wage for all interns, whether virtual or in-person. Housing costs should be allocated within budgets for intern. On-site housing costs may possibly be reallocated to support rent for virtual interns.
An intern may struggle to find a quiet place within their home to focus on work.	Virtual	Help the intern identify local options that would promote quiet work, such as a library or shared workspace, or provide noise-canceling headphones if allowed within the scope of your budget.
An intern's home life may require them to work outside of regular business hours.	Both	Be flexible to allow the intern to work during hours conducive to their schedule, while also ensuring that meetings with laboratory members and other interns still occur. A virtual internship may be particularly conducive for an intern who needs to work outside of regular business hours.
An intern may not have the appropriate technology (e.g., reliable Internet access, computer, webcam) to allow for virtual work or meetings.	Virtual	While working within the limitations of your funding, these technologies can be provided to the intern in place of travel costs.
An intern's motivation may wane while working from home	Virtual	Schedule frequent check-ins and mini-deadlines to ensure tasks are being completed in a timely manner and to remotivate the intern through informal science discussion.
An intern may lose sight of work-life balance and work too many hours.	Both	Remind the intern to take frequent breaks and help them set up a routine that avoids pulling all-nighters. Additionally, encourage interns to speak up if initial deadlines turn out to be too ambitious, and adjust expectations accordingly.
The intern or advisor may find the internship format (virtual or in-person) is not working out.	Both	Within written expectations, list allies and protocols for safe conflict resolution within the internship program, department, and/or institution. Offer flexibility, allowing an intern to switch advisors/laboratories or develop a co-advisor agreement. Find a way to switch formats if possible, or offer an exit ramp if necessary.

laboratory during the course of a primarily virtual internship, or allowing on-site access for field or laboratory experiences after the end of the formal internship period. Alternatively, interns or advisors may identify opportunities in the intern's local area to gain field or laboratory skills using the same or similar methods to those used to collect data for the internship, adding important context that enriches the experience. Scientific conferences may also provide venues for in-person interaction between advisors and interns during the virtual internships or soon thereafter. This could include opportunities local to the intern that the advisor travels to attend, or both the advisor and intern may travel to the same conference in another location. Conference experiences can be especially beneficial for interns who have the opportunity to present their independent research project for a broad scientific audience. Conference travel opportunities are an important component of many internship programs, such as NSF REUs and USDA REEUs, and funding for conference attendance may also be available from research grants, scientific societies, universities, or other sources. Providing in-person opportunities can strengthen the mentoring relationship, broaden the intern's scientific community, and provide additional training opportunities.

Normalize the virtual experience

Our positive experiences this year suggest that virtual internships can be normalized as a regular component of ecology internship programs. We are not suggesting that in-person experiences be replaced, rather that virtual experiences can increase flexibility and opportunity in internship programs. This could be done by offering a certain number or percentage of opportunities as virtual positions or even by offering virtual-only opportunities. Hybrid programs with some in-person and some virtual opportunities may need to pay special attention to creating community-building activities to connect in-person and virtual mentees (see Recommendation 7) and providing equitable access to resources (Resnik, 2005). When virtual internships are possible, these opportunities should be highlighted in traditional program advertisements, websites, social media, and other materials. Normalizing virtual opportunities may allow for creative new avenues for the engagement of underrepresented groups in ecology.

PITFALLS AND LIMITATIONS

As with any research or educational activity, those wishing to establish a virtual internship program for their lab,

department, or institution should carefully consider the potential pitfalls and limitations. Virtual internship experiences are not immune to many of the same pitfalls and limitations of in-person internships. Conversely, virtual internships can provide useful solutions to the pitfalls and limitations of in-person internships. With careful planning and consideration of the above recommendations, many of these issues can be addressed within the scope of the internship program for both internship types. However, some may be unavoidable, and should be acknowledged and discussed with the intern at the start of the program and revisited as needed. Some possible pitfalls and limitations to consider, as well as potential solutions, are outlined in Table 2.

CONCLUSION

Internships in 2020 were heavily impacted by the COVID-19 pandemic; however, programs that adapted by offering virtual internships were able to conduct successful programs that supported interns as they gained experience with the scientific process and acquired important technical, networking, and values-based skills for their career. At SERC, interns were able to work on a variety of research projects virtually, many of which provided experience with aspects of scientific research that frequently receive less attention during in-person experiences (e.g., data management and analysis, data synthesis, and remote collaboration). From our collective experiences, we learned more about the types of projects that can be conducted, ways to successfully advise and mentor, and common pitfalls of virtual internships. Although the transition from in-person to virtual formats requires forethought and hard work, it paves the way to successfully conduct virtual internships with a workload and benefits similar to the current in-person format in future (DiBiase, 2000). While our success with a virtual internship program supports the idea that these internships can equally achieve the broad goals of in-person STEM internships, virtual internships are inherently different from in-person opportunities. As a result, virtual or hybrid internship opportunities cannot and should not replace in-person opportunities or projects. Researchers and interns considering or planning to pursue virtual opportunities in future need to honestly assess their specific goals, needs, and capabilities (see Recommendation 1). We provide an overview of virtual project types and common pitfalls and limitations with examples. Given the breadth of existing internship programs and opportunities, these should be viewed as guidelines to help determine when virtual or hybrid opportunities are appropriate.

The success of virtual internship programs highlights the capacity to offer virtual or hybrid in-person/virtual internships in future to create more opportunities for experience in ecology and other STEM fields. Future virtual or hybrid internships can also be developed to promote interdisciplinary training and collaboration between fields and institutions. Continuing to offer virtual internships in future increases not only the types of projects and experiences that are possible, but also the accessibility of internships to students. Virtual internships provide the flexibility to accommodate and be more inclusive of the nontraditional life scenarios many students face. As a result, continuing to offer virtual experiences will likely increase diversity, equity, and inclusion in STEM. However, more pedagogical research is needed to understand the more nuanced aspects of virtual and hybrid internships and mentoring in STEM (Faulconer & Gruss, 2018; Faulconer et al., 2020).

An important aspect of continuing to offer virtual internships not well addressed here is the bureaucratic changes that are needed to support virtual and hybrid programs. To make virtual internships available in future, internship programs, institutions, and funding sources need to continue to permit the flexibility that was granted during the COVID-19 pandemic. For example, funds intended for travel could be reallocated to internship extensions or providing interns with the necessary technology. We hope that researchers, administrators, and funders recognize the potential value in supporting virtual or hybrid programs to promote diversity, equity, and inclusion in science and create the necessary changes to support these experiences.

ACKNOWLEDGMENTS

Thank you to the internship coordinators, intern advisors, staff, and administration at the Smithsonian Environmental Research Center who rose to the challenge of flipping from an in-person program to a virtual one. Specifically, we thank members of the Ecosystem Conservation Lab, Fisheries Conservation Lab, Marine Disease Ecology Lab, and the Public Engagement team for contributing to our success at developing virtual internships. We thank the laboratories within the SERC Terrestrial Guild for helpful feedback on a manuscript draft. We also thank our virtual interns for their flexibility and thoughtful feedback throughout the process. Finally, we would like to thank our funding sources NSF REU DBI 1659668, NSF REU DBI 1950656, NSF REU DBI 2031880, Chesapeake Student Recruitment, Early Advisement, and Mentoring (C-StREAM), University of Chicago, Wabash College, and Bryn Mawr College.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ORCID

Amy M. Hruska  <https://orcid.org/0000-0002-8165-3243>

Alison Cawood  <https://orcid.org/0000-0002-7849-0412>

Katrina M. Pagenkopp Lohan  <https://orcid.org/0000-0003-3885-7985>

Matthew B. Ogburn  <https://orcid.org/0000-0001-5417-555X>

Kimberly J. Komatsu  <https://orcid.org/0000-0001-7056-4547>

REFERENCES

- Armstrong, V. O., T. R. Tudor, and G. D. Hughes. 2020. "Course Retention in Community Colleges: Demographics, Motivation, Learning Style, and Locus of Control." *American Journal of Distance Education* 35: 32–47.
- Burgio, K. R., C. M. D. MacKenzie, S. B. Borrelle, S. K. M. Ernest, J. L. Gill, K. E. Ingeman, A. Teffer, and E. P. White. 2020. "Ten simple rules for a successful remote postdoc." *PLoS Computational Biology* 16: 1–9.
- DiBiase, D. 2000. "Is Distance Teaching More Work or Less Work?" *American Journal of Distance Education* 14: 6–20.
- Faulconer, E., L. Faulconer, and J. Hanamean. 2019. "Arriving at a Better Answer: A Decision Matrix for Science Lab Course Format." *Journal of College Science Teaching* 48: 31–5.
- Faulconer, E. K., and A. B. Gruss. 2018. "A Review to Weigh the Pros and Cons of Online, Remote, and Distance Science Laboratory Experiences." *The International Review of Research in Open and Distance Learning* 19: 156–68.
- Faulconer, E. K., Dixon, Z., Griffith, J. & Faulconer, L.(2020) Perspectives on Undergraduate Research Mentorship: A Comparative Analysis between Online and Traditional Faculty. *Online Journal of Distance Learning Administration*, 23(2), <https://commons.erau.edu/publication/1545>
- Francescato, D., M. Mebane, R. Porcelli, C. Attanasio, and M. Pulino. 2007. "Developing Professional Skills and Social Capital through Computer Supported Collaborative Learning in University Contexts." *International Journal of Human Computer Studies* 65: 140–52.
- Frassl, M. A., D. P. Hamilton, B. A. Denfeld, E. de Eyto, S. E. Hampton, P. S. Keller, S. Sharma, et al. 2018. "Ten Simple Rules for Collaboratively Writing a Multi-Authored Paper." *PLoS Computational Biology* 14: 6–13.
- Frater, P. N., and L. L. Sullivan. 2018. "Six Tips for Happy, Productive Remote Working." *Science*. <https://doi.org/10.1126/science.caredit.aaw2750>
- Graham, M. J., J. Frederick, A. Byars-Winston, A. B. Hunter, and J. Handelsman. 2013. "Increasing Persistence of College Students in STEM." *Science* 341: 1455–6.
- Grineski, S., H. Daniels, T. Collins, D. X. Morales, A. Frederick, and M. Garcia. 2018. "The Conundrum of Social Class: Disparities in Publishing among STEM Students in Undergraduate Research Programs at a Hispanic Majority Institution." *Science Education* 102: 283–303.
- Hernandez, P. R., P. D. Hopkins, K. Masters, L. Holland, B. M. Mei, M. Richards-Babb, K. Quedado, and N. J. Shook. 2018. "Student Integration into STEM Careers and Culture: A Longitudinal Examination of Summer Faculty Mentors and Project Ownership." *CBE Life Sciences Education* 17: 1–14.

- Jeske, D. 2019. "Virtual Internships: Learning Opportunities and Recommendations." In *Total Internships Management—The Employer's Guide to Building and Sustaining the Ultimate Internship Program*, 3rd ed., edited by R. Shindell, 1–5. Cedar Park, TX: Intern Bridge.
- Jeske, D., and C. Linehan. 2020. "Mentoring and Skill Development in e-Internships." *Journal of Work-Applied Management* 12: 245–58.
- Jose, B., M. Berry, and L. Andrews. 2019. "Course Format and Student Learning Styles: A Comparison of Political Science Courses." *American Journal of Distance Education* 33: 262–75.
- Kumar, S., and C. Coe. 2017. "Mentoring and Student Support in Online Doctoral Programs." *American Journal of Distance Education* 31: 128–42.
- Litchfield, R. E., M. J. Oakland, and J. A. Anderson. 2010. "Relationships between Intern Characteristics, Computer Attitudes, and Use of Online Instruction in a Dietetic Training Program." *American Journal of Distance Education* 16: 23–36.
- Lopatto, D. 2007. "Undergraduate Research Experiences Support Science Career Decisions and Active Learning." *CBE Life Sciences Education* 6: 297–306.
- Maestre, F. T. 2019. "Ten Simple Rules towards Healthier Research Labs." *PLoS Computational Biology* 15: 14–6.
- Medeiros, A. R., D. İcen, E. A. Morciano, and M. Cortesão. 2015. "Using Virtual Internships as an Innovative Learning Technique." In *2015 IEEE Global Engineering Education Conference*. 262–6. Estonia: Tallinn.
- Miltiadou, M., and C. H. Yu. 2000. *Validation of the Online Technologies Self-Efficacy Scale (OTSES)*. Washington, DC: U.S. Department of Education, Educational Resources and Information Center.
- National Science Foundation. 2020a. Award Search. [nsf.gov/awardsearch](https://www.nsf.gov/awardsearch)
- National Science Foundation. 2020b. Research Experiences for Undergraduates Program Solicitation. <https://www.nsf.gov/pubs/2019/nsf19582/nsf19582.htm>
- Nash, C. 2021. "Improving Mentorship and Supervision during COVID-19 to Reduce Graduate Student Anxiety and Depression Aided by an Online Commercial Platform Narrative Research Group." *Challenges* 12: 1–18.
- Nocco, M. A., B. M. McGill, C. M. D. MacKenzie, R. K. Tonietto, J. Dudley, M. C. Bletz, T. Young, and S. E. Kuebbing. 2021. "Mentorship, Equity, and Research Productivity: Lessons from a Pandemic." *Biological Conservation* 255: 1–10.
- Payne, D. 2018. "The Pros and Cons of Mentoring by Skype." *Nature*. <https://doi.org/10.1038/d41586-018-05794-7>
- Pei, L., and H. Wu. 2019. "Does Online Learning Work Better Than Offline Learning in Undergraduate Medical Education? A Systematic Review and Meta-Analysis." *Medical Education Online* 24: 1–14.
- Pender, M., D. E. Marcotte, M. R. Sto Domingo, and K. I. Maton. 2010. "The STEM Pipeline: The Role of Summer Research Experience in Minority Students' Graduate Aspirations." *Education Policy Analysis Archives* 18: 1–39.
- Resnik, D. B. 2005. "Using Electronic Discussion Boards to Teach Responsible Conduct of Research." *Science and Engineering Ethics* 11: 617–30.
- Rillig, M. C., M. Bielik, V. Bala Chaudhary, L. Grünfeld, S. Maaß, I. Mansour, M. Ryo, and S. D. Veresoglou. 2020. "Ten Simple Rules for Increased Lab Resilience." *PLoS Computational Biology* 16: 1–5.
- Rock, A. J., W. L. Coventry, M. I. Morgan, and N. M. Loi. 2016. "Teaching Research Methods and Statistics in Elearning Environments: Pedagogy, Practical Examples, and Possible Futures." *Frontiers in Psychology* 7: 1–11.
- Scanlon, E., P. McAndrew, and T. O'Shea. 2015. "Designing for Educational Technology to Enhance the Experience of Learners in Distance Education: How Open Educational Resources, Learning Design and Moocs Are Influencing Learning." *Journal of Interactive Media in Education* 1: 1–9.
- Scott Price, O., K. Luis, A. L. Price, B. Harden, J. Howard, L. E. Valentin, G. Liles, and A. Jearld. 2020. "Same Program Different Delivery: Adapting the Woods Hole Partnership Education Program for a Virtual Era." *Limnology and Oceanography Bulletin* 29: 117–24.
- Zimeri, A. M. 2015. "Direct from AEHAP: Professional Training Agreement Development for Undergraduate Environmental Health Internships Required by EHAC-Accredited Program." *Journal of Environmental Health* 77: 34–5.

How to cite this article: Hruska, Amy M., Alison Cawood, Katrina M. Pagenkopp Lohan, Matthew B. Ogburn, and Kimberly J. Komatsu. 2022. "Going Remote: Recommendations for Normalizing Virtual Internships." *Ecosphere* 13(3): e3961. <https://doi.org/10.1002/ecs2.3961>