Why teach natural history through hybrid and online courses?

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In this paper, we describe the current trends in online enrollment in higher education and summarize the research on the effectiveness of online learning in general and with a focus on online education in the natural sciences. We conclude that teaching hybrid courses with face-to-face field experiences or fully online courses with autonomous field experiences may be an effective way to educate a larger, more diverse student population about natural history. Furthermore, we describe some of the current online offerings in natural history and provide examples of how natural history topics could be approached in both hybrid and fully online courses.

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Opportunities for natural history education at American colleges and universities are in decline (Noss 1996, Futuyma 1998, Wilcove and Eisner 2000, Schmidly 2005, Tewksbury et al. 2014). Reduced natural history knowledge threatens scientific advancement (Futuyma 1998, Wilcove and Eisner 2000, Fleischner 2005, Peay 2014), an ability to skillfully manage ecosystems and natural resources (Fleischner 2005, Woods and Ruyle 2015), and the conservation of species and their habitats (Futuyma 1998, Noss 1996, Wilcove and Eisner 2000, Fleischner 2005), as it perpetuates human isolation from the natural world (Lopez 2001, Pyle 2001).

Different kinds of courses can include online learning, and unfortunately the terms used to describe them are not consistent. In this paper, we will use the definitions adopted by the Babson Survey Research Group in their annual survey of online education in the United States. Allen and Seamen (2015) deem face-to-face courses that use web technology, such as a learning management system (LMS) for posting a course syllabus and assignments, as *web-assisted*. They define *hybrid courses* as those with a substantial proportion (between 30 and 79%) of the content delivered online and typically having a reduced number of face-to-face meetings. *Online courses* are those that deliver most of the content (80% or greater) online and typically lack face-to-face meetings. Because they have the potential to increase student access to higher education by reducing requirements for face-to-face meetings, we focus on the promise of hybrid and online natural history courses for increasing natural history educational opportunities for students who otherwise might not experience any natural history education.

Online learning may seem antithetical to traditional ways of studying nature directly through careful observation of specimens in the field, museum, or laboratory. We contend, however, that natural history topics are amenable to online learning. Online and hybrid natural history courses that incorporate the best practices in online teaching and include face-to-face field and/or laboratory experiences or similar guided autonomous experiences, in which students conduct instructor-guided studies in the field or at home on their own, can effectively engage more students in the study of nature to help halt declines in natural history knowledge and the resulting consequences.

Online and hybrid natural history courses could reach a broader audience

At the same time that opportunities to formally study natural history are dwindling (Futuyma 1998, Noss 1999, Wilcove and Eisner 2000, Schmidly 2005, Tewksbury et al. 2014), demand for online learning opportunities is expanding. In 2012, 33.5% of American college and university enrollments were in online

courses. This represents a threefold increase in 10 years (Allen and Seaman 2013) and college administrators are projecting that this number will continue to grow (Allen and Seaman 2014). There appears to be strong interest not only in hybrid and online courses but entire degree programs; 53% of people who were interested in pursuing post-secondary education indicated that their preferred mode of delivery would be totally online or an equal balance between online and on-campus instruction (Garrett 2007) with the number of students taking all of their courses online rising to 14% in fall of 2014 (Allen et al. 2016).

Due to mistrust and concerns about the quality of education at private, for-profit institutions, we feel it is important to note that only about 16% of the students taking at least one online course in fall of 2014 were enrolled at such institutions (Allen et al. 2016). Furthermore, while online enrollments continue to grow at private non-profit and public institutions, despite declines in enrollments in higher education in general, online enrollments are declining at private for-profit institutions (Allen et al. 2016).

While demand is high for online courses and programs in general, it appears that undergraduate online learning options in the sciences and related fields are lagging. For example, during the 2007-8 academic year, students enrolled in natural science, mathematics, and agriculture programs were 30% less likely to be taking an online course and 75% less likely to be enrolled in an online degree program than their peers in other disciplines (Radford 2011). Furthermore, a search of Peterson's Online Schools™ database revealed that only three American institutions offered online bachelor's degrees in biology (Peterson's 2017).

Additionally, a survey of 96 US institutions of higher education found nearly half of the institutions with no undergraduate online biology course offerings (Varty 2016); of the biology courses that were offered online, only two had an obvious emphasis on natural history (Varty unpublished data). This may indicate that the sciences, including biology, are particularly challenging to teach online. It could also indicate that there is unmet demand for online offerings in the sciences, including biology and natural history.

Hybrid and online courses are more convenient for some students and make accessing higher education a possibility for others as they create educational opportunities with fewer time and geographic constraints (Geith and Vignare 2008). This is particularly important for non-traditional students, who currently make up 74% of undergraduates in the United States (Radford et al. 2015). Non-traditional students – a group including students who are independent for financial aid purposes, have one or more dependents, are single caregivers, have delayed post-secondary education enrollment, and/or are employed full-time – are more likely than traditional students to complete online courses and programs (Radford et al. 2015). Non-traditional students also include higher percentages of women and minorities (Radford et al. 2015), demographic groups that are typically underrepresented in STEM fields.

Furthermore, many non-science majors are interested in studying natural history (Schmidly 2005). Thus, natural history courses have a unique appeal to students who may not be enrolled in any degree program and to students pursuing degrees in other fields who need to fulfill their science general education requirements. In our experience, teaching at 2-year public institutions, these populations are a significant portion of the students in our natural history courses. For some of these non-traditional students, online learning may be their best or only option. Thus, from the instructors' or colleges' perspectives online natural history courses could increase access to new student populations while boosting course and departmental enrollments and diversity. Because the highest percentages of students with one or more non-traditional characteristic are attending 2-year public colleges (Radford et al. 2015), faculty members at these institutions may be uniquely poised to successfully expand hybrid and online natural history offerings. From a broader perspective, higher enrollments could elevate global natural history knowledge while increasing public interest in and support of natural history, which some believe is crucial to elevating the importance of the field (Schmidly 2005).

Natural history content is a 'natural' fit for online and hybrid modalities

As a result of the difficulties one can encounter timing field studies throughout a full semester course, the impressive array of online tools related to the study of natural history, and the relative ease at which natural history studies can be performed by students autonomously, we feel that many natural history topics are well suited for hybrid or online courses. For example, there is a precedent for concentrating the laboratory hours in hybrid laboratory science courses into a small number of long days, often meeting on the weekends, instead of shorter, regular weekly laboratory periods (Lyall and Patti 2010, Jeschofnig and Jeschofnig 2011, Brewer et al. 2013). This type of scheduling benefits students with varied responsibilities outside of school. We contend that this level of flexibility in the timing and length of laboratories in this model of hybrid

instruction can also be advantageous when studying organisms in the field.

For example, some climates are not hospitable to field study throughout the duration of an academic quarter or semester. Even in moderate climates, the phenology of most organisms makes them better suited for field study during limited times of the year. Hybrid courses with irregularly-timed and concentrated laboratory periods can allow the instructor to take longer field trips and schedule them when study organisms are present and identifiable, such as scheduling ornithology field trips during spring migration or botany field trips when local species are in flower. Fewer and longer field trips could also help reduce transportation costs associated with a field course.

Additionally, instructors have an impressive array of online tools to engage their students in the study of natural history. Examples include:

- Collecting or analyzing data from citizen science efforts such as Project Budburst (http://budburst.org/), Ebird (http://ebird.org/content/ebird/), or Animal Diversity Web (http://animaldiversity.org).
- Studying digital images of plant specimens from herbaria across the globe including the Harvard Herbaria (http://huh.harvard.edu/pages/digital-resources) and Kew Herbarium (http://apps.kew.org/herbcat/gotoHomePage.do). For ideas about using digital herbarium specimens in related courses, see Flannery (2013).
- Preparing for audio or visual identification quizzes by listening to audio recordings or watching videos of thousands of animals through the Cornell Laboratory of Ornithology's Macaulay Library (http://macaulaylibrary.org/) and Xeno-Canto bird sound online collection (http://www.xeno-canto.org).
- Creating interactive maps with data points (GPS coordinates of specific nature observations or specimen collections) gathered by students in the field using GPS units or smartphones. Multiple online mapping tools are available such as Google Maps (https://www.google.com/maps/), Google Earth (https://www.google.com/earth/), National Geographic Map Maker Interactive (https://mapmaker.nationalgeographic.org), and MapHub (https://maphub.net).
- Using interactive identification smart phone applications such as the one developed by the Oregon Flora Project (http://oregonflora.org/).
- Using online interactive identification tools (http://ucjeps.berkeley.edu/keys/) or traditional online dichotomous keys such as those developed by the University and Jepson Herbaria at the University of California at Berkeley. For example, one of us (AKV) developed an activity for a hybrid Field Botany course using an online key to seedless vascular plant families from the Jepson Herbarium (http://ucjeps.berkeley.edu/IJM_keys/IJM_key_Group3.html) and digital images of from her college's herbarium specimens. Students used the online key to key out ten seedless vascular plants from the collection to family. This provided students with practice using a dichotomous key and the opportunity to become more familiar with the characteristics and anatomical terminology of the seedless vascular plant families.

The laboratory content of many natural history courses is also well-suited for virtual or hands-on distance education laboratories such as autonomous field trips or at-home activities. Virtual laboratories in an online natural history course could include utilizing some of the online resources mentioned above or watching instructor-created videos about target communities or organisms or videos containing instructions for conducting surveys or using dichotomous keys. As a way to complement or reinforce the autonomous or instructor-led study of the anatomy of certain organisms in the laboratory or field, students could examine photographs or watch virtual dissections. There are also high quality options for virtual ecology and evolution laboratories such as those created by Sim Bio (http://simbio.com) and the University of Colorado-Boulder (https://phet.colorado.edu/).

Compared to other biological sub-disciplines, such as cellular and molecular biology, the equipment and supplies needed for hands-on study of natural history can be minimal, easily obtained, and inexpensive. At-home laboratory activities could include instructing students to:

- Make regular phenological and/or behavioral observations of backyard organisms;
- Census backyard populations or communities;
- Dissect organisms or parts of organisms (i.e., flowers and fruits) purchased locally or collected around their homes;
- Identify backyard organisms using a dichotomous key; or
- Collect and preserve organisms when appropriate.

For example, in a Field Botany course taught in a hybrid format at College of the Siskiyous, students engaged in the weekly practice of identifying backyard or nearby native plants and documenting the experience in a

digital journal. The goals of this assignment were to help students learn how to recognize and correctly apply plant anatomical terms while using a dichotomous key to identify vascular plants on their own, after being introduced to the skill during a face-to-face field trip early on. In their electronic plant identification journals (either a Google Doc or a Word document), students included the following information about their experience keying at least one plant per week:

- Observation date and location of plant;
- Description of the life form, vegetative (i.e., leaf type, leaf arrangement, margin description, venation, bark description) and reproductive features of the plant (i.e., type of flower or inflorescence, floral symmetry, number and fusion of floral parts, fruit type, etc.);
- Digital photograph of the specimen that was useful for identification;
- Explanation of how they proceeded through the key (including the order of couplets considered) and an estimate of the amount of time spent identifying the plant;
- Scientific name assigned to the specimen; and
- Discussion about the keying experience including reflections about obstacles encountered, level of confidence that the assigned name is correct with reasoning, and whether the activity was becoming easier with practice.

The assignment was worth 12% of the total course points. Students were awarded points for completeness and thoroughness of journal entries, appropriate use of anatomical terms, evidence of improvement, and clarity of journal format and writing.

To be clear, we are not arguing for the elimination of direct field experiences in natural history education. Field trips are highly valued by students (Spicer and Stratford 2001, Scott et al. 2012), play a crucial role in natural history education (Noss 1996), and can be a highly effective way to teach (Scott et al. 2012). Thus, these course components should not be omitted from hybrid and online courses. We are, however, highlighting approaches and opportunities to integrate field experiences into online education as a way to increase accessibility for students.

In hybrid courses, the field trips can be face-to-face. In both modalities, most students will be able to access field sites on their own for autonomous field trips. These types of experiences can get students into the field studying organisms in a variety of local habitats. Examples of autonomous field trips could include using an instructor-created guide to interpret habitats and introduce organisms while visiting a specific local natural area or a collection of organisms at a museum, zoo, or botanical garden.

Another option could be to send students into a local natural area of their choosing to describe and interpret some aspect of the biota or generate a species list of a specific group. Incorporating service learning opportunities into online and hybrid natural history courses could be another way to get students into the field. Students could get hands-on experience by volunteering at a local natural science museum; zoo; botanical garden; wildlife rehabilitation center; national, state, or local park; federal land management agency such as the Forest Service or Bureau of Land Management; or even at a local chapter of a conservation or nature-based organization such as the Audubon Society or local native plant society.

Online modalities can be effective

Because early criticisms about the quality of online courses and programs were common and still persist, we present here some of the research supporting the effectiveness of online teaching and learning. The perception of low quality was often reported as a barrier to offering online courses (Berge 1998, Bower 2001, Seaman 2009) and was more commonly held by faculty and administrators with little experience with online education (Seaman 2009). Empirical evidence, including three large meta-analyses that reviewed 76 (Tallent-Runnels et al. 2006), 51 (Means et al. 2010), and 125 studies (Shachar and Neumann 2010), contradicts these perceptions of reduced quality in hybrid and online courses. These studies found that, on average, student attainment of learning outcomes was similar or higher in online or hybrid compared to face-to-face courses. Importantly, Means and her colleagues (2010) noted that some of the hybrid courses they surveyed included instructional elements not found in the face-to-face counterparts. This emphasizes that the modality itself may not be the cause of improved learning outcomes and highlights the importance of careful design and facilitation of hybrid and online courses.

Similar or increased attainment of learning goals in online or hybrid courses compared to traditional face-to-face courses is not occurring just in non-science disciplines. For examples from the natural sciences see Johnson (2002), Riffell and Sibley (2005), Lundsford and Bolton (2006), Reuter (2009), White and Skykes (2012), Barbeau et al. (2013), and Gonzalez (2014). Evidence also indicates that online course quality has improved through time (Shachar and Neumann 2010,

Brinson 2015), likely as a result of improved technology and the adoption of effective online teaching practices.

In any discipline, the quality of courses will vary whether they are face-to-face, hybrid, or online courses. Not all instructors have seen similar or enhanced learning in their online courses (for an example see Adams et al. 2015). However, a growing body of evidence indicates that distance education courses can be highly effective and should not be dismissed solely because of the format.

Science courses are less likely to be offered online (Radford 2011) than courses in other disciplines; the laboratory requirements are a commonly cited explanation (Kenepohl and Shaw 2010, Jeschofnig and Jeschofnig 2011). Despite fears about offering online laboratory science courses, data indicate that they are often of equal or higher quality than face-to-face laboratories. Specifically, 89% of studies that compared outcomes in traditional laboratory science courses to those with remote or virtual laboratories found equivalent outcomes or educational benefits of the non-traditional teaching methods (Brinson 2015).

Other researchers have described specific benefits of online laboratory science courses including the following: higher final course grades (Reeves and Kimbrough 2004, Lyall and Patti 2010), deeper learning (hypothesized by Jeschofnig and Jeschofnig [2011] to be because students are forced to work independently through issues they encounter doing autonomous laboratory activities), and the ability to transcend time and space limitations imposed by traditional on-campus laboratories (Forinash and Wiseman 2001).

Some research also indicates that autonomous field experiences in hybrid and online natural history courses can be effective. For example, Reuter (2007, 2009) showed that student performance on laboratory assignments and attainment of laboratory skills were similar in a face-to-face and fully online soils course that included autonomous field and laboratory exercises. Clary and Wandersee (2008) incorporated autonomous field activities into their paleontology course and concluded that students were generally more successful at these activities than traditional online laboratories.

However, in some cases, autonomous or instructor-led field trips may be superior to other kinds of distance learning methods. For example, some researchers have documented lower performance on plant identification quizzes when students were introduced to plants through web-based activities rather than live plants (Taraban et al. 2004, Teolis et al. 2007). In one of our recent hybrid natural history courses, students were asked to rank which elements of the course were most useful in helping them achieve course learning outcomes; they ranked the face-to-face field trips higher than any other course component (Varty unpublished data). Studies such as these and our personal experiences teaching field courses underlie our emphasis on the importance of field experiences in online and hybrid natural history courses, whether they are autonomous or instructor-led face-to-face field trips in hybrid courses.

Drawbacks of teaching at a distance

We acknowledge that there are drawbacks to online learning. Some students lack the motivation, academic skills, technical skills, and/or access to required technologies (Muilenberg and Berge 2005) to be successful in hybrid or online courses. These barriers may help explain why student attrition rates are generally higher in online courses (Carr 2000). Notably, while attrition was higher in online compared to face-to-face courses, the University of Central Florida found no significant difference in withdrawal rates of their students in hybrid courses compared to their face-to-face courses (Dziuban et al. 2004).

Another drawback from the student perspective is transferability of online courses. When transferring courses, some institutions will not count laboratory courses lacking traditional, face-to-face laboratories as equivalent to their own face-to-face courses (Brewer et al. 2013). Although this issue may be resolved in time as online laboratory courses become more common, transferability of laboratory courses between institutions is currently a serious concern that online instructors, counselors, and potential students should carefully consider.

College and university faculty members have also noted drawbacks of teaching online. Some studies have found that teaching an online course requires more time than teaching a similar face-to-face course (Tomei 2004). Additionally, many faculty members are reluctant to teach online because of the enormous task of designing a new online course and getting to know all of the related technologies (Bower 2001). Finally, many faculty members resist teaching online because of the culture shift these modalities present to higher education (Berge 1998).

We agree that developing expertise in related technologies, creating online course materials, and teaching online are significant time investments. However, we found the related challenges to be invigorating and that the new skills and perspectives gained were beneficial to all of our courses.

Others are already doing it

We feel that the benefits of increasing access to natural history education outweigh the drawbacks and, fortunately, faculty members interested in developing online or hybrid natural history offerings have many innovative models to emulate.

In spring semester of 2017, the College of the Siskiyous began offering a hybrid Field Botany course taught by Varty. This 3-unit laboratory course, which is often taken by community members with an interest in botany or horticulture and non-science majors fulfilling their general education science requirements, included weekly readings, discussions, video lectures, plant identification practice via a keying journal, and hands-on activities as well as a laboratory report describing plant community data collected in local communities. The remaining laboratory hours were fulfilled on four face-to-face Saturday field trips that focused on woody plant identification, plant ecology, and wildflower identification (the flowering plant identification field trips were both offered within 2 weeks of each other near the end of the semester to coincide with the flowering of local plants).

The hybrid nature of the course appeared to promote access to a unique audience; over 40% of the students completing the course reported being employed to work more than 31 hours per week. This appeared to benefit the course greatly; several exceptionally motivated STEM professionals in the class set excellent examples of high-quality contributions (i.e., discussion posts, writing assignments for peer-review, contributions to group laboratory activities) that provided models for the rest of the students to emulate. A detailed analysis of student performance in this hybrid course compared to past face-to-face versions is outside the scope of this paper. However, anecdotally, student participation and performance exceeded the instructor's expectations and it was an exceptionally positive teaching experience.

The Global Expedition Program at Shasta College has been offering 6- to 7-week summer hybrid natural history courses where 4 to 5 weeks take place online, while 2 to 3 weeks take place in the field in an international location. Summer 2015 was the pilot year for this program. Two sections of the course Natural History of the Neotropics (3 lecture units + 1 lab unit) were offered with about 20 students enrolled in each section. Lectures, assignments, class discussions, readings, and quizzes were given online before departing for Honduras to offer background on the natural history of the Neotropics with a focus on the habitats students were going to encounter in the field. During the 2 weeks in Honduras, students partnered with a conservation research organization, Operation Wallacea (http://opwall.com), to help collect field data for biodiversity surveys in cloud forest and coral reef habitats. Sampling techniques included using (a) mist nets to sample birds and bats, (b) pitfall traps to sample dung beetles, (c) light traps to sample moths, and (d) transect line quadrats to sample coral reefs. While in the field, students kept a field journal and completed multiple field assignments. Upon returning home, students submitted their field journals and completed their final discussions, assignments, and submitted a final presentation that included a summary of their international field experience using their own photos and focused on a specific experience, organism, and/or biodiversity survey technique that resonated with them the most.

The following summer (2016), Shasta College offered another science-based study abroad program also taught in a hybrid format, but this time including an interdisciplinary course combination. The courses offered were Field Biology (4 units), Physical Field Geography (1 unit), and Human Field Geography (1 unit), with students traveling to Sulawesi, Indonesia, for their 2-week field experience. Combining biology and the study of geography and human cultures was very successful; students performed well in the courses and spoke highly of the interdisciplinary experience.

In the summer of 2017, Shasta College again partnered with Operation Wallacea to offer another interdisciplinary science-based study abroad course combination that included students studying and assisting with wildlife conservation research in South African savannahs and marine ecosystems. Students gained 6 semester units by signing up for Diversity of Life and Human Geography and completing both online and face-to-face field-based coursework in South Africa.

This model of online learning allows students from all over the world to meet abroad for a limited amount of time for cultural immersion and field work, thus keeping costs of the experience lower. This format of combining online education with short-term international field experiences has allowed Shasta College to provide study abroad options to some of their lower income, non-traditional students who would normally not have the opportunity to study abroad. Furthermore, instructors can enhance what students learn from the experience with flexible online pre- and/or post-trip work. The Shasta College courses involved are transferable and meet science general education requirements.

Since many of the students taking these courses are non-science majors (at least 50%), these hybrid interdisciplinary study-abroad options provide a unique opportunity to introduce scientific processes in a hands-on and engaging way and help students connect with the natural history of a region while establishing greater global awareness. In addition, the international field experience may enhance student resumes as well as their undergraduate and graduate school applications.

Santa Barbara City College (SBCC) has generated an entire online degree in Natural History. In the 1990's, an Instructor at SBCC used a photo album to help catch up students who had missed field trips. Gradually, these and other resources created by SBCC faculty, including natural history textbooks, were moved online. SBCC offered its first online natural history course in 1998; it was the first online laboratory science course offered in California. Since then, SBCC faculty have developed many more online and hybrid natural history courses, which are taken by over 1,200 students each academic year, and currently offer a fully online natural history Associate's degree.

Other online options to study natural history exist for students interested in pursuing Bachelor's degrees, graduate degrees and certificates, and continuing education credits. Oregon State University's Ecampus hosts many online courses in natural history and entire online Bachelor's and Master's degrees in related disciplines such as fish and wildlife biology and natural resources. Several options exist for undergraduate and graduate students to study entomology online including options to earn an undergraduate certificate in entomology from North Carolina State University and a Master of Science degree or graduate certificate geared toward educators from the University of Nebraska-Lincoln. Additionally, the American Museum of Natural History offers a selection of courses for continuing education and/or graduate credit through several universities on topics such as the link between dinosaurs and birds and the diversity of specific groups such as fishes and arachnids.

Suggestions for creating an online or hybrid natural history class

Creating a high-quality hybrid or online natural history course is not trivial. In addition to providing the models of online and hybrid course formats and assignments above, we list the following general suggestions below:

- As already mentioned several times, we highly recommend that hybrid natural history courses include face-to-face field trips and that fully online courses include autonomous field and hands-on laboratory experiences. Thus, our paper should not be taken by administrators as a justification for eliminating field experiences in natural history curricula; rather it should be viewed as a pathway to engage students who otherwise would have no access to those curricula at all.
- We agree with others who have found that teaching online takes a significant amount of time (Tomei 2004). We highly recommend that new online instructors invest time getting to know the tools within the institution's LMS and learning to use other online teaching tools such as video production and screen capture software, online video conferencing tools, web-based collaborative tools such as Google Docs, and discussion platforms such as Voicethread. Tools such as Turnitin and online exam proctoring software may also be of interest to online instructors concerned about academic dishonesty. Instructors should expect to spend a significant amount of time developing online course materials prior to start of a new online course and then also interacting with students one-on-one via email or video conference during the course.
- Make the format and presentation of the online course materials intuitive. This is often achieved by creating consistently well-organized weekly modules. We recommend that these modules include weekly learning goals, a list of things to do for the week, and the links to the relevant materials and assignments. This will help students easily navigate through the online components of your courses and save you time directing them towards the appropriate resources.
- We agree that regular instructor-student communication is critical to student success in online courses (Dreon 2013) as it can help students develop a relationship with their instructor and feel more comfortable learning in an online environment. Clear communication before class begins via a welcome letter can help set clear student expectations for course workload, online learning, and technology needs. Regular communication via weekly announcements keeps students on track with the class, and clear and timely instructor feedback on student work helps them gauge their progress in the course. Additionally, online instructors should try to respond quickly to student emails and set clear guidelines about how he or she prefers to be contacted.
- Create a community of learners in an online course. This practice is thought to help decrease attrition

(Angelino et al. 2007) and promote learning (Dreon 2013) as it reduces the feeling of isolation some online learners experience and gives students opportunities to learn from each other. These kinds of student-to-student interactions can be facilitated in online ice-breakers, regular discussion forums, and online collaborative activities (i.e., having students review each other's writing assignments or interpret datasets in small groups).

- Limiting online instruction to passive learning tools such as video lectures may not promote student's success (Adams et al. 2015). Engage students in the content through hands-on activities as described in Riffell and Sibley (2003). We recommend including weekly activities that give students the opportunity to work with and improve understanding of the week's content.

Conclusion

Some natural history topics are well-suited for hybrid and online courses, and research indicates that these modalities can be effective. We encourage college and university faculty to make use of the excellent online resources and diverse models of existing courses and programs to generate high-quality and engaging online natural history courses. Considering their growing popularity, especially among non-traditional students, online courses and programs as described here could play a vital role in increasing global access to natural history knowledge thereby help establish connections between people and the planet that foster environmental appreciation and conservation.

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References

Adams, A.E., S. Randall, and T. Traustadóttir. 2015. A tale of two sections: An experiment to compare the effectiveness of a hybrid versus a traditional lecture format in introductory microbiology. *Life Science Education* 14: 1-8.

Allen, I.E., and J. Seaman. 2013. *Changing Course: Ten years of tracking online education in the United States*. Babson Survey Research Group and Quahog Research Group; http://www.onlinelearningsurvey.com/reports/changingcourse.pdf

Allen, I.E., and J. Seaman. 2014. *Grade Change: Tracking online education in the United States*. Babson Survey Research Group and Quahog Research Group; http://www.onlinelearningsurvey.com/reports/gradechange.pdf

Allen, I.E., and J. Seaman. 2015. *Grade Level: Tracking online education in the United States.* Babson Survey Research Group and Quahog Research Group; http://www.onlinelearningsurvey.com/reports/gradelevel.pdf

Allen, I.E., J. Seaman, R. Poulin, and T.T. Straut. 2016. *Online Report Card: Tracking online education in the United States.* Babson Survey Research Group and Quahog Research Group; http://onlinelearningsurvey.com/reports/onlinereportcard.pdf

Angelino, L.M., F.K. Williams, and D. Natvig. 2007. Strategies to engage online students and reduce attrition rates. *Journal of Educators Online* 4: 1-14.

Barbeau, M.L., M. Johnson, C. Gibson, and K.A. Rogers. 2013. The development and assessment of an online microscopic anatomy laboratory course. *Anatomical Science Education* 6: 242-252.

Berge, Z. 1998. Barriers to online teaching in post-secondary institutions: Can policy changes fix it? *Journal of Distance Learning Administration* 1, http://www.westga.edu/~distance/Berge12.html

Bower, B.L. 2001. Distance education: Facing the faculty challenge. *Journal of Distance Learning Administration* 4(2); http://www.westga.edu/~distance/ojdla/summer42/bower42.html

Brewer, S.E., B. Cinel, M. Harrison, and C. Mohr. 2013. First year chemistry laboratory courses for distance learners: Development and transfer credit acceptance. *International Review of Research in Open and Distance Learning* 14: 488-507.

Brinson, J.R. 2015. Learning outcome achievement in non-traditional (virtual and remote) versus traditional (hands-on) laboratories: A review of empirical research. *Computers and Education* 87: 218-237.

Carr, S. 2000. As distance education comes of age, the challenge is keeping the students. *Chronicle of Higher Education*, 11 February 2000, A39.

Clary, R.M., and J.H. Wandersee. 2008. Earth science teacher's perception of an autonomous fieldwork assignment in a nationwide online paleontology course. *Journal of Geoscience Education* 56: 149-155.

Dreon, O. 2013. Applying the seven principles for good practice to the online classroom. *Faculty Focus*, 25 Feb 2013; https://www.facultyfocus.com/articles/online-education/applying-the-seven-principles-for-good-practice-to-the-online-classroom/

Dziuban, C.D., J.L. Hartman, and P.D. Moskal. 2004. Blended learning. *ECAR Research Bulletin 7;* http://www.educause.edu/ecar/

Flannery, M. 2013. Plant collections online: Using digital herbaria in teaching biology. *Journal of College Biology Teaching* 39: 3-9.

Fleischner, T.L. 2005. Natural history and the deep roots of resource management. *Natural Resources Journal* 45: 1-13.

Forinash, K., and R. Wiseman. 2001. The viability of distance education science laboratories. *T.H.E. Journal* 29: 40-45.

Futuyma, D.J. 1998. Wherefore and whither the naturalist? *American Naturalist* 151: 1-6.

Garrett, R. 2007. Expanding demand for online higher education: Surveying prospective students. *Journal of Asynchronous Learning Networks* 11: 49-53.

Geith, C., and K. Vignare. 2008. Access to education with online learning and open educational resources: Can they close the gap? *Journal of Asynchronous Learning Networks* 12: 105-126.

Gonzalez, B.Y. 2014. A six-year review of student success in a biology course using lecture, blended, and hybrid methods. *Journal of College Science Teaching* 43: 14-19.

Jeschofnig, L., and P. Jeschofnig. 2011. *Teaching Lab Science Courses Online: Resources for Best Practices, Tools, and Technology*. Jossey-Bass.

Johnson, M. 2002. Introductory biology online: Assessing outcomes of two student populations. *Journal of College Science Teaching* 31: 312-317.

Kenepohl, D., and L. Shaw. 2010. *Accessible Elements: Teaching Science Online and at a Distance*. AU Press.

Lopez, B. 2001. The naturalist. *Orion* Autumn: 38-43.

Lunsford, E., and K. Bolton. 2006. Coming to terms with the online instructional revolution: A success story revealed through action research. *Journal of College Biology Teaching* 32: 12-16.

Lyall, R., and A.F. Patti. 2010. Taking the chemistry experience home: Home experiments for kitchen chemistry. Pages 83-108 in D. Kenepohl and L. Shaw, editors. *Accessible Elements: Teaching Science Online and at a Distance*. AU Press.

Means, B., Y. Toyama, R. Murphy, M. Bakia, and K. Jones. 2010. *Evaluation of Evidence-Based Practices in Online Learning: A meta-analysis and review of online learning studies.* U.S. Department of Education, https://www2.ed.gov/rschstat/eval/tech/evidence-based-practices/finalreport.pdf

Muilenburg, L.Y., and Z.L. Berge. 2005. Student barriers to online learning: A factor analytic study. *Distance Education* 26: 29-48.

Noss, R. 1996. The naturalists are dying off. *Conservation Biology* 10: 1-3.

Peay, K.G. 2014. Back to the future: Natural history and the way forward in modern fungal ecology. *Fungal Ecology* 12: 4-9.

Peterson's. 2017. Peterson's Online Schools. https://www.petersons.com/online-schools.aspx

Pyle, R.M. 2001. The rise and fall of natural history: How a science grew that eclipsed direct experience. *Orion* Autumn: 16-23.

Radford, A.W. 2011. *Learning at a Distance: Undergraduate enrollment in distance education courses and programs* (NCES 2012-0154). U.S. Department of Education.

Radford, A.W., M. Cominole, and P. Skomsvold. 2015. *Demographic and Enrollment Characteristics for*

Non-Traditional Undergraduates: 2011-12 (NCES 2015-025). U.S. Department of Education.

Reeves, J., and D. Kimbrough. 2004. Solving the laboratory dilemma in distance learning chemistry. *Journal of Asynchronous Learning Networks* 8: 47-51.

Reuter, R. 2007. Introductory soils online: An effective way to online students in the field. *Journal of Natural Resources and Life Sciences Education* 36: 139-146.

Reuter, R. 2009. Online versus in the classroom: Student success in a hands-on lab class. *American Journal of Distance Education* 23: 151-162.

Riffell, S.K., and D.F. Sibley. 2003. Online learning: Student perceptions of a hybrid learning format: Can online exercises replace traditional lectures? *Journal of College Science Teaching* 32: 394-399.

Riffell, S.K., and D.F. Sibley. 2005. Using web-based instruction to improve large undergraduate biology courses: An evaluation of the hybrid course format. *Computers and Education* 44: 217-235.

Schmidly, D.J. 2005. What it means to be a naturalist and the future of natural history at American universities. *Journal of Mammology* 86: 449-456.

Seaman, J. 2009. *Online Learning as a Strategic Asset Volume II: The paradox of faculty voices: Views and experiences with online learning.* Association of Public Land Grant Universities and Babson Survey Research Group, http://www.onlinelearningsurvey.com/reports/online-learning-strategic-asset.pdf

Shachar, M., and Y. Neuman. 2010. Twenty years of research on the academic performance differences between traditional and distance learning: Summative meta-analysis and trend examination. *MERLOT Journal of Online Learning and Teaching* 6: 318-334.

Scott, G.W., R. Goulder, P. Wheeler, L.J. Scott, M.L. Tobin, and S. Marsham. 2012. The value of field work in life and environmental science in the context of higher education: A case study in learning about biodiversity. *Journal of Science Education and Technology* 21: 11-21.

Spicer, J.I., and J. Stratford. 2001. Student's perceptions of a virtual field trip to replace a real field trip. *Journal of Computer Assisted Learning* 17: 345-354.

Tallent-Runnels, M.K., J.A. Thomas, W.Y. Lan, S. Cooper, T.C. Ahern, S.M. Shaw, and X. Liu. 2006. Teaching courses online: A review of the research. *Review of Educational Research* 76: 93-135.

Taraban, R., C. McKenney, E. Peffley, and A. Applegarth. 2004. Live specimens more effective than worldwide web for learning plant material. *Journal of Natural Resources and Life Sciences Education* 33: 106-110.

Teolis, I., E.B. Peffley, and D.B. Wester. 2007. Comparing student performance in live versus web-based instruction in herbaceous plant identification. *Hort Technology* 17: 120-124.

Tewksbury, J.J., J.G.T. Anderson, J.D. Bakker, T.J. Billo, P.W. Dunwiddie, M.J. Groom, S.E. Hampton, S.G. Herman, D.J. Levey, N.J. Machnicki, C.M. Del Rio, M.E. Power, K. Rowell, A.K. Salomon, L. Stacey, S.C. Trombulak, and T.A. Wheeler. 2014. Natural history's place in science and society. *BioScience* 64: 300-310.

Tomei, L. 2004. The impact of online teaching on faculty load: Computing the ideal class size for online courses. *International Journal of Instructional Technology and Distance Learning* 1: 39-50.

Varty, A.K. 2016. Options for online biology courses at American colleges and universities. *Life Science Education* 15, http://www.lifescied.org/content/15/4/ar58

White, S., and A. Sykes. 2012. Evaluation of a blended learning approach used in an anatomy and physiology module for pre-registration healthcare students. *Proceedings of eLmL 2012, The Fourth International Conference on Mobile, Hybrid, and On-line Learning.* ThinkMind/IARIA, 1-9.

Wilcove, D.S., and T. Eisner. 2000. Whatever happened to natural history? *Chronicle of Higher Education,* 14 September 2000, B24.

Woods, S.R., and G.B. Ruyle. 2015. Informal rangeland monitoring and its importance to conservation in a US ranching community. *Rangeland Ecology and Management* 68: 390-401.