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REVIEW

Innovation in teaching and learning invertebrate zoology in remote and online classrooms

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Abstract

The COVID-19 global pandemic caused instructors to pivot to remote and online teaching, an especially challenging task in hands-on classes such as invertebrate biology. In this special 25th anniversary issue of *Invertebrate Biology*, the authors present a variety of clever and effective ways to help invertebrate biology instructors adapt to teaching in an online environment. Student-centered research and learning are essential in all biology classes, and we explore scientific writing, field trips, do-it-yourself laboratories, and more. These techniques will be useful for classes of varying sizes and types, from non-major undergraduates to graduate students, even after the pandemic is over. Innovation for teaching invertebrate biology online may help facilitate more inclusive courses that serve diverse students more equitably. Ideas for how to best move traditionally hands-on laboratories into online or remote formats are currently also being informally discussed in a collaborative online space for instructors.

KEYWORDS
active learning, invertebrates, pedagogy, undergraduate research

1 | INTRODUCTION

The need to move online sparked by the COVID-19 pandemic has required educators in all fields to re-think many aspects of their curricula, adding to the stresses and high workloads already experienced by faculty (Hodges et al., 2020; Houlden & Veletsianos, 2020; Rapanta et al., 2020). In biology, many laboratory-based courses are centered around hands-on examination and dissection of specimens to study diversity, form, and function; translating such experiences into online or remote modalities has been especially challenging (e.g., Lashley et al., 2020; Procko et al., 2020). For the 25th anniversary of *Invertebrate Biology*, we decided to use this unique moment in time to reflect on how we teach invertebrate zoology and microscopy. This collection of papers brings together expertise in teaching, writing, and research that reflects the breadth and scope of the field. Since the creation of the American Microscopical Society in 1878, our goals have been to advance and encourage microscopy on invertebrates. Our hope in this special issue is to further research and teaching on the fascinating subject of invertebrate zoology, with the exciting possibility of expanding our reach to a wider range of learners through novel techniques for pandemic times and beyond.

2 | TEACHING INVERTEBRATE ZOOLOGY

In the wake of the COVID-19 pandemic, a group of invertebrate zoology educators gathered via Slack (InvertZooEducators.slack.com; see Discussion for how to join) to share their concerns about moving courses involving hands-on dissections, microscopy, experiments, and field trips to an online format. Most of us found it difficult to imagine teaching invertebrate zoology—a course that typically surveys the vast diversity, form, and function of animals without backbones—without hands-on examination of specimens in the laboratory. Likewise, many invertebrate zoologists point to their own field course experiences, such as turning over rocks in tide pools, digging for worms in mud flats, or snorkeling in reefs or seagrass beds, as formative experiences in their own

development as scientists. Field experiences are challenging, if not impossible, to provide during a pandemic. Hands-on activities and active learning clearly improve outcomes in science education (American Association for the Advancement of Science [AAAS], 2011; Handelsman et al., 2004), and many of these principles can be used to improve online education (Darby & Lang, 2019; Conrad & Donaldson, 2011). In short order, ideas began to pour out from our discussions, and included suggestions for many activities that were online-teaching friendly and had already been demonstrated to be effective by members of the group or others (e.g., Ecological Society of America, n.d.; Procko et al., 2020; Society for Integrative and Comparative Biology, n.d.). New ideas for how to modify, convert, or reimagine existing laboratory exercises, such that our learning outcomes could be achieved while teaching remotely, were also shared in our collaborative online space (e.g., Davis-Berg, 2011).

In summer 2020, many instructors taught online-only versions of their courses for the first time, and several invertebrate zoologists kindly shared their experiences and newly developed resources with the group. Many of us started off with the simple substitutions of videos and photographs in lieu of dissections and observations. In our case, we found that these substitutions can even be an improvement from older jarred specimens and should be continued—at least as a supplement to preserved specimens—even after face-to-face classes return. In fall 2020, another crop of instructors taught their courses online for the first time and continued the spirit of sharing ideas and materials. By the time this special issue is published, the spring 2021 semester will be well underway, and we will all be improving our remote, hybrid and online teaching of hands-on activities.

Assessment and grading concerns can be different in the remote or online environment and the face-to-face classroom, and the movement of most assessments online during the pandemic added additional concerns for both students and instructors (Elsalem et al., 2020; Reyneke et al., 2021). A student adjusting to online learning and assessment may have concerns about understanding how to navigate and use online platforms and tools, and reaching out to the instructor for guidance or for help with technical problems could compound their normal titer of test anxiety. Meanwhile, many instructors are worried about increased plagiarism and cheating, which seem to have increased amid COVID-19 lockdowns (e.g., Bilen & Matros, 2020). Avoiding plagiarism in writing assignments has been well studied (e.g., Belter & du Pré, 2009; Selwyn, 2008), and computer-based exam proctoring tools can help to reduce cheating (Lee et al. 2020; Nguyen et al. 2020). The exercises described in this issue should be enjoyable for our stressed-out students while fostering student integrity and reducing cheating through deeper connections with course material, which tend to reduce such issues (Orosz et al., 2015; Robinson et al., 2004).

3 | INTERACTIVE FIELD TRIPS

Field trips are valuable for biology students; these first-hand experiences, provide enhanced context to learning, sharpen observation and perception skills, stimulate interest, engagement, and motivation, and offer opportunities for social interaction with classmates and the instructor (Rahman & Spafford, 2009; Larsen et al., 2017; Zavaleta et al., 2020). Although the COVID-19 pandemic has made traditional field trips impossible—at least in the same manner as many instructors are used to—several invertebrate biology educators have devised field-based course components to leverage the impact of field opportunities and independent research on undergraduate education.

Eugene et al. (2021) present a field-based independent research project where students survey the prevalence and intensity of cysts of the digenetic trematode flatworm *Pleurogonius malaclemys*. The definitive host of this parasite is the diamondback terrapin, which is classified as Near Threatened by the IUCN, and its intermediate host is the eastern mudsnail. Because the parasite produces large, pearl-like metacercarial cysts that settle on mudsnail shells and/or opercula, they can easily be detected and enumerated to determine where terrapin hosts are present, and even estimate definitive host abundance. Because they occur along most of the east coast of the United States, this exercise will be broadly useful to provide field experiences for students, while teaching concepts in parasitology, data collection, and analysis.

Middlebrooks and Salewski (2021) present self-guided field trips in which students went to a local field site to photograph animals and make detailed observations. Students were assigned a maximum number of species that they needed to identify. This contribution specifically discusses the logistics of sending students out into the field without an instructor and how to work on a field site with COVID protocols. They created video guides to the assignment and the locations, a variety of supplies, and asked students to photograph the animals. Photographing animals allowed everyone to avoid chemical preservatives and made for easy submission of student work.

Berke and Clark (2021) sought to teach students through collaborative inquiry-based research projects. They present a student-centered field project exploring terrestrial invertebrate herbivory on plants compatible with students working in person, remotely, or both. This project incorporates experimental design, plant identification (largely leveraging free apps), statistics, scientific writing, and collaborative research skills. Although it is clear the approach used was a success, the authors present a number of ways their approach could be modified to improve learning outcomes, streamline the timing of the project to fit into a more restrictive schedule, and make the course more accessible.

Cowles and Onthank (2021) took remote students along on instructor-led field trips. In areas where mobile service permitted, the instructors led live, interactive field trips using a smartphone and readily available meeting software. In areas with poor or no mobile service, the instructor wore a head- or chest-mounted GoPro and videos (supplemented with photographs taken on a separate camera) were provided to students for later viewing. Likewise, examination of specimens in the classroom and keying exercises were conducted via live, instructor-led video meetings.

4 | WRITING

Scientific writing and engagement with the primary literature are important in all subfields of the biological sciences. Courses with significant writing components have been shown to improve biology undergraduate students' perceptions and confidence of their ability to understand scientific literature and communicate about science (Brownell et al., 2013; Jerde & Taper, 2004). However, writing assignments can be difficult to incorporate into undergraduate courses because of the effort required to evaluate them and provide feedback. Palmer (2021) reports an annotated bibliography writing assignment that has been used over 20 years in an invertebrate biology course. This assignment is aimed at maximizing student engagement with a topic while minimizing the effort required by the instructor to grade the assignments and check for plagiarism. Students like this assignment because it gives them the freedom to explore a topic of their interest. Instructors will find this approach appealing because it enables them to incorporate student exploration of the primary literature and scientific writing with a reasonable amount of work in terms of grading and screening for plagiarism.

5 | REMOTE SPECIMEN-BASED LEARNING

Invertebrate zoology lab courses generally seek to educate students about the diversity, form, and function of animals without backbones by providing guided, hands-on opportunities to study biological specimens. Although there are commercial options for distance learning that send boxes of specimens to students, these kits typically offer limited invertebrate diversity. As part of a fully online invertebrate biology course, Novo et al. (2021) decided to provide students a box of take-home materials so that they could do hands-on work while working remotely. The kits include alcohol-preserved specimens, dried specimens, and microscope slides as well as an affordable but adequate-quality USB microscope. Such kits enable students to perform close-up examinations and dissections of specimens synchronously or asynchronously with guidance from the instructors. Notably, because the students had uninterrupted access to the specimens, they were able to engage with them more than they normally would in a limited laboratory period.

6 | STEAM LEARNING: BRINGING THE ARTS INTO SCIENCE

Lindsay (2021) helps us as scientists make the connection that observation is the first step in both the scientific method and also in art. Through that connection, we can learn about the natural world. Following the call from *Vision and Change: A Call to Action in Undergraduate Biology Education* (AAAS, 2011), Lindsay developed exercises to teach observational skills through "Brain-On" observing. These exercises start with students working in pairs to observe a photograph and then using microscopy to get a closer look at the organism in the photograph. Using microscopy as public outreach can also increase interest in science via programs like the BioBus (www.biobus.org), FoldScope (www.foldscope.com), and Bugscope (bugscope.beckman.illinois.edu). In the classroom exercises, Lindsay has students draw and label marine invertebrates and posit hypotheses as to how anatomical structures function. Lindsay has also used Shick's (2008) suggestion to show illustrations and art related to the topic before class as a means to further link science and art. This links nicely with Schultze et al.'s paper on film festivals, which was inspired by Lindsay's talk at the Society for Integrative and Comparative Biology (SICB) meeting in January 2020.

Schulze et al. (2021) describe a semester-long assignment for their Marine Invertebrate Zoology course that tasked students with researching a topic in invertebrate zoology and creating a 3–5-min video about the topic. Through investigation, design, and creation of an original work, students were able to engage with the material beyond what is normally taught in lab. The instructors provided flexible rules for the videos, with an emphasis on scientific accuracy and creativity. In addition to learning about a specific topic of invertebrate zoology in-depth, students also developed skills in scientific communication and peer-review.

7 | MOBILE LEARNING

Because of their near ubiquity, smartphones are increasingly used by educators to provide students access to interactive teaching materials. These may be as simple as portable versions of textbooks or as advanced as the extended reality applications developed by Verdes et al. (2021). The authors present three diverse applications utilizing virtual reality (VR), augmented reality (AR), and a stand-alone app to make a catalog of the most common species encountered on a field trip. The authors detail the approach used to produce each resource such that similar resources could be produced to fit the needs of other courses.

8 | DISCUSSION

The fascinating topic of invertebrate zoology provides excellent opportunities in both face-to-face and remote/online classrooms for active learning and student-led activities. We know that the ideas presented here will be useful long after this pandemic is over. In fact, the nature of these activities will likely increase course accessibility for all students over more traditional face-to-face classrooms (Freeman et al., 2014; Gin et al., 2020; Izzo & Bauer, 2015), which often do not have students participating in such active roles (Richardson, 2008). We will not stop innovating and improving our teaching, so please join over 150 of us from over 100 institutions as we continue to learn from each other and improve the teaching of invertebrate biology at InvertZooEducators.slack.com. Interested parties are encouraged to reach out to either of the authors via email for an invitation link.

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