Lessons from the unexpected adoption of online teaching for an undergraduate genetics course with lab classes

Chun Zhou

Abstract
In the spring semester of 2020, colleges and universities adopted online teaching as the primary modality due to campus closure for social distancing. While lectures could be more readily converted to online classes, biology labs were challenging to handle since students could not physically conduct experiments in lab classrooms. In the present report, various online teaching materials, including educational and research videos, simulation labs, and real research data, were utilized to achieve the learning objectives of the originally in-person lab classes of an upper-level undergraduate genetics course. Furthermore, certain advantages of online teaching, such as detailed and high-quality annotation of lecture slides using the Apple Pencil and iPad, were observed. While online teaching has its unique strengths, it could not provide students with hands-on experience in performing real biology experiments to master technical skills; the latter are essential for students to develop a career in conducting research in an academic or industrial laboratory setting. Hence, a well-designed hybrid modality of using online teaching to complement conventional face-to-face instruction may allow for better teaching in undergraduate biology courses.

KEYWORDS
COVID-19, CUREs, face-to-face instruction, genetics, hybrid modality, online teaching, simulation labs, undergraduate
only can highlight important concepts but also can reveal mechanistic connections hidden in textbook graphs. Notably, annotation quality appeared much better than that produced with the current smart projection software in classrooms. Furthermore, the ability to record online classes enables students to access the instructor’s “mind” and annotations to help them review the lecture slides after the class at their own pace. This can allow students to focus on critical thinking and synthesizing questions for in-class discussions, rather than taking lecture notes.

To make the transition to online teaching, the instructor used the following two web-based tools as the virtual class platform with the lecture recording function: Blackboard Collaborate Ultra and Zoom. The former is a component of the learning management system—Blackboard Learn (Blackboard Inc., Washington, DC), which is provided to all instructors and students at Mercy College. Zoom (Zoom Video Communications, San Jose, CA) has a free version that is limited for the use of 40 min for group meetings. In response to the COVID-19 pandemic, Mercy College provided a paid full version of Zoom to its faculty and students. From March 11 to 15, the 5-day period given by the college for faculty to prepare for online teaching, the instructor learned how to use these two applications to set up online classes. After the initial intensive learning process, the preparation of each online lecture took about 2 hr. This preparation time was mainly used to figure out how to accurately annotate the lecture slides as the lectures were to be recorded for students’ use. In addition to interacting with students directly during in-class discussions, the instructor offered regular virtual office hours weekly as well as additional Zoom meetings per students’ request. Furthermore, the instructor took time every week to manage the prelecture textbook-reading and postlecture exercise assignments using an online learning platform—Connect (McGraw-Hill, New York, NY) that came with the textbook used for the genetics course.

Second, the teaching objectives of biology labs can still be partly achieved through different types of online lab activities. The genetics course has both lecture and lab classes. Previously, the labs of this course had been redesigned for students to conduct research to identify telomere-regulating genes in *Drosophila melanogaster*, a course-based undergraduate research experience (CURE).³ These CURE labs consist of bioinformatic gene analysis, fruit fly phenotype observation and culture, isolation of genomic DNA, DNA electrophoresis and analysis, polymerase chain reaction (PCR), and real-time PCR. By the time the in-person class was stopped due to the COVID-19 pandemic, only the first two labs had been completed. To achieve the learning objectives of the remaining four labs, the instructor explored free online lab resources and selected a set of online labs to meet the curricular requirements (Table 1). According to the instructor’s observations, students had a good understanding of the mechanisms of the experiments. Although students were not able to physically conduct the experiments, they were able to use their computers to carry out the experiments through simulation activities in which they had to complete the experiments step-by-step. In addition, high-quality educational and research videos played a significant role in showing students how to conduct authentic research experiments and allowing the instructor to dissect the experimental steps. Furthermore, the instructor was able to share the computer screen to demonstrate how to use real-time PCR software (micPCR, Bio Molecular Systems) and analyze the real research data that had been generated from the instructor’s research project.

To conduct these online labs, the instructor designed each lab that consisted of three components: a prelab assignment, in-class lab experiments, and a postlab assignment. The prelab assignments included reading lab protocols, watching videos, and answering some questions designed to probe students’ understanding of the lab protocols. During the synchronous 3-h online lab classes, students conducted the lab activities under the guidance of the instructor. To assess students’ lab performance, the instructor asked students to record their in-class experimental results in their individual electronic lab notebooks on Benchling (San Francisco, CA); the latter provides a free online notebook service for academic uses. The postlab assignments aimed to deepen the student’s understanding of the experiments. Generally, an instructor would need to spend several hours to identify and select a set of high-quality, free, online lab activities that match the lab learning objectives. The selected online lab materials in the present study were of free access. They included the following types: educational videos from Science Education of Journal of Visualized Experiments (JoVE) and YouTube, research experiment videos from PubMed Central-archived JoVE articles,⁴ simulations from JoVE and online open educational resources (OERs) such as HHMI BioInteractive, and the instructors’ research data (Table 1). For each lab, the instructor also took a couple of hours to test lab activities and to design the prelab and postlab assignments. Hence, the instructor in the present report, on average, took about 6 h to prepare for an online lab class. Notably, the prelab and postlab assignments were not planned initially for face-to-face instruction. They were assigned to students to make online teaching of the labs more effective. With the strategy mentioned above, the learning objectives listed in Table 1 for these CURE labs were...
effectively achieved by combining properly selected, different types of online lab activities.

Finally, while the author noticed some advantages of online teaching, it needs to be reminded that the hands-on experience in using micropipettes and other experimental equipment was not feasible in the online teaching modality for the CURE labs. This may not be vital for some students with a major in health professions, such as physician assistant or physical therapy. However, such genuine research experience would be crucial for students in biology majors to develop a career in conducting research in academia or industry. Upon reflection of the unusual past semester, it appears that well-designed online labs can be used to engage students in achieving an in-depth understanding of the science, technology, and experimental protocols. In contrast, in-person labs can give rise to more hands-on experience in conducting the actual experiments. Hence, with the lessons learned from this semester’s exploration of the online teaching modality in a CURE genetics course, when appropriate, a well-designed hybrid course can be implemented to utilize the online teaching modality to benefit the conventional face-to-face instruction for undergraduate biology courses.5

### TABLE 1 Online CURE labs of BIOL 360—Genetics

| DNA isolation and restriction enzyme analysis | Source | Science Education of *Journal of Visualized Experiments* (JoVE) (https://www.jove.com/science-education-library) |
| --- | --- | --- |
| Availability | Temporarily free access<sup>a</sup> | |
| Nature of the lab | Video demonstration and simulation experience | |
| Brief learning objectives | Understand the DNA extraction process and the mechanisms of the protocol | |
| | Understand the DNA gel electrophoresis protocol and the usefulness of the involved reagents | |
| | Master the concepts and mechanisms of restriction enzymes | |
| | Conduct the online DNA digestion experiments, generate digestion results, and interpret the data | |

| Bacterial identification virtual lab | Source | HHMI BioInteractive (https://www.biointeractive.org/) |
| --- | --- | --- |
| Availability | Free access; open educational resource (OER) under the creative commons attribution-noncommercial-ShareAlike 4.0 international license | |
| Nature of the lab | Simulation | |
| Brief learning objectives | Understand the mechanism of PCR | |
| | Understand the PCR protocol and the roles of the involved reagents | |
| | Be able to set up the parameters of PCR | |
| | Be familiar with PCR data analysis | |

| Real-time PCR Part I (procedure) | Source | PubMed Central |
| --- | --- | --- |
| Availability | Free access of a JoVE article via PubMed Central, a digital repository of open access full-text articles including certain video articles from JoVE | |
| Nature of the lab | Video | |
| Brief learning objectives | Understand the mechanism of real-time PCR | |
| | Understand the experimental settings of real-time PCR | |
| | Be familiar with the protocol of real-time PCR | |

| Real-time PCR Part II (data analysis) | Source | Real data from the real-time PCR experiments of the instructor’s research project on the identification of telomere-regulating genes in *Drosophila melanogaster* |
| --- | --- | --- |
| Availability | Free access for the data from the instructor’s research project | |
| Nature of the lab | Instructor’s demonstration and students’ analysis of the real experimental results | |
| Brief learning objectives | Understand the ΔΔCt method | |
| | Conduct calculation and analysis of real-time PCR results | |

<sup>Note: BIOL 360 is a four-credit undergraduate course to discuss the fundamental principles of heredity and variations, spanning transmission genetics, molecular genetics, population genetics, and cytogenetics. There were 20 students in this genetics class in spring 2020. The course met twice a week for a lecture class and a lab class. Each class was scheduled for 2 h and 50 min.<sup>a</sup>Science Education of JoVE was free to use during the COVID-19 pandemic. Other completely free online materials of similar content can also be identified. For example, The Jackson Laboratory has posted free videos of DNA Extraction (https://www.youtube.com/watch?v=tcPgdR9t64 and https://www.youtube.com/watch?v=1PisbDHKXTU) and Restriction Digest (https://www.youtube.com/watch?v=sEjN_fxJN1s) on YouTube.</sup>
ACKNOWLEDGMENT
The author received a Faculty Development Grant from Mercy College.

CONFLICT OF INTEREST
The author declares no conflicts of interest.

ORCID
Chun Zhou https://orcid.org/0000-0003-4114-0897

REFERENCES
1. Carrol N, Burke M. Learning effectiveness using different teaching modalities. Am J Business Educ. 2010;3:65–76. https://doi.org/10.19030/ajbe.v3i12.966.
2. Ahern K. Teaching biochemistry online at Oregon State University. Biochem Mol Biol Educ. 2017;45:25–30. https://doi.org/10.1002/bmb.20979.
3. Zhou C. Identification of telomere regulating genes in Drosophila melanogaster. Northfield, MN: CUREnet CURE Collection, Science Education Resource Center. Available from: 2019. https://serc.carleton.edu/curenet/institutes/mercy/examples/199962.html.
4. Ogrean C, Jackson B, Covino J. Quantitative real-time PCR using the Thermo Scientific Solaris qPCR assay. J Vis Exp. 2010; (40):1700.
5. Potter J. Applying a hybrid model: Can it enhance student learning outcomes. J Instruct Pedag. 2015;17:1–11.

How to cite this article: Zhou C. Lessons from the unexpected adoption of online teaching for an undergraduate genetics course with lab classes. Biochem Mol Biol Educ. 2020;1–4. https://doi.org/10.1002/bmb.21400