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Adapting a Cell and Tissue Engineering Laboratory Course to an Online Delivery Format

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Work in Progress: Adapting a Cell and Tissue Engineering Laboratory Course to an Online Delivery Format

Introduction

The delivery of instruction during the COVID-19 pandemic has required adaptation of lab courses to online formats across higher education. While hands-on laboratory courses are common offerings in biomedical engineering undergraduate programs that improve learning outcomes [1], adapting them for online and remote instructional formats presents a significant challenge. Specifically, practical skills, such as using scientific equipment, technology, and instrumentation, following technical protocols and demonstrating proficiency in physical laboratory techniques [2] are widely regarded as challenging to teach outside a traditional laboratory setting [3]. At-home lab kits are emerging instructional tools currently being used to address this challenge in a variety of scientific courses, such as general biology [4], physics [5], chemistry [6], and engineering controls [7]. To provide students enrolled in an online section of a cell and tissue engineering lab course with hands-on activities for learning laboratory techniques, we prepared a kit containing the equipment and supplies needed to perform various activities remotely. The overarching goal of the class is to educate students on how to safely and skillfully manipulate bacterial and mammalian cells and perform quantitative analyses. The activities included micropipetting exercises, casting and loading DNA gels, simulating cell culture, performing protein quantification, and studying enzyme kinetics using protocols that were adapted to meet safety and lack of equipment limitations. The instructors prepared detailed videos explaining the experimental techniques and organized synchronous lab session meetings with students to review lab protocols as well as to discuss experimental design and data analysis. Here we describe the format of the online sessions, at-home lab activities, and preliminary student feedback. We further discuss limitations and areas for future improvement.

Methods

Course Design Cell and Tissue Engineering Lab is a two-credit core course for second-year students in the bioengineering major at the University of Illinois Urbana-Champaign [8] and was offered both in-person and online during the Fall of 2020. Online students were provided with a kit that contained micropipettes, digital scale, glucose meter, lab consumables, 3D printed gel casting mold and comb, and reagents to perform a BCA and an enzyme assay. The Division of Research Safety at the institution was consulted on the safe handling and disposal of all reagents shipped to students and students were required to complete online safety trainings before beginning lab work. All equipment was disinfected with 70% IPA before shipping and when the equipment was returned. Both in-person and online students completed an introductory lab asynchronously (without a live instructor) over the first two weeks of class that taught basic micropipetting skills [9]. Next, during online sections, instructors played a video of the lab protocol with no audio, pausing the video to explain critical concepts about technique or experimental design or to answer student questions. The instructors also provided additional demonstrations to students (e.g., using a cell spreader to plate bacteria) and explained how to use the kits to follow along with the protocol video. In addition to these live, synchronous sessions, students were also provided additional activities to complete using the lab kits (Table 1).

Plasmid Module The goal for this module is to educate the students on both bacterial cell culture and basic experimental design. Online students were tasked with designing and implementing an experiment to test an antiseptic using LB/agar plates. Students were challenged to identify controls, use of replicates, and discuss potential confounding variables. Students presented one slide summaries of their experiments. This set of labs meets the objective of the module as it mimics the in-person labs ability to educate the students about setting up control schemes, interpreting different variables, and maintaining bacterial cells.

Mammalian Cell Culture Module The goal for this module is for the students to become comfortable with aseptic technique and learn about culturing mammalian cells. The online section practiced cell culture techniques using lab kits, including creating a video demonstrating aseptic technique to assess their progress. Online students also completed a virtual cell culture simulation [10]. Although outside of a biosafety cabinet, the students were able to learn about and practice aseptic technique, meeting the objective of this section.

Pharmaceutical Drugs Module The goal for this module is to quantify protein concentration in cell lysates and understand how a drug treatment may cause changes in cellular signaling. While in-person students created cell lysates and measured protein concentrations with a BCA assay, online students received a BSA solution of unknown concentration and performed a BCA assay to determine protein concentration. Since 37ºC incubators were not available to students, reactions were incubated for 30 minutes at room temperature instead of the standard 15 minutes at 37ºC for BCA assays. Students imaged their BCA assay using their cell phones and used ImageJ software [11] to measure color change of the samples as a surrogate for absorbance readings measured with a spectrophotometer.

Enzyme Module The goal for this module is to quantify enzyme kinetics. Online students compared the kinetics of two different brands of lactase supplements by digesting lactose solutions following the instructions provided by instructors. Students also independently designed an experiment to test how altering a single variable of their choice influenced lactase kinetics. Digestion of lactose to glucose was measured using glucose meters. Additionally, students practiced gel loading using 3D printed gel casting trays and combs to cast a gel using Jell-O. Students practiced loading samples into the gel with a dye and glycerol solution provided in the lab kit. The online students completed essentially the same lab as the in-person students, with only minor changes to the enzyme of choice, allowing for the course objective in this unit to be met.

Data Collection Institutional Review Board approval was obtained to conduct student surveys (University of Illinois Urbana-Champaign IRB #21224). Students were asked to assess the effectiveness of the online delivery format in accomplishing the learning objectives. Survey items included 5-point Likert scale questions and open-ended questions. The questions covered topics such as perceived effectiveness (e.g. "The remote lab was effective at helping me meet the course objects") and areas for course improvement (e.g. "What course resources or activities did you find least useful in learning how to perform the lab techniques covered in this class?"). No incentives were offered for participation in the surveys. In the initial survey 8 of 29 students responded and in the second end-of-semester survey 3 of 29 students responded (27.5% and 10% response rate, respectively).

Results

Though the low response rates make generalization difficult, the student feedback about the online labs and lab kits was overall positive. The at-home lab activities that were identified as the most useful by the students were the BCA assay and enzyme assay, which we attribute to being closest to the in-person section activities. While student feedback on the technique videos provided was mixed, students indicated that the live lectures that included technique demos was helpful and further suggested that additional sessions for online students to get instructor feedback on their technique would be beneficial. Finally, students indicated a preference for synchronous compared to asynchronous lab sessions, which was in agreement with student feedback received in Spring 2020 when all labs were asynchronous.

Module	Lab #	Experiment	Online Section Supplemental Activity
Intro	1	Pipetting skills*	Pipetting skills*
Plasmid	2	Serial dilutions of bacteria culture, plating liquid bacteria cultures on to solid cultures, measuring optical density	Design an experiment to test a disinfectant by growing bacteria on solid culture
	3	Bacteria transformation	Discuss experimental designs in small groups
	4	qPCR and miniprep	Discuss experimental results
Mammalian Cells	5	Cell Culture	Practice cell culture and aseptic technique
	6	Cell lysis and freezing	Practice cell culture protocol
	7	Cell thawing and staining	Virtual cell culture tutorial
	8	Fluorescence microscopy	Create a video showing a daily activity using aseptic technique
Pharmaceutical Drugs	9	BCA assay	BCA assay
	10	Western blot	Discuss BCA results and data processing
Enzymes	11	Restriction enzyme assay DNA gel electrophoresis	Lactase enzyme assay Cast and load gel

*All students completed this asynchronous lab and at-home activity

Table 1. Summary of in person and online lab activities.

Discussion and Future Work

Here we describe an online cell and tissue engineering laboratory course. We developed at-home lab kits for students to learn basic laboratory skills as well as design and conduct experiments at home. Despite the unique opportunities provided by these activities, we do not believe they are a complete replacement for in-person lab instruction. The overall student feedback indicated that the addition of the lab kits was a welcome approach given the limitations of COVID-19 for lab instruction but, nonetheless, we identified several areas for further improvement. Additional student feedback and assessment of learning outcomes will be necessary to continue improving the course delivery. IRB-approved incentives such as extra credit or a gift card raffle could be offered to increase the number of survey responses. Student ratings of self-efficacy, perceived lab authenticity, and personal interest compared to performance could offer valuable insights for future classes. Assessing student’s ability to perform hands-on experiments is particularly challenging for online students, who were only assessed based on their conceptual knowledge. For future classes, it could be useful to compare the data between the written exams scores of online students and in-person students. The results of this work can be used to adopt similar at home instructional lab models at other institutions as well as guide the implementation of future online lab course offerings or supplemental activities for in-person lab course offerings.

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