Special Sections: Opportunities and Challenges of Online Instruction

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Educating Online Students in Laboratory Safety

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INTRODUCTION

The importance of laboratory safety education for students enrolled in a face-to-face course is understandable. For students to avoid harming themselves or causing injury to others in the physical lab space, they need to be instructed on how to behave safely. This is typically achieved by taking time the first day to review college-specific regulations and going over the American Society for Microbiology (ASM) biosafety guidelines (1) as well as reviewing important safety considerations at each lab period. Properly implementing the industry standards for laboratory biosafety (1–3) increases the likelihood that students will mitigate potential threats and develop the necessary precautions (4, 5). By creating a culture of teaching and implementing laboratory safety we can ensure that students will retain these instructions as a skill and not merely course content.

In a face-to-face course, taking the time to learn laboratory safety makes sense to both the instructor and the student, and is considered an essential skill (6). Over the years, lab safety education has been diminishing as many instructors are not properly trained on implementation or have a lack of administrative support (7–10). This can result in students that are not educated in safety, nor understand the importance of why those guidelines exist (9) and are potentially placed in dangerous situations (1, 2, 6).

The challenge then arises when instructors attempt to teach laboratory safety to students that are not required to physically enter a lab during the semester. When the transition to online teaching occurred in March 2020, faculty had to find alternative resources to teach lab material, including biosafety techniques (11), while continuing to offer authentic laboratory experiences even in the absence of being in the lab face-to-face (12). Although students may not physically be in a lab during their current semester, they may be in a future semester or their career. Therefore, understanding the rules, protocols, equipment, and expectations for operating safely in a laboratory of any type (i.e., school, company, hospital, etc.) is not just important, but necessary.

While there are online labs and simulations (such as Labster; https://www.labster.com/) that introduce students to lab safety via a simulation with embedded questions, we aspired to create a full lab period of instruction about lab safety without using a company's product which would increase the cost for the student. Online simulations have proven to be an effective tool in student engagement (13–15). Burke et al. (16) showed that as training becomes more engaging, the transfer of knowledge to safety understanding is shown. For schools with limited resources, lab simulations and web-based resources allow students to be flexible with their education as well as highly interactive (17).

We took a universal design for learning (UDL) approach by using a variety of resources (simulations, videos, pictures, etc.) to ensure equitable access to learning that reduces barriers in instruction and fosters student engagement (18), In UDL, faculty incorporate a variety of materials such as text, charts, images, simulations, videos, and animations that allow students with a wide variety of abilities to understand, and engage with, the material (18). Incorporating UDL principles leads to improved quality of student work in online courses (19, 20). UDL is a proven mechanism for meeting the learning needs of students that come from diverse backgrounds (19).

The student objectives of this online, asynchronous laboratory activity are to (i) interpret and demonstrate the importance of online laboratory safety instruction, and (ii) discuss how to implement proper laboratory safety techniques during future face-to-face instruction. In this article, we provide a suggested sequence of activities using a variety of resources to relay the importance of laboratory safety to students while also providing flexibility in the information presented to ensure engagement.

PROCEDURE

With the shift to online instruction, we wanted to reinforce the importance of laboratory biosafety education. We looked to published resources with materials that met UDL criteria (18–20), showed to increase student engagement (13, 14), and offered web-based equitable resources to serve those

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institutions that are considered under-resourced (such as minority-serving or community colleges) (7). We selected activities that would address the main safety concerns, show students the consequences when lab safety protocols are neglected (5), and cover the ASM Guidelines.

We designed our online lab at the Community College of Rhode Island (CCRI) in a PowerPoint format containing a total of seven exercises with additional exercises for microbiology courses. The PowerPoint included background information on each of the exercises, pictures, safety videos for students to watch (Appendix 1), as well as virtual simulations. Videos made by the instructors with captioning were posted in Blackboard to offer students additional instruction: for example, one explains how students should proceed through the lab (while highlighting safety themes) while the second one is a postrecording of the answers to the lab assignment.

As students worked through the exercises, they completed a lab assignment. The lab assignment consisted of questions on the exercises and information provided, and when completed was approximately five typed pages. An example of these lab assignment questions is listed in Appendix 3. Once the exercises were completed, students took a content quiz through Blackboard. We applied the UDL principle of multiple methods of assessment by offering students both a lab assignment and a quiz to demonstrate their understanding of the content.

Students needed a computer, Internet connection, and Microsoft Office to access the PowerPoint, Blackboard, websites, and lab assignment (in Microsoft Word). The lab completion time averaged 4 hours (simulations, quizzes, lab assignment, lab videos, study time). There are no safety issues associated with these exercises since it is a completely online procedure.

The PowerPoint started with an introduction to laboratory safety and an explanation of its importance. Students proceeded through the following exercises (links located in Appendix 2):

- Exercise 1 – American Society for Microbiology (ASM) (1) and CCRI-specific laboratory safety guidelines. Students reviewed the guidelines and answered questions focused on comprehension of proper laboratory biosafety.
- Exercise 2 – Lab safety violation pictures. Students viewed pictures and had to identify lab safety violations. For example, a picture may have shown a student dressed in shorts and flip-flops, or an image of the lab door propped open. Students then completed a chart in the lab assignment identifying each violation and describing the importance of the rule being broken.
- Exercise 3 – Occupational Safety & Health Administration (OSHA) and Safety Data Sheets (SDS). Students received links to websites where they reviewed specific sections of the sixteen main SDS components. https://www.osha.gov/sites/default/files/publications/OSHA3493QuickCardSafetyDataSheet.pdf.
- Exercise 4 – OSHA and Hazard Communication Standard pictograms. Students received links to websites where they reviewed the pictograms used to describe chemical safety. https://www.osha.gov/sites/default/files/publications/OSHA3491QuickCardPictogram.pdf.
- Exercise 5 –NC Bionetwork lab safety simulation. Students received the link to an interactive simulation demonstrating proper lab safety that includes choosing PPE, identifying dangers in the lab, recognizing safety equipment and the appropriate time to use it. Students were asked to screenshot the completion certificate and insert it into their lab assignment. https://www.ncbionetwork.org/iet/labsafety/.
- Exercise 6 – NC Bionetwork Zombie college safety simulation. Students received the link to a simulation that used a zombie apocalypse to demonstrate the potential hazards of ignoring lab safety. Students were asked to screenshot the completion certificate and insert it into their lab assignment. https://www.ncbionetwork.org/iet/zombie-college/index.html.
- Exercise 7 – SDS agreement. Students chose two chemicals and answered questions using the appropriate SDS. Completion of this assignment is required for students to remain enrolled in the course. We have the same rule for face-to-face courses as well.

For our upper-level and Microbiology courses, we added three additional exercises that directly pertain to biosafety when handling microorganisms.

- Exercise 8 - Blood Borne Pathogen (BBP) training. Students received a link to review a PowerPoint on BBP training. https://ccri.edu/biology/faculty_and_staff_training.html.
- Exercise 9 - The Centers for Disease Control Biosafety Levels. Students visited the website and completed a quick-learn lesson on biosafety levels. Students inserted a screenshot of the final screen into their lab assignment. https://www.cdc.gov/training/quicklearns/biosafety/.
- Exercise 10 - Risk group microorganisms. Students visited a website that described the various risk groups and examples of microorganisms located in each. Students answered questions in the lab assignment to measure their comprehension of relationships between the groups and biosafety levels from the previous exercise. https://2021.igem.org/Safety/Risk_Groups.

CONCLUSION

This asynchronous, online remote laboratory activity is a comprehensive way to teach students the importance of laboratory biosafety. The combination of simulations and information from professional organizations immerses students in a more interactive and thorough lab safety education, compared to the instructor-led review of safety guidelines typically presented on the first day of an in-person lab. This offered flexible and varied types of instruction for students that may require a range of support materials.

This assignment can be used in any course (remote or in-person) that requires students to know how to properly implement

laboratory safety when working in a lab space. Additionally, remote instructors using biology take-home laboratory kits can modify this assignment to align with the materials and procedures of the kits their students are using (12). Offering lab experiences to students through asynchronous online and distance education provides a more flexible schedule to students in different geographic locations. This model for learning lab safety is not only necessary during semesters when lab courses are forced into or scheduled in a remote format but will also serve students (and instructors) well in their face-to-face courses. Assigning these interactive activities before the first lab meeting will allow students to be informed and prepared upon entering the laboratory (5). Further, it can save valuable hours that may be better used for hands-on, chemical-based activities, or dissection (i.e., wet labs) that are poorly simulated on the computer and require instructor supervision and equipment (17). We envision this as also being used in a flipped classroom setting or hybrid instruction.

In the wake of the pandemic, schools can take full advantage of using online resources (4) such as simulations to master lab safety while also creating an engaging, active learning experience that can improve conceptual learning (13) in either an in-person, online, or hybrid modality. This could be a particularly useful alternative resource for institutions that may not have adequate faculty training or are considered to be underresourced as an alternative source (7).

Future additional content might include a pre-lab assignment, a discussion board on lab safety to foster collaboration (20), a student recorded lab procedures (21), and a rubric on the lab assignments. Maldarelli et al. (14) discussed videotaping laboratory techniques as a virtual way to increase students' confidence with certain techniques. Videos of the instructor practicing these techniques could make it more significant and form a further connection to students.

The lessons of laboratory safety are wide-reaching. One of the greatest challenges for educators is to help students understand the importance of course content not only "across the curriculum," but also as it pertains to the many nonacademic roles they play each day. By using these activities and simulations, students are taught the importance of laboratory safety even when participating in a remote lab science course.

SUPPLEMENTAL MATERIAL

Supplemental material is available online only.

SUPPLEMENTAL FILE 1, PDF file, 0.1 MB.

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