4-7-2022

Microbiology Laboratory Simulations: From a Last-Minute Resource during the Covid-19 Pandemic to a Valuable Learning Tool to Retain—A Semester Microbiology Laboratory Curriculum That Uses Labster as Prelaboratory Activity

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JMBE Journal of Microbiology & Biology Education

Microbiology Laboratory Simulations: From a Last-Minute Resource during the Covid-19 Pandemic to a Valuable Learning Tool to Retain—A Semester Microbiology Laboratory Curriculum That Uses Labster as Prelaboratory Activity

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KEYWORDS online learning, simulations, microbiology, pedagogy, curriculum

INTRODUCTION

The Covid-19 pandemic forced many educators to quickly change the way we teach. We needed to find ways to deliver our curriculum virtually rather than in person. Those of us who teach laboratory skills found ourselves challenged to modify hands-on laboratory lessons to virtual laboratory lessons while maintaining satisfactory learning outcomes. When the pandemic-related demand for home-lab kits overwhelmed supply, I was forced to consider using online simulations as a substitute for in-person laboratory.

At first, I was skeptical that online lab simulations would be an acceptable substitute for the in-person experience. However, after experimenting with various programs, I found the Labster simulations created by scientists, curriculum designers, and game developers well-designed and engaging for students. They also align with the ASM Curriculum Guidelines for Undergraduate Microbiology (1). The Labster platform offers a range of simulations from biology to chemistry, including microbiology and biotechnology (https://www.youtube.com/watch?v=I8LXQq5_VL0). Instructors can adopt an entire package, such as the microbiology package, or pick the simulations that best suit their curriculum. Supplemental resources accompany the simulations for both instructors and students. Available for download are the questions students will have to answer during the simulations, the theory that the simulations cover with background concepts, and templates to assign as homework, such as a lab report. During the simulations, students control the hands of a scientist with their mouse and go from wearing safety equipment before entering the lab to analyzing results at the end of a simulation (Fig. 1). The simulations are educational and connect to entertaining real-world scenarios. For example, the PCR simulation is set up as a murder mystery that students have to solve using DNA profiling.

I decided to adopt Labster and used the simulations for the first time in the Fall semester of 2020 microbiology course since we were forced to deliver the course entirely online. After the course ended, we surveyed the 92 students, distributed in 4 different online lab sections, who had completed the course. Ninety-one students completed the survey, a 98.9% response rate. Fig. 2 shows the distribution of the students' response to the question asking them how much they like the Labster simulation on a scale from 1 to 10, with 1 being the lowest. The distribution is left skewed, with the majority of students indicating they liked the simulation (skewed toward the high end of the scale). Table 1 shows the supporting descriptive statistics. The mean response was 8.19 (SD = 1.84), the median was 8 (Q1 = 7 and Q3 = 10), and the mode 10.

Students reported that they liked the simulations and learned from them, providing reasons why they did or did not find them useful for learning (Appendix 1). The students' feedback aligned with the available literature documenting the efficacy of online tools in improving student learning (2–4). Based on this feedback, I decided to retain the simulations and incorporate them into the curriculum as prelaboratory tools when we returned to in-person teaching in Fall 2021. This article outlines a semester-long microbiology curriculum that integrates the Labster simulations as prelaboratory exercises to enhance student

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The author declares no conflict of interest.
Received: 1 October 2021, Accepted: 13 January 2022

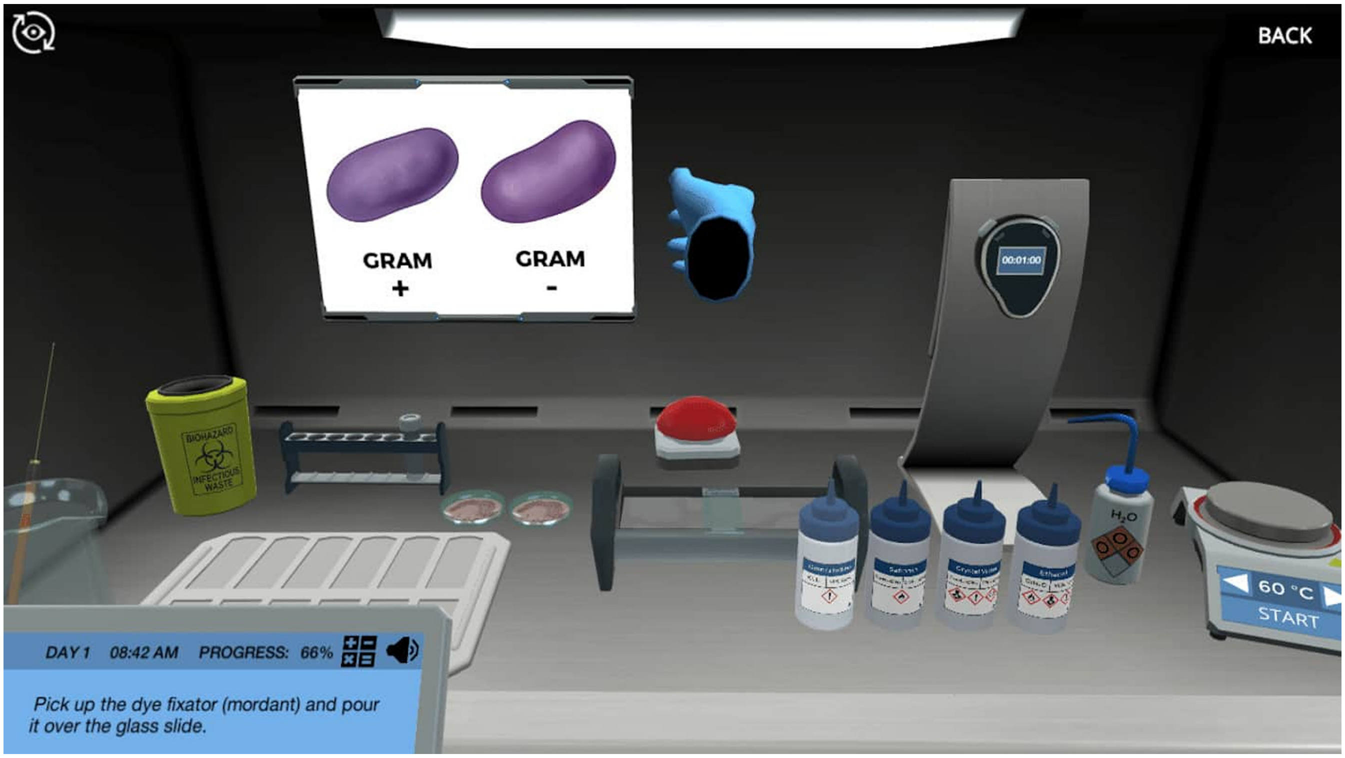

FIG 1. Snapshot of part of the Gram staining simulation. Students control the hands of the scientist with their mouse. On the bottom left, the lab pad is available to students during the entire simulation. Students record the data on the lab pad and can access the information on the theory behind the lab through it.

learning and help students prepare for the in-person laboratories that follow the simulations (Table 2).

PROCEDURE

Labster integrates with many Learning Management Systems (LMS), including Canvas, Blackboard, and Google classroom. This allows instructors to easily deploy the simulations by downloading them as a cartridge package and then uploading them into the LMS of choice. The students can access the simulations in their LMS and are not required to login via the Labster website. For example, Canvas displays the Labster simulations under assignments. To assess the students' progress, Labster has built-in quiz questions running through each simulation and reports scores directly to the LMS. Instructors can also use the question bank provided on the website to test the students after the simulation, and they can assign lab reports using the files available for download. The simulations are assigned to students before the in-person lab meeting time. Table 1 shows the simulations that I selected for the semester, the in-person laboratory that follows the simulation, the learning outcome of each simulation, and the techniques that students will practice. Reading resources and links for the kits used for the in-person laboratory are provided in Appendix 1.

Intended audience

This laboratory sequence is intended for undergraduate students taking a microbiology course. It can be adopted for biology majors and health science majors. Table 1 shows a semester-long course designed for an in-person laboratory that is supplemented with the lab simulations. Instructors can adopt the sequence for full online delivery by removing the in-person laboratories listed.

Safety issue

The first simulation assigned to the students is the lab safety simulation. The instructor reiterates lab safety guidelines during the first in-person meeting as well. The experiments listed for the in-person teaching laboratory follow the safety guideline available on the American Society of Microbiology website (https://asm.org/Guideline/ASM-Guidelines-for-Biosafety-in-Teaching-Laborator). This study is IRB exempt.

CONCLUSION

This paper provides a guide for instructors who are interested in adopting simulation as a prelaboratory activity in a semester of microbiology for undergraduate students. Many

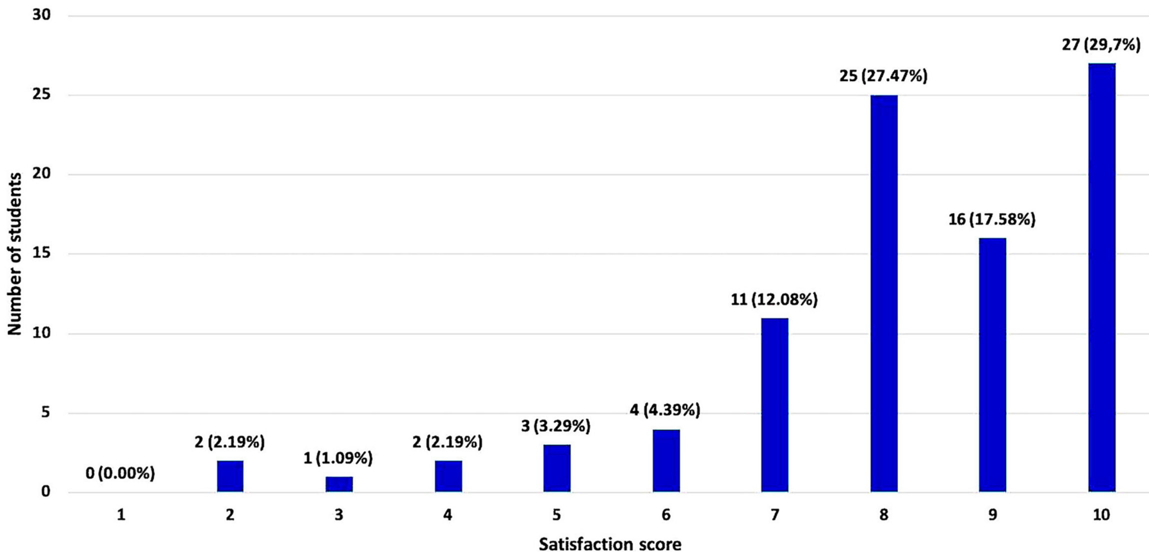

FIG 2. Distribution of student ratings of the online simulations. 91 students, who were distributed in 4 different online lab sections in the Fall semester 2020, responded to the following question: "from 1 to 10 (1 being the lowest), how much did you like the Labster simulation as a learning tool?" On the <ix> axis the scores are reposted, and on the <iy> axis the number of students and the percentage in parenthesis are reported.

studies, especially during the Covid-19 pandemic, have discussed the important role that online simulations can play in advancing student learning, both when in-person laboratories are not possible and as a supplement to in-person laboratories (5, 6). Online laboratory simulations can be integrated in a laboratory setting to improve student learning and their preparedness for in-person laboratory activities. They also provide students with experience in the application of some laboratory instruments that could be costly for an undergraduate institution to upgrade or purchase. For example, the Gram staining simulation can cover important concepts without the worry of visualizing the results because it does not require microscopes. Laboratory simulations also enable the switch to fully remote delivery of laboratory classes, even at short notice, and they can accommodate the needs of students who cannot attend face-to-face laboratory.

TABLE 1
Descriptive statistic of the distribution of student's rating[a]

Analysis variable: scores								
N	Mean	Std dev	Lower 95% CL for mean	Upper 95% CL for mean	Mode	Median	Lower quartile	Upper quartile
91	8.1868132	1.8373416	7.8041683	8.5694581	10.0000000	8.0000000	7.0000000	10.0000000

Scores	Frequency	Percent	Cumulative frequency	Cumulative percent
2	2	2.20	2	2.20
3	1	1.10	3	3.30
4	2	2.20	5	5.49
5	3	3.30	8	8.79
6	4	4.40	12	13.19
7	11	12.09	23	25.27
8	25	27.47	48	52.75
9	16	17.58	64	70.33
10	27	29.67	91	100.00

[a]The mean is 8.19 (SD = 1.84), the median was 8 (Q1 = 7 and Q3 = 10), and the mode 10.

TABLE 2
Prelab online simulation and corresponding laboratory activities for an 11 weeks laboratory class[a]

Topic	Learning outcome for the laboratory simulation[b]	Techniques applied
wk 1 Lab safety[c] (22) BioSafety[c] (48')	• Wear the correct clothing to work in the lab. • Describe the do's and don'ts in a laboratory • Correctly use the lab safety equipment • React in an emergency situation • Understand how a Biosafety containment level III laboratory is constructed • Understand the basic safety rules of a Biosafety containment level III laboratory • Handle microorganisms in a Biosafety containment level III laboratory	• Students go through the simulation for laboratory safety and bio safety before coming to in person lab. • The biosafety laboratory simulation is more advanced and can be skipped based on instructor needs.
wk 2 Aseptic technique: Culture your sample without contamination[c] (20') Testing antimicrobial agents[d] Column contents from https://www.labster.com/.	• Understand the principles of aseptic technique for the prevention of infection and contamination • Create and maintain a sterile work area • Use sterile equipment and consumables correctly • State potential sources of microbial contamination • Assess whether a sample was contaminated	• Aseptic technique • Culturing
wk 3 Control of Microbial Growth: Explore decontamination and selective toxicity[c] (54') Foiling Spoilage with Chemical Preservatives[d]	• Explain how and why microbial colonization occurs • Recognize potential sources of contamination. • Describe the consequences of unregulated population growth. • Describe the ideal environments for microbial growth and how they can be manipulated. • Appreciate different levels of selective toxicity • Describe modes of microorganism growth control. • Define selective toxicity and what it means for host organisms. • Differentiate between disinfectants, antiseptics, and antimicrobials. • Explain the utility of antimicrobial agents • Appreciate why different antimicrobials are effective against different infections. • Select an appropriate antimicrobial to target a given microorganism. • Compare the effectiveness of different antimicrobial compounds.	• Diffusion disk assays • Decontamination methods • Sterilization techniques
wk 4 Gram staining[c] (55') Gram staining[d]	• Describe the structure of the Gram-positive and Gram-negative bacteria • Appreciate theoretical and technical aspects of the Gram staining procedure	• prepn of bacterial smears • The Gram stain technique • Light microscopy

(Continued on next page)

TABLE 2 (Continued)

Topic	Learning outcome for the laboratory simulation[b]	Techniques applied
	• Know the most commonly made mistakes in Gram staining • Critically interpret the results of a Gram staining expt using a light microscope	
wk 5 Pipetting lab[c] (11') Gel electrophoresis (10')[c] Viral Diagnostics Lab: Beating the Next Pandemic[d]	• Explain why micropipettes are used in laboratory settings • Choose the correct pipettor for a given use case • Describe how to correctly use of the two stops on a micropipette plunger • Explain the visualization and separation of nucleic acid molecules through gel electrophoresis • Summarize how nucleic acid molecules migrate through an agarose gel • Explain the principles behind size separation and direction of migration • Analyze and interpret a nucleic acid gel by using a DNA ladder and controls	• Pipetting • Gel electrophoresis
wk 6 Genetic Transfer in Bacteria[c] (32') Rainbow transformation[d]	• Distinguish vertical gene transfer from horizontal gene transfer • Understand the concept of genetic variability and survivability in bacteria • Describe the concept of horizontal gene transfer • Identify genetic elements and cell machinery required for DNA transfer • Outline the main events that occur during conjugation, transformation, and transduction • Discuss the outcome and barrier of genetic transfer in bacteria	• MEGA-Plate setup • Basic agar plate setup • Bacteria morphology examination
wk 7 Polymerase Chain Reaction[c] (33') GMO detection (part 1)[d]	• Explain the function of DNA polymerase in DNA replication and synthesis • Perform a PCR expt using DNA from a blood sample as the template • Carry out a gel electrophoresis that separates DNA according to its size • Interpret the unique signature of the human genome and the use of tandem repeated regions (TRR) in DNA profiling	• Polymerase Chain Reaction (PCR) • Gel electrophoresis • DNA profiling
wk 8 Molecular cloning[c] (57') GMO detection (part 2)[d]	• Understand molecular cloning techniques: DNA extraction and prepn, ligation, transformation, plate streaking and antibiotic selection • Understand inducible gene expression regulation • Understand the use of GFP as a reporter gene	• DNA extraction • Transformation • Colony screening • Cloning

(Continued on next page)

TABLE 2 (Continued)

Topic	Learning outcome for the laboratory simulation[b]	Techniques applied
	• Understand DNA damage and DNA repair system	
wk 9 CRISPR-Cas applied to TGF-beta induced EMT[c] (49') Knockout! A CRISPR/Cas Gene Targeting Lab 1[d]	• Describe the basics of CRISPR-Cas technique • Design a guide RNA construct for knock-out strategies • Evaluate CRISPR-Cas9 results	• Immunofluorescence • CRISPR-Cas9
wk 10 Introduction to Immunology Simulation[c] (57') Knockout! A CRISPR/Cas Gene Targeting Lab 2[d]	• Discuss the fundamental need for the immune system • Identify physical and chemical barriers against pathogen invasion • Describe mechanisms of immune evasion by pathogens • Predict the outcome of scenarios of immune deficiency • Summarize the key features of innate and adaptive immune responses • Describe antigen-antibody interactions • Classify immune cell types by their role in responses • Define immunological memory and its importance • Explain the importance of lymphocyte clonal selection & deletion processes • Explain the concept of diagnostic serology Identify common features and principles of serological methods • Compare the applications for serological methods in biomedical research and healthcare	• Serological investigation • Enzyme-linked immunoassay
wk 11 Elisa[c] (48') Covid testing Elisa[d]	• Explain the principle of different ELISA techniques • Apply sandwich ELISA to quantify protein samples • Analyze the standard curve of ELISA expt • Understand the function of reagents and equipment used in ELISA • Describe the basic troubleshooting process of ELISA	• Sandwich ELISA
wk 12 Antibodies[c] (37') Identifying the Epstein Barr virus using ELISA[d]	• Understand the structure and function of antibodies • Understand the formation of the antibody-antigen complex	• Blood typing

[a]The online simulations are assigned ahead of the in-person laboratory meeting. The length of the online simulation is listed in column one in minutes. Learning outcome of the online simulations as reported from the Labster website, is listed in column two.
[b]Column contents from https://www.labster.com/.
[c]Simulations available on the Labster website, https://www.labster.com/.
[d]In-person lab activities. Link to kit is available in Appendix 1.

SUPPLEMENTAL MATERIAL

Supplemental material is available online only.

SUPPLEMENTAL FILE 1, PDF file, 0.03 MB.

ACKNOWLEDGMENTS

I thank Helen Powell for her help with the statistical analysis, the Jefferson Center for Teaching and Learning for the help with the proof of this paper, and Labster for the permission to reproduce images and materials from their website. Publication made possible in part by support from the Thomas Jefferson University Open Access Fund.

I have no conflicts of interest to declare.

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