

A Case Study Exploring the Development of a Quality Open Education Clinical Microbiology Lab Manual and Online Experiential Lab Course

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Abstract

The benefits of online instruction favor the flexibility of teaching and learning anywhere, anytime. However, online education poses a specific challenge for courses within the hard sciences, such as microbiology, due to the specificity of laboratory equipment utilized and laboratory safety guidelines followed in traditional (in-person) lab courses. As such, traditional experiments may not readily transition to an “at home” environment nor are virtual lab instruction platforms considered “equal” by many hard science departments. Research suggests that effective online learning results from careful planning and instructional design strategies through a systematic model for design and development (Hodges et al., 2020).

The University of North Alabama (UNA) is primarily a teaching institution focused on student success, academic access, and affordability. It had been working on expanding its online programming in the three years prior to the pandemic through committed funding to support robust online experiences, including funding for Quality Matters (QM) course reviews and stipends for faculty to investigate and adopt Open Educational Resources (OER). UNA not only successfully transitioned to the online

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environment during the pandemic but also experienced record growth in overall enrollment due in part to the support systems available for professors who were interested in transitioning online prior to the pandemic. This paper explores how the combined efforts of a microbiology professor, OER librarian, and instructional designer created a high-quality, practical, and experiential laboratory learning opportunity for students using an open, online environment in microbiology.

Introduction

Background

In March 2020, the COVID-19 pandemic introduced striking changes in higher education, as professors transitioned to “emergency remote teaching” (Hodges et al., 2020). However, transitioning to a remote teaching environment during a crisis or disaster does not reflect the ideal approach for professors moving their instruction online. Prior to the pandemic, online learning—especially in the hard sciences—carried a stigma of being lower quality than its traditional classroom counterparts (Hammerness et al., 2022). While the benefits of online instruction favor the flexibility of teaching and learning anywhere, anytime, online education poses a specific challenge for the hard sciences. Furthermore, courses, such as microbiology, that study microscopic organisms (e.g., bacteria, viruses, fungi, protozoans, and other microbes) require expensive and specialized equipment like microscopes, incinerators or Bunsen burners, stains, growth media, and incubators. They also pose a potential health hazard when students are not properly supervised during use of equipment and microbial cultures. As such, traditional experiments may not readily transition to an “at home” environment nor are virtual lab instruction platforms considered “equal.”

In addition to the challenges presented by moving a microbiology course online, the University of North Alabama’s (UNA) Anderson College of Nursing and Health Professions (ACONHP) requires that all students complete a microbiology course. The Department of Biology created a clinical microbiology course specifically to support ACONHP’s nursing programs.

To address these challenges, a clinical microbiology course was developed using the Quality Matters (QM) internal review process, so that lecture and lab components could be offered in either a traditional or online modality for ANCOHP students. Research suggests that effective online learning results from careful planning and instructional design strategies through a systematic model for design and development (Hodges et al., 2020). To accomplish the goals of the course development, the instructor of record, an instructional designer (ID), and an Open Education Resources (OER) librarian combined efforts to build an open online laboratory manual using the respective frameworks.

This paper explores the frameworks, support systems and the innovative ideas detailing how the disciplines worked collaboratively to produce a quality online learning experience for the clinical microbiology laboratory by creating a novel OER that meets the American Society for Microbiology (ASM) standards for allied health science students.

The University of North Alabama

Like other higher education institutions worldwide, UNA was faced with the need to rapidly transition courses online at the beginning of the pandemic. UNA had been working on expanding their online programming in the three years prior to the pandemic and had committed funding to support robust online experiences, including funding for QM course reviews and stipends for faculty to investigate and adopt OER. UNA is primarily a teaching institution focused on student success, academic access, and affordability. To address these focus areas, the university implemented banded tuition in 2018, which is a flat rate fee for students taking between 12 and 18 credit hours and has frozen tuition since the Fall semester of 2018 (Eubanks, 2019). In the 2020-2021 North Alabama Online Annual Report, Provost Ross Alexander noted “Additionally, and notably, the University has celebrated record enrollment every consecutive term since Summer 2018, including this past Fall and Spring during the pandemic, as a direct result of online education” (p. 3).

During 2019, the Department of Biology and ACONHP began to discuss the development of online courses that would be offered through the Department of Biology to support programs of study in ACONHP. One class that emerged from these discussions was a new clinical microbiology course for nursing and allied health majors that provided a microbiology course tailored to the scientific background of allied health students. As with many other nursing programs, UNA’s ACONHP requires a course in microbiology as a prerequisite to their nursing program. Rather than mixing ACONHP students in courses with Biology majors, who have more rigorous training within chemistry and physics, and trying to introduce all aspects of microbiology, this new clinical microbiology course focuses on content that would best prepare allied health majors for their later coursework and professions. In addition to creating a course specific to the needs of ACONHP students, the new course was designed with the additional advantage of being offered in either the traditional or online modality while maintaining ASM standards for microbiology education in the allied health sciences for both lecture and laboratory course components (ASM, 2018a). A lab manual was written specifically for the course that attempted to keep content and experiments as similar as possible between the two modalities thus giving online and traditional laboratory students hands-on practice for the development of necessary microbiological skills. The lab manual is openly licensed and available to students at no costs; traditional laboratory students pay a \$50.00 lab course fee to cover microbiological media costs including bacterial growth media and cultures while online lab students pay \$60.00-\$70.00 to purchase pre-made bacterial media plates and a microscope with staining kit from online vendors such as Amazon.com.

The Department of Biology is made up of 15 full-time faculty members including two microbiologists—one who specializes in microbial ecology and one clinically oriented microbiologist. The clinically oriented microbiologist designed and developed the new course in clinical microbiology. As an added benefit, this microbiologist works part time for a clinical laboratory at a local regional hospital and can relate experiences from an actual clinical laboratory to experiences students encounter in the teaching laboratory.

Instructional Design and Quality Matters

UNA created a new course development program in 2018 to ensure that professors interested in teaching online had the skills and design necessary to deliver quality experiences to students. Through this process, professors work one-on-one with an ID over twelve weeks to ensure the course is designed to meet QM Standards through an internal institutional review process. The process is initiated by the professor through the creation of a course development agreement. Once the agreement has received administrative approval, the professor and ID schedule the initial meeting to establish the project timeline, objectives, and expectations. The primary function of the ID is to provide support throughout the development process. Additionally, the ID offers suggestions for improvement and serves as a sounding board to hash out design ideas. At the end of the development period, the ID reviews the course utilizing the institution's internal review process which follows the QM course review guidelines and expectations.

UNA currently employs five IDs. All IDs hold at least a master's degree and have been trained to frequently facilitate QM workshops in *Applying the Quality Matters Rubric*, *Designing Your Online Course*, and *Improving Your Online Course* (Quality Matters, 2022a). The ID who worked on this microbiology course holds a doctoral degree in Instructional Leadership and Technology. She has 24 years of experience in higher education, worked with QM for 10 years, has reviewed over 100 online courses, and now leads the university's master's degree program in Instructional Technology and Design.

Open Education Program

Prompted by a statewide OER initiative, UNA began scaffolding a comprehensive campus program in 2018. To emphasize the priority of this effort, OER was written into UNA's 2019-2024 campus strategic plan, *Roaring with Excellence*, as an aspirational goal to "adopt, implement, and utilize Open Educational Resources (OER) in half of all academic programs" (University of North Alabama, 2019). A working group was formed in late 2019 to assess campus understanding and use of OER. The results of that assessment showed a need for education and promotion of OER across campus (Pate et al., 2020). To achieve the strategic goal and to increase faculty understanding and utilization of OER, a stipend program was launched in May of 2020 to compensate faculty who adopted, adapted, or authored OER, just as the pandemic was altering higher education and the need for open, online resources became more vital than ever.

UNA's OER program is currently facilitated by a librarian from Collier Library and Information Services in conjunction with the executive director of Educational Technology Services (ETS). The librarian has completed extensive training in open education, including the Open Education Network's Certificate in OER Librarianship. She has also completed copyright training through the Library Copyright Institute as well as completed the Creative Commons Certificate program. She designed a self-paced "Intro to OER" course in UNA's learning management system, Canvas, that is required for faculty who apply for stipend funding, and she is available for one-on-one consults as faculty begin working with OER. The executive director of ETS has made it a requirement for all new online course development to include the OER

librarian during the initial meeting between the faculty and ID team to discuss utilizing OER instead of traditional costly course materials.

Literature Review

Microbiology

Jeff Seaman, Director of Bay View Analytics, conducted a science, technology engineering, and mathematics (STEM) survey in 2020 of 896 instructors at two- and four-year institutions. It was reported that 73% of STEM instructors transitioned to remote learning during COVID, with more than one-third having never taught online. Within this same survey, faculty reported the biggest perceived barriers included academic integrity, student motivation, and student engagement with online coursework (McKenzie, 2021; Seaman et al., 2021).

According to McKenzie (2021), “The shift to remote learning forced STEM instructors to increasingly accept online education, but the concerns about how to give students meaningful lab experiences remain” (para. 1). For STEM professors already leery of the online experience, this necessary and quick transition may have cracked open a door, piqued curiosity, and allowed for opportunities to begin exploring effective open and online education. This is leading to the important question of how online STEM labs can offer high-quality, practical, and experiential learning opportunities for students in an open, online environment. Brogan et al. (2021) notes that while some OER resources were available for general biology labs, the content was either insufficient for a semester-long biology lab, designed for traditional biology laboratory environment, or required instructor guidance, and commercially available virtual labs were cost-prohibitive. Brogan et al. also notes that due to a lack of an OER resource that met their need, they elected to design and write their own second-semester OER general biology laboratory manual.

According to Brockman et al. (2020), “Laboratories provide students with a stimulating learning environment to acquire and develop practical skills which are otherwise unattainable through lectures and readings. The evaluation of laboratories is critical for educators to develop a well-rounded microbiology curriculum” (p. 1). As such, instructor observation of students and feedback to students provides essential checkpoints within the microbiology curriculum. In addition, skills learned in the microbiology laboratory are often used in subsequent courses, thus ensuring proper teaching and student performance of key microbiological skills are essential. For example, aseptic technique is a key concept that is often learned in either the first or second lab meeting and is a concept that students will use to ensure their own safety while working with microbes. For allied health majors, aseptic technique will lay foundations for necessary clinical techniques such as how to maintain a sterile field. Thus, ensuring the online and traditional microbiology labs are similar will benefit students by ensuring proper acquisition of and proficiency in necessary techniques for later coursework and clinical practice.

McKenzie (2021) reports that some faculty try to ensure that online experiences are enriching in addition to being as similar as possible to in-class experiences, and that students are challenged to apply skills and knowledge gained from coursework rather than simply relying on testing to determine student understanding. Recognizing the concern of faculty to shift laboratory experiments online, McKenzie (2021) notes that 35% of surveyed instructors felt that commercially available online labs failed to meet

instructor needs thus leading faculty to experiment with a wide range of solutions for online lab content, including lab kits mailed to students, adaptation of commercially available online lab programs, or staggering of virtual and traditional laboratory meetings during the COVID-19 challenge. For microbiology, the challenge of teaching during the COVID-19 pandemic was not related to lecture instruction but how the laboratory could transition to the online environment while still ensuring that students learned the necessary skills required for their later coursework in a safe environment.

Quality Matters Quality Assurance Framework

QM is a nonprofit global organization comprised of over 1,500 organizations, in over 30 countries across six continents and is known for its expertise in online education quality assurance standards and evaluation practices focusing only on course design (Quality Matters, 2022b). Course design is the planning and preparation that occurs prior to the delivery of the course to students. The program offers a variety of professional development opportunities, quality assurance rubrics, and review processes for Higher Education, K-12, Continuing and Professional education, and publisher products for both K-12 and Higher Education. (Quality Matters, 2022c).

The primary reason for QM's widespread adoption is that it offers a faculty-driven peer review process that was designed by faculty for faculty and utilizes a continuous quality improvement process rather than an evaluative format. QM does not offer a pass/fail approach to quality assurance. Instead, it provides an extensive opportunity for collegial collaboration through feedback and course revision opportunities whether or not minimum expectations are met in an initial course review. Additionally, the rubrics are based on standards of best practices, current research literature, and instructional design principles to promote student learning while serving as a guide for IDs, faculty, institutions, and students as they navigate online and hybrid learning endeavors. To ensure the standards meet current expectations, QM conducts a review of the standards and rubric every three years by a 12-person Rubric Committee that is advised by an eight-person Legacy Committee composed of previous Rubric Committee members (Quality Matters, 2022d).

OER in Instructional Design

In their 2020 paper on collaboration between library, faculty, and instructional design, George and Casey noted that integrating OER in new course development added little to the workload since all logistical issues such as “integration, workability of links, databases, and any other LMS issues” were being addressed as the course was being built (p. 109). As a result, George and Casey state that the instructional design team “has recommended that all new courses should at least consider OER for all course content or a portion to benefit students” (p. 109).

Harrison and Devries (2019) found that utilizing open education practices (OEP) made course development workflows more efficient, creative, and collaborative. In their paper, they note “many of the instructional designers who participated in the study see OEP involvement as an opportunity to rethink education, and to provide local and global public service in their professional role” (p. 12).

Similar to what Morgan discusses in her 2019 study, the ID for this microbiology course sees herself as an advocate for OER and has developed most of the courses in the instructional design master's program at UNA using OER instead of costly course material. Because of her familiarity with OER, she can navigate the faculty barriers that Morgan cites such as time and resistance to change, and she is able to

provide, in conjunction with the OER librarian, strong institutional support. Ren (2019) also examines the impact of the ID/faculty partnership and, like Morgan, writes “there is a rationale to examine the effectiveness of building partnerships between IDs and faculty to overcome the OER adoption barriers in higher education institutions, such as the lack of time, expertise, or supportive resources” (p. 3485). Ren also emphasizes the importance of administration prioritizing OER, ID, and faculty collaboration.

Methods

American Society for Microbiology Standards

ASM is the national microbiology society for the United States and serves as both a national and international leader for microbiological scientific research and education. The ASM curriculum committee has published standards for undergraduate microbiology to support the education of science majors (ASM, 2018b) and allied health majors (ASM, 2018a). The two standards differ in the scope of general microbiology covered and specific skills assessed. For example, Microbiology in Nursing and Allied Health (MINAH) guidelines focus more on how microbes impact human health, pathogen identification and treatment, and the spread of infectious disease while ASM standards for a general microbiology (suitable for science major courses) address microbial evolution, cell structure and function, and microbial processes in addition to briefly covering healthcare related microbiology (ASM, 2018a; ASM, 2018b). Undergraduate microbiology courses and programs that follow ASM guidelines for undergraduate education ensure that students are receiving a common core of knowledge and skills thus standardizing the microbiology curriculum across various colleges and universities.

Quality Assurance Framework

The QM Higher Education Rubric served as the framework for designing the microbiology online lab. It consists of eight general standards with forty-two specific review standards which are distributed among them. The eight general standards address the following: 1) Course Overview and Introduction; 2) Learning Objectives or Competencies; 3) Assessments and Measurements; 4) Instructional Materials; 5) Learning Activities and Learner Interaction; 6) Course Technology; 7) Learner Support, and 8) Accessibility and Usability (Quality Matters, 2022d). Each standard is supported by current scholarly literature and best practices and places emphasis on the concept of alignment. This ensures that the critical course components of learning objectives, assessments and measurements, instructional materials, learning activities, learner interaction, and course technology work together to ensure students achieve the desired learning outcomes.

OER Framework

The development of new OER material for courses requires an understanding of the principles of OER and open licensing of the completed work. When creating OER, authors should make sure the final product meets the 5R framework outlined by Wiley (2014), which includes the ability to retain, reuse, revise, remix, and redistribute the work. The work should be freely available to students and should strive to meet or exceed accessibility standards. Since this microbiology course is offered online, WCAG 2.1 accessibility standards should be addressed during the development of the lab manual as part of the

QM process and will be reviewed again before the lab manual is published (Accessibility Principles, 2019).

Once the lab manual is ready to be imported into the Digital Press at Collier Library, which is built on the Pressbooks platform, the OER librarian will work with the author to choose the appropriate Creative Commons (CC) license for the manual. During preliminary discussions about CC licenses, the decision was made to not consider any version that includes the “No Derivatives” designation because the author hopes others will find and adapt her work. She has benefited from adapting other lab manuals in her courses and wishes to contribute to the library of available biology OER.

Merging the Frameworks for Microbiology

The laboratory component to the course was designed to provide students in either the traditional or online modality with as similar an experience as possible to ensure that online students were receiving training in core microbiology techniques while at the same time meeting ASM, QM, and OER standards thus allowing consistency between the two course modalities.

To accomplish this goal, meetings were held every two weeks during the course design and QM process via Zoom. During each meeting, aspects of OER, QM, and ASM standards were discussed, and coursework was developed to support each goal. This process benefited from the professor’s previous exposure to the QM and OER frameworks. Prior to this project, she had completed two QM certification courses and had attended an OER workshop which led to her adapting a different OER microbiology lab manual. Because of her work adapting the OER lab manual, she was familiar with open licensing as well as searching for images and other materials that could be included in the manual she created specifically for this course. Due to the previous training with QM, the professor was familiar with the expectations of quality course design. The team collaboration ensured that critical course components such as course objectives, module objectives, instructional materials, learning activities, tools and assessments worked together to contribute to student mastery, while maintaining OER compliance and meeting ASM standards.

Results and Discussion

Microbiology Lab Course Set Up

The lab course was designed to be presented in two formats: a traditional format appropriate for face-to-face laboratory instruction and an online format termed Lab@Home which contains modified protocols that are safe for students to use where they live. Both formats were developed utilizing Canvas and contain videos to introduce the specific lab topic and procedures utilized during the lab, a link to the instructor written OER lab manual designed specifically for the clinical microbiology course, and assessments for each lab. See Table 1 for examples of how the modalities for the in person and Lab@Home compare. For Lab@Home, students can work ahead while traditional laboratory students would complete one lab experiment per week (see Table 1).

Table 1

Assessment comparison between the traditional and Lab@Home (online) developed clinical microbiology laboratory.

Lab Experiment	Traditional Lab	Lab@Home	Difference
Lab 1: Aseptic Technique	Tech Exam: Aseptic Technique	Tech Exam: Aseptic Technique	Content and assessments are the same between the labs though procedures differ. [Students use different tools and cultures between the two modalities. Lab@Home students work near a candle and collect skin bacteria or bacteria from the surface in their home while traditional laboratory students are given specific cultures and work with a Bunsen burner.]
	Lab Quiz: Aseptic Technique	Lab Quiz: Aseptic Technique	
	Lab Report: Aseptic Technique	Lab Report: Aseptic Technique	
Lab 2: Isolation Streak & Types of Media	Tech Exam: Isolation Streak	Tech Exam: Isolation Streak	Content and assessments are the same between the labs though procedures differ. [Students use more microbiological media types in the traditional lab.]
	Lab Quiz: Isolation Streak	Lab Quiz: Isolation Streak	
	Lab Report: Isolation Streak	Lab Report: Isolation Streak	
Lab 3: Enumeration	Tech Exam: Serial Dilution	Tech Exam: Serial Dilution	Content and assessments are the same between the labs though procedures differ. [Lab@Home students serially dilute milk or yogurt while traditional lab students collect a urine sample for serial dilution and work with more media types.]
	Lab Quiz: Enumeration & CFU/ml	Lab Quiz: Enumeration & CFU/ml	
	Lab Quiz: CFU/ml calculation	Lab Quiz: CFU/ml calculation	
	Lab Report: Enumeration & CFU/ml	Lab Report: Enumeration & CFU/ml	

Lab 4: Microscopy	Lab Quiz: Microscopy	Lab Quiz: Microscopy	Content and assessments are the same between the labs though procedures differ. [The traditional lab has a wide variety of slides compared to Lab@Home.]
	Lab Report: Microscopy	Lab Report: Microscopy	
Lab 5: Staining	Tech Exam: Staining	Tech Exam: Staining	Content and assessments are the same between the labs though procedures differ. [Lab@Home uses fewer staining methods than the traditional lab.]
	Lab Quiz: Staining	Lab Quiz: Staining	
	Lab Report: Staining	Lab Report: Staining	
Lab 6: Biochemical Tests	Lab Quiz: Biochemicals	Lab Quiz: Biochemicals part 1	Lab@Home receives a data set to interpret rather than inoculating various media. Both modalities use biochemical data to identify bacterial unknown.
	Lab Report: Biochemical Tests Unknowns	Lab Quiz: Biochemicals part 2	
		Lab Report: Biochemical tests Unknowns	

Lab 7: Methods of Control	Lab Quiz: Physical Methods	Lab Quiz: Physical Methods	Content and assessments are the same between the labs though procedures differ. [Lab@Home students expose plates to sunlight and incubate plates in fewer temperature environment than traditional lab students. The traditional lab students also have access to UV lights for physical methods of control testing and potentially a wider variety of antiseptics and disinfectants than Lab@Home students. Lab@Home students are given a data set for antibiotic data while traditional students would test several antibiotics as part of their experiment.]
	Lab Quiz: Chemical Methods	Lab Quiz: Chemical Methods	
	Lab Report: Control of Growth	Lab Report: Control of Growth	
Lab 8: ELISA	Lab Quiz: ELISA	Lab Quiz: ELISA	Content and assessments are the same between the labs though procedures differ. [At present, Lab@Home student use home ELISA test kits such as pregnancy, drug, or ovulation tests available from local stores while traditional students use an ELISA kit from Edvotek. This lab will be rewritten so that traditional lab students will use a commercially available hCG (pregnancy) test kit.]
	Lab Report: ELISA	Lab Report: ELISA	
Final Exam	Comprehensive Final Exam	Comprehensive Final Exam	Assessment is the same between the labs.

Microbiology Lab Course Completion

Data for Fall 2021 and Spring 2022 semesters are from traditionally taught in-person lecture and laboratory sections while data for Summer 2022 are from an online lecture and Lab@Home. All lab sections were taught with the designed OER lab manual. Fall and Spring semesters are four months while the Summer online microbiology course was one month (June 1-June 29). Because the Summer class is more intensive, students often struggle with mastery of content, especially when working or taking classes outside of BI302. Notwithstanding the summer term time constraints, lecture grades reflect the same general trend of B and C letter grades being most common among all three semesters (Table 2). While some students do better with the hands-on experiments of the laboratory component of BI302, many students struggle with application of lecture information thus resulting in a wider grade distribution among the laboratory sections compared to the lecture sections. The lecture component of BI302 includes a group project, an individual epidemiology project, chapter quizzes, and module exams which help students to apply lecture information in a variety of contexts whereas the laboratory component assessments focus on collecting, analyzing, and applying experimental data.

Student comments were not collected, nor was Institutional Review Board permission received to include student comments. Course evaluation data is only collected for Fall and Spring semesters; thus, it was not included as the online only course would not have been reflected in the data set.

Table 2

Comparison of percentage of lab grade, drop, fail, and withdrawal between traditional BI302 lab and online BI302.

Term	Fall 2021		Spring 2022		Summer 2022	
Total Enrollment	36		42		17	
Course	Lecture	Lab	Lecture	Lab	Lecture	Lab
% Withdrawal	5	5	7	7	0	0
% A	11	0	33	19	12	0
% B	42	31	41	43	47	18
% C	31	31	17	22	41	29
% D	3	19	2	7	0	47
% F	8	14	0	2	0	6

QM/ NCD Internal Review Results

At the end of the New Course Development process, the Clinical Microbiology Laboratory online course underwent an Internal Quality Assurance Review utilizing the guidelines and expectations set forth by QM. As previously stated, QM does not offer a pass/fail approach to quality assurance but provides an extensive opportunity for collegial collaboration through feedback and course revision opportunities whether or not minimum expectations are met in the initial course review. The microbiology course met all essential standards and received a perfect score of 100% on the internal review process.

After the initial offering, lab protocols for Lab@Home were modified to more closely match the protocols used with the traditional laboratory experiments. For example, the Control of Growth experiments in the traditional and online modalities differ (see Table 3).

Table 3

Comparison of the Control of Growth Lab between traditional and Lab@Home modalities.

Experiment	UV	Temperature	Antiseptic/ Disinfectant	Kirby Bauer (Antibiotic)
Traditional Lab	UV light exposure (230nm wavelength)	4C (refrigerator)	Mouthwash	Antibiotic disc
		21C (room temperature)	Hydrogen peroxide	
		37C (incubator)	Bleach/ Lysol	
		65C (incubator)	Isopropanol	
Lab@Home	Sunlight exposure	-10C (freezer)	Mouthwash	Data set
		4C (refrigerator)	Hydrogen peroxide	
		21C (room temperature)	Bleach/ Lysol	
		37C (sunny car)	Dish soap	

Both modalities use common household antiseptics and disinfectants for the Control of Growth experiment. Differences between the modalities occur with temperatures, UV sources, and antibiotic testing as students in the Lab@Home section would not have access to high temperature incubators, UV cabinets, and antibiotics at the correct concentrations for the Kirby Bauer test. Continual improvement goals for the laboratory manual strive to keep procedures as close as possible between the two modalities.

With the shift to online learning brought about by the pandemic and continued through Hyflex learning (shifting to online modality to accommodate student absences and university closings due to weather events), a lab manual that accommodates both online and traditional modalities while at the same time meeting ASM standards is needed. This lab manual is available in the Digital Press at Collier Library via the Pressbooks publishing platform and is one of the first widely available OER lab manuals specifically designed for an online microbiology lab course. In addition to being able to accommodate a Hyflex teaching model, cost savings to students is significant in that commercially available laboratory manuals range \$100-\$150 per manual, or approximately \$150 per student, for prepackaged kits from vendors such as Carolina Biological. The manual can be viewed at <https://una.pressbooks.pub/bi302-lab/>.

Conclusion

Microbiology OER Lab Manual Implementation

Two challenges were initially faced with the creation of the clinical microbiology course: 1) splitting of the original microbiology course which serviced both hard science majors and allied health science majors and 2) creating a laboratory for online and traditional instructional modalities that offered comparable learning experiences for students.

Splitting the mixed majors microbiology laboratory was relatively straightforward in that experiments took on more of a clinical focus with an instructor written OER laboratory manual for the allied health science students, while the science majors laboratory continued to use the previously adapted OER lab manual from McLaughlin and Petersen (2016). For example, the clinical microbiology experiments focus more on student provided specimens or procedures that are important for clinical identification and treatment of pathogens – skills that allied health students will employ daily during clinical rotations and later in their careers. The students majoring in science use instructor provided stock cultures for laboratory experiments with the goal of exposing majors to a variety of techniques and a broader skill base that science majors will use in later courses or graduate studies. Both the science majors' lab manual and the clinical microbiology lab manual for the allied health sciences have a core set of experiments that are offered in the same sequence to offset excessive lab set up as the two classes are frequently offered on the same day for traditional laboratory formats.

The second challenge was the creation of an OER lab manual that supported both traditional and online modalities of instruction while at the same time ensuring that students received hands-on experiences and acquired the necessary foundational skills for subsequent coursework. The first time the laboratory was offered online, students made their own bacterial media using agar or gelatin commercially available from most grocery stores and searched the internet for microscopic images to complete labs; subsequently offered sections of the online laboratory use pre-made media and student grade microscopes purchased from online vendors which provide more standardized supplies for student experiments, hands-on experience for the staining lab, and the ability to view student made slides as well as prepared slides provided with the microscope. As such, there are currently only two labs that significantly differ from the traditional and online lab manuals – the biochemical lab (see Appendix A) including the unknowns project and the Enzyme-linked immunosorbent assay (ELISA) lab.

Future Directions

Now that the laboratory manual has been launched and tested in the online classroom, the instructor and the OER librarian will work together to finalize details of the laboratory manual, including locating or creating openly licensed images for inclusion in the text in preparation for publication in UNA's Digital Press. The instructor will be applying for an OER stipend to help her complete the work to get the manual ready for publication. Once that process is complete, the instructor, OER librarian, and ID will begin working on transitioning the class from a traditional (costly) textbook to OER for the lecture. They are currently assessing the use of PLOS Pearls, "a living collection of short educational and highly useful articles that address topics of relevance and importance within the wide-ranging field of pathogens research" for inclusion in lecture instruction (PLOS, 2019).

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Conflict of Interest Statement

The authors have no knowledge of any conflicts of interest.

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Appendix

Appendix A: Comparison of the Biochemical lab for the Traditional and Lab@Home modalities. Differences between the two modalities are highlighted in yellow.

Lab 6 (L6): Biochemical Tests [Traditional Lab]

Course (CO)	Objectives	Lab Objective (LO)	Learning Activities	Evaluations & Assessment
1. Apply Aseptic Technique to lab processes and methodologies. (MINAH 22,24)	1. Use Aseptic Technique to inoculate biochemical media. (LO1,6)	1. Use Aseptic Technique to inoculate biochemical media. (LO1,6)	<p>1. Read: Blankinship, L.A. (2021). Biochemical Tests. In <i>BI302 Clinical microbiology lab manual</i>. (LO1-3)</p> <p>Blankinship, L.A. (2021). Dichotomous key. In <i>BI302 Clinical microbiology lab manual</i>. (LO2,4)</p> <p>2. Watch: Blankinship, L.A. (2021). <i>Lab Lecture: Biochemical Tests</i>. [Video]. Canvas Studio. (LO2-3)</p> <p>Blankinship, L.A. (2021). <i>Lab Lecture: Overview of Dichotomous Key</i> [Video]. Canvas Studio. (LO4)</p> <p>3. Complete: · <i>Lab Quiz: Biochemicals (LO2-3)</i></p>	<p><i>1. Lab Quiz: Biochemicals (LO2-3)</i></p> <p>2. Lab Report: Biochemical Tests (LO1-3)</p> <p>3. Unknowns (LO2-4)</p>
2. Examine microbiological processes in pure culture. (MINAH 22-23)	2. Classify microbes based on their biochemical results. (LO2-5)	2. Classify microbes based on their biochemical results. (LO2-5)		
3. Relate experimental findings to lab and lecture concepts. (MINAH 23-25)	3. Apply the use of pH indicators to determine metabolic processes by or within a cell. (LO3,5)	3. Apply the use of pH indicators to determine metabolic processes by or within a cell. (LO3,5)		
4. Classify microbes based on microbial physiology or biochemistry. (MINAH 23)	4. Provided a dichotomous key, identify a bacterial unknown. (LO2-5)	4. Provided a dichotomous key, identify a bacterial unknown. (LO2-5)		
5. Use appropriate terminology when communicating microbiological concepts and findings. (MINAH 23-25)				

6. Use
microbiological
equipment correctly.
(MINAH 23-24)

- Lab Report:
Biochemical
Tests (LO1-3)
 - Unknowns
(LO2-4)
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