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Moving a Journal Article–Based Upper-Level Microbiology Dry Lab from In-Person to Online Instruction†

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During the spring semester of 2020, a journal article–based upper-level microbiology laboratory course was offered through Western New Mexico University at Glendale Community College in Glendale, AZ. Because most of the students had taken a lower-level microbiology class with a traditional wet laboratory, a dry lab format was used instead. In the first period of each 2-week cycle, a microbiology article selected by the instructor from the primary literature was discussed using a PowerPoint presentation and a detailed study sheet. Students then turned in answers to five specific questions about the article. In the second period of each 2-week cycle, students met to discuss possible research projects based on that article. They then turned in a two- to three-page research proposal describing their project. Before the COVID-19 pandemic became severe and the college moved to online instruction, there were active discussions between the instructor and the students in both class periods. After the campus was shut down, discussions of the journal articles and preparation of the research proposals were done online using Canvas as the learning platform. Students were provided with discussion sites, but no video instruction systems were used. In general, the answers to the journal article questions and the quality of the research proposals were better during in-person instruction. Instructors may be able to adapt this journal article–based lab approach to a fully online format, but it will require extensive training and the use of Zoom or other video instruction methods.

INTRODUCTION

During the spring semester of 2020, I taught an upper-level majors microbiology class (BIO 471, BIO 473) through Western New Mexico University at Glendale Community College (GCC) in Glendale, AZ. The course was part of a B.S. program in Cell and Molecular Biology aimed at students who were completing an A.A.S. Biotechnology program at GCC and wanted to continue their education locally. The lecture course (BIO 471) was traditional in structure but had a more advanced textbook (1) than that used in the lower-level microbiology class offered at the community college. Because most students had taken a basic "wet lab" in the lower-level class, a "dry lab" format was used for BIO 473 instead. There is an extensive literature about the use of dry or virtual labs in science classes (2–5), which may include online simulations (6–8), case studies or problem-based learning (9, 10), and discussion of journal articles (11–13). Since most of my students were also engaged in research projects as part of their Biotechnology program, I chose to use journal articles as the primary resources and to include both analysis of the articles and development of research proposals based on them.

A total of 20 students were enrolled in two sections that met for one 75-minute period each week. The primary learning objectives for students were (i) to understand the basis of the concepts and facts presented in the textbook and lecture class; (ii) to read scientific journal articles with greater skill and understanding; (iii) to describe and interpret the data from microbiology experiments as presented in figures or tables; and (iv) to develop research proposals and to plan protocols or flow charts for carrying out experiments appropriate to their proposals. In the first period of each 2-week cycle, a microbiology journal article I selected was discussed using a PowerPoint presentation and a detailed study sheet. In the second period of each 2-week cycle, students developed a possible research project based on that article. The outbreak of COVID-19 during 2020 led the college to move all courses to remote instruction halfway through the semester. Consequently, while students met with me in person during the first half of the semester, all instruction, class discussions, and submission of assignments were done online during the second half of the semester. This thus provided a "natural experiment" in which to

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TABLE 1.
Summary of majors microbiology dry lab articles.

Mode of Instruction	Topic	Journal Article	Mean Score on Questions	Mean Score on Proposal
In person	Microbiological Media	Svanevik CS, Lonestar BT. 2017. Introducing a novel media to improve the recovery of cultural bacteria from the fish parasite *Anisakis* spp. larvae (Nematoda: Anisakidae). Curr Microbiol 74:1043–1048	19.5	20.8
	Bacterial Structure	Burghardt T, Näther DJ, Junglas B, Huber H, Rachel R. 2007. The dominating outer membrane protein of the hyperthermophilic *Archaeum Ignicoccus hospitalis*: a novel pore-forming complex. Mol Microbiol 63:166–176.	18.8	17.0
	Bacterial Growth	Greeter N, Marin K, Krämer R, Thomas GH. 2012. Sialic acid utilization by the soil bacterium *Corynebacterium glutamicum*. FEMS Microbiol Lett 336:131–138.	21.6	18.9
Remote	Bacterial Metabolism	Richhardt J, Bringer S, Bott T. 2013. Role of the pentose phosphate pathway and the Entner-Doudoroff pathway in glucose metabolism of *Gluconobacter oxydans* 621H. Appl Microbiol Biotechnol 97:4315–4323.	20.6	19.8
	Microbial Development	Sukenik A, Kaplan-Levy RN, Viner-Mozzini Y, Quesada A, Hadas O. 2013. Potassium deficiency triggers the development of dormant cells (akinetes) in *Aphanizomenon ovalisporum* (Notables, Cyanoprokaryota). J Phycol 49:580–587.	21.8	20.2
	Bacterial Pathogenesis	Qiu J, Feng H, Lu J, Xiang H, Wang D, Dong J, Wang J, Wang X, Liu J, Deng X. 2010. Eugenol reduces the expression of virulence-related exoproteins in *Staphylococcus aureus*. Appl Environ Microbiol 76:5846–5851.	23.1	18.5

compare the effects of the two modes of instruction on this type of course.

PROCEDURE

The course began with a preliminary class on How to Read a Scientific Paper that included short handouts (e.g., https://www.sciencemag.org/careers/2016/03/how-seriously-read-scientific-paper) and discussion of a short paper with a simple data set (14). A study guide was provided which included definitions of key terms or techniques used in the paper along with a series of 12 to 15 study questions (15). This class was followed by more extensive work on six papers coordinated with the BIO 471 lecture course. Students worked individually or in groups of up to three to prepare written answers to questions about each journal article and to write research proposals. Table 1 shows the topics, journal articles, and mean scores on the journal article questions and research proposals during the in-person and online phases of the course. Appendix 1 contains the study guide for the paper on Bacterial Structure and Appendix 2 contains the study guide for the paper on Bacterial Pathogenesis as examples. After the class discussion of each paper, students turned in half-page to full-page written answers to five of the study guide questions, which were worth 5 points each for a total of 25 points. I graded the answers on the basis of their accuracy and level of detail and returned them with comments the following week. Students then developed a research project based on each journal article. They were asked to identify a question or problem not answered by the paper, to propose a specific hypothesis, and to describe a new set of experiments. They were encouraged to look up related papers from the primary literature as necessary using PubMed or other online resources but were not asked to include a budget or a description of the facilities involved. They then submitted a two- to three-page research proposal describing their project, again worth 25 points. Because students took different approaches to this assignment, no specific grading rubric was used, but the research proposals were returned with detailed written comments the following week.

During the in-person phase of instruction, there was a steady exchange of questions and answers as we considered the background and procedures in each paper. In discussing the figures and tables, there were ample opportunities to focus on any ambiguities in the data, the presentation of results, and the appropriate conclusions. While some students participated more than others, it was possible to draw most of them into the discussions. During the development of the research proposals, I moved from group to group, asking them questions and helping them develop their own ideas and approaches. While most of the work was done in class, several students came regularly to office hours for

additional help. Because this was a novel experience for many of the students, who had primarily taken undergraduate labs where they simply followed a written protocol, some of the research proposals were relatively simple (replacing one organism by another or substituting one condition for another), while others were more complex.

During the online phase of instruction, the students were left to work more on their own. I posted the journal articles, study guides, and PowerPoint presentations on the course Canvas site and replaced the in-class discussions with Canvas-based discussions. During the spring of 2020, both students and instructors struggled to move their work online. I do not have a web camera on my personal computer and neither do most of my students. The college was trying to get video instruction methods such as Zoom or WebEx up and running but they never became functional. While some students used the Canvas discussion sites and I regularly replied to comments posted there, many did nothing more than turn in their assignments electronically. I did provide more detailed critiques on their research proposals through e-mails. Many of the students fell behind in their classes during the online phase, but I did not deduct points for late assignments.

DISCUSSION

This approach to an advanced microbiology lab has both advantages and disadvantages. It can expose students to more advanced techniques than are usually available on a community college or university campus. It has very low cost and can be done remotely using online technologies. On the other hand, reading journal articles, analyzing experimental data, and developing research proposals are more difficult skills for students to acquire than those needed in a traditional lecture or laboratory class. This course does not involve memorization but, rather, relies on the higher-order cognitive skills of Bloom's pedagogy (16, 17). In particular, it depends on the students' ability to analyze and to evaluate as part of reading the journal article and to create a new piece of work as part of the research proposal. I deliberately selected papers from peer-reviewed journals that contained clear introductions and that had manageable methods and results sections, but other instructors may prefer to use different articles. Because the goals for this class were more about the scientific process than content, there was little change in the average scores over the course of the semester. At the end of the semester, there were 5 As, 12 Bs, 2 Cs, and 1 W. It was hard to learn much from the student course evaluations, since only five were returned and evaluation of the dry lab course was combined with evaluation of the lecture class. If I were to teach this class again, I would replace the paper on bacterial metabolism with one that is more accessible and include additional papers on antibiotics or the immune system. I would also include a template or example for the research proposals and give students the opportunity to revise and resubmit their proposals based on further discussion and my comments.

The sudden shift to online instruction during the spring of 2020 created major problems for students and teachers at the primary school, secondary school, and university levels (18). Among the major issues were student and instructor access to and use of appropriate technologies, the development of new class materials geared to online systems, and the effects of online learning on student emotional and social development. A series of recent papers indicates that laboratory instruction is especially problematic (19, 20) and that online education affects learning in ways which are different from in-person instruction (21, 22). In my experience, an in-person approach is much better for the journal-based dry lab format I used than an online one because the course depends so highly on discussion. There is now an extensive literature on how to help faculty make the transition to online instruction (23, 24). An instructor who is highly proficient in the use of interactive video platforms such as Zoom may be able to adapt this approach to a fully online format at their institution. However, this will require extensive out-of-class time and depend on the students having ready access to appropriate devices and an internet connection. The period in which each journal article is discussed using a PowerPoint presentation could best be done synchronously, with all of the students participating as a group with the instructor. The second period, in which research proposals are developed, could be done asynchronously, with the instructor discussing the proposals online with each student or group of students at a mutually convenient time. It will take more detailed pedagogical experiments like this one comparing in-person and online instruction to determine what types of courses can best be offered with each approach.

SUPPLEMENTAL MATERIALS

Appendix 1: Journal article #2. Bacterial structure study guide

Appendix 2: Journal article #6. Bacterial pathogenesis study guide

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