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Teaching in the Time of COVID-19: Creation of a Digital Internship to Develop Scientific Thinking Skills and Create Science Literacy Exercises for Use in Remote Classrooms†

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The extreme academic and social disruption caused by COVID-19 in the spring and summer of 2020 led to the loss of many student internships. We report here our creation of a novel internship for students majoring in the biological sciences. Student interns worked together to systematically categorize multiple episodes of This Week in Microbiology (TWiM). They annotated episodes by labeling relevant ASM fundamental curricular guidelines and the microbiology techniques described in several podcast episodes. Interns worked together, which advanced their written and oral communication skills while improving their scientific thinking skills. Faculty then enhanced each annotation by adding short figure-reading exercises that can be used in a variety of educational settings to teach science literacy. When surveyed, students reported greater confidence in analyzing and interpreting results from a variety of microbiological methods, improved communication of fundamental microbiology concepts in written and oral form, and enhanced ability to collaborate with others. Combined, this digital internship provided a unique opportunity for students to develop critical technical and scientific thinking skills and generated useful open education resources for teaching general microbiology in the form of annotated podcasts.

INTRODUCTION

In the spring of 2020, the world's status quo was up-ended with the response to the COVID-19 pandemic. With distant learning enacted, and physical distancing and economic shortfalls realized, numerous academic and industry internship programs were cancelled, leaving many undergraduates without the professional experience they had planned (1). Most student internships are designed for students to develop both their technical skills and scientific thinking skills. These competencies include the ability to design both hypotheses and experiments, analyze results, use mathematics and graphing, and effectively communicate microbiology in a variety of formats (2). Indeed, internships and experiential learning are considered high-impact practices leading to active student learning about the "real world" within a specific discipline or career (3, 4). The loss of these opportunities will likely negatively impact students, employees, and employers for years to come.

The loss of these more traditional internship opportunities has led students and educators to reassess and think creatively about solving this dilemma, that is guiding students to learn these scientific reasoning skills using other methods, currently available resources, and limited human face-to-face contact. To this end, we developed a project involving open-access primary scientific and popular science resources, peer–peer interaction, and problem-based learning with the Next Generation Science Standards (5) and the American Society for Microbiology Curriculum guidelines (2) in mind.

Reading and discussing primary scientific literature has long been used to introduce students to the process of science and the structure of primary sources and the value of reading them (6–9), as well as demonstrating the relevance of course concepts. Faculty often direct student inquiry by reviewing experimental design, data presentations, and conclusions drawn from relevant papers. Students, on the

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other hand, often struggle with scientific jargon and with thinking in terms of experimental design and hypothesis testing (10–13).

Science-oriented popular press articles, blogs, and podcasts are readily accessible resources and are targeted to the educated and curious citizen. These science communication formats can help bridge the gap between expert and novice scientific thinking skills (14–16). One podcast that is particularly approachable is This Week in Microbiology (TWiM) (https://www.microbe.tv/twim/). This is a long-running, free podcast hosted by microbiologists that are also exceptional science communicators. Most TWiM episodes have a similar structure, are based on open-access literature, and often distill difficult principles into common language. Most TWiM podcasts include the "snippet" which is a short description of a newly published paper as well as a longer discussion of a second "main" paper. This freely available resource has been used as both a source of primary papers to teach students in introductory courses and assigned in conjunction with data interpretation exercises (7). In addition, some journals are not easily accessible to all educational institutions, making the use of open-access resources a valuable step towards equitable science accessibility.

This project was designed to creatively resolve the following three separate but related problems generated by COVID-19: (i) late spring–early summer student internship cancellations, (ii) the switch to remote learning of these necessary ASM skills, and finally, (iii) the need for faculty to provide active learning opportunities for their online or remote learning classrooms. Combining these challenges provided an opportunity to help students looking for internship experiences and provide a long-term resource for faculty. We designed a digital internship that enables junior and senior students majoring in microbiology or biology to gain valuable scientific skills by annotating TWiM episodes using a supervised peer–peer discussion model (17). The resulting faculty-reviewed learning objectives, conceptual annotations, and data-driven student questions will be of use by microbiology educators for years to come.

Intended audience

The audience for this internship is instructors teaching general microbiology courses looking for creative pedagogical activities, or, alternatively, those planning on hosting a similar digital internship. The student interns and faculty team for this project have created annotations to help faculty adopt TWiM podcasts as teaching tools. These annotations include both details of each podcast and a short exercise for use in general microbiology classrooms.

In addition, this paper describes the details of the digital internship itself, for other faculty to host student interns using podcasts in general and TWiM in particular. The digital internship experience described in this paper was designed for students who have completed the first two years of training in a biological science major such as biology, microbiology, biochemistry, or genetics. During the summer of 2020, students from five states and two countries collaborated to annotate TWiM episodes. These interns had completed general microbiology and one to three advanced microbiology courses so were able to also develop links between TWiM episodes and introductory microbiology course content. The students were organized into two groups, with the first group focusing on clinical/medical microbiology, and the second group focusing on microbial ecology and genetics.

Learning time

Students reported working individually for three to five hours each week before collaborating with their team for one to two additional hours each week during the summer. Both teams attended a synchronous weekly meeting for one to two hours with the instructor to summarize their annotations, address questions, and review the other team's podcasts.

Prerequisite student knowledge

The format of this digital internship assumes students have completed a general microbiology course and have a familiarity with the ASM fundamental concepts (2). It is beneficial, but not required, that they have completed advanced microbiology coursework, such as medical microbiology or microbial ecology and physiology. In fact, including students that may not have taken the advanced courses encourages discussion within the group, as senior students guide and mentor their junior colleagues.

Student learning objectives for internship

By the end of this internship, students will

1) Be able to apply concepts from general microbiology and medical microbiology to categorize new information based on the ASM curricular framework.
2) Be able to write concise summaries of technical presentations for an audience of educators in the biological sciences.
3) Gain confidence in their abilities to analyze both the experimental design and data from primary literature.
4) Collaborate professionally to present data from primary papers.

PROCEDURE

Materials

Students were provided an annotation template (Appendix 1) that required them to identify the fundamental microbiology concepts, potential student learning outcomes, and microbiology techniques described in each podcast. The template was initially designed by NB and collaboratively refined with all authors based on student feedback and intended outcomes for this project. All of the students and faculty used a Cloud-based document sharing platform which allowed tracked changes and documented submissions from each student, increasing accountability. Students used a meeting platform (GroupMe) to meet with each other each week.

Student instructions

As a warm-up, the internship began with the entire group of interns listening to the same podcast episode, assembling a draft annotation, and reviewing the draft annotation with their peers and instructor. Following this, each week, students listened to an episode and independently filled out a draft of the annotation template. Students listened to each podcast once, taking notes of key points. They then listened a second time to add details of techniques used and experimental design and started categorizing the ideas presented in the podcast based on the ASM curricular guidelines. The students then met virtually as a small group to discuss the episode and come to a consensus to compile a draft annotation for review each week. During weekly meetings, the groups presented two podcast annotations as follows: One presentation would be an annotation in first draft form. For the first draft, students presented their ideas about the podcast episode and ask questions addressing format, experimental design, relevant microbiology concepts, potential learning objectives, and ASM fundamental statements. For the second presentation, students presented an updated annotation from the previous week. The second presentation emphasized the key figures from the primary papers discussed in the podcast episode and their alignment with the learning objectives and microbiology concepts. This second presentation included an open question-and-answer period for peers and the instructor to review the near-final draft. Each week, the interns practiced applying microbiology concepts, formulating questions, peer review, writing concise summaries, and presenting primary literature to the other intern group and faculty in oral and written forms. The iterative aspect of the weekly annotation presentations demonstrated the collaborative nature of scientific exploration and the value of peer review. The final student product was a written document that had been collaboratively created. The students' names are documented on the final product, providing students ownership of the works produced.

Faculty instructions

Faculty should ask students about their interests and professional goals early in the project. Students can then be grouped by general interest. We have found setting up groups of three worked well, as it allowed for students to discuss their annotations. During the first week, each group establishes a work schedule and ground rules as to the pace of work, small group meeting times, and a method to handle disagreements within the group. The first podcast that the whole intern cohort annotates together should be chosen by the students. Faculty can present a list of candidate episodes aligned to student interests. Students can then come to a consensus as to which podcast episode they would like to annotate first. This provides practice evaluating podcast topics and, more importantly, making decisions collectively.

During each weekly meeting, faculty should ask the students to present their annotations to the group and lead a cordial discussion about the differences in the group annotation compared with the individual annotations. The first-draft annotation often includes input from all of the students without much synthesis. Questions at this stage include:

1) What was the main idea of both the short (snippet) paper and the main paper presented?
2) What techniques did you find the most interesting?
3) Why did you pick the fundamental statements that you did?
4) What questions do you have about the techniques or experimental design?
5) Which figures do you think illustrated the main ideas of the papers best?
6) What would you want students to be able to do after listening to this podcast?

Students demonstrate more synthesis of ideas when they present the second draft of each podcast annotation. This second draft typically has fewer, better justified, fundamental statements, clearer student learning objectives, time stamps, and key figures from the papers discussed in the episode.

Once the students finalized their annotation, the author team working on this project refines the learning objectives and uses the figures from the papers discussed in each podcast to craft a brief exercise of multiple-choice and short-answer questions that can be used with each of the annotated podcasts. These provide an effective active learning exercise to be used in conjunction with the associated TWiM episode in either a face-to-face or remote classroom.

Suggestions for determining student learning

Since this project was designed as an internship, grades are based on satisfactory–fail, similar to specifications grading (18). Students are assessed on completion of a finished annotation that includes ASM fundamental statements, general microbiology topics and key figures and on their oral presentations. In the future, we plan on using the microbiology concept inventory (MCI) (19) at the start and end of the internship to assess student learning, but not to determine grades.

Sample data

Appendix 2 provides an example of student work that includes timestamps for key microbiology concepts, the relevant ASM fundamental statements, and potential learning objectives for faculty using each annotated podcast to teach these concepts in their class. Currently, the intern and faculty groups have completed and peer-reviewed ten finished annotations with exercises. The annotated podcasts illustrate 25 of 27 ASM curriculum fundamental statements (Appendix 3). Each annotation includes a short exercise for other faculty to use with the annotated episode in a variety of learning settings (remote, online, face-to-face, or flipped). An example of these short exercises is provided in Appendix 2. These completed annotations and short exercises can be accessed by contacting the corresponding author at nan1@iastate.edu, as we do not want the potential homework answers to be freely available on the internet. The library of completed annotations with short exercises is found at: https://iastate.box.com/v/TWiMAnnotations.

Safety issues

None.

DISCUSSION

Evidence of student learning from field testing

Students were better able to categorize podcast information based on the ASM curriculum framework as the summer progressed. Early full-group meetings often lasted two hours, and the group frequently only reviewed a single podcast, as students would struggle to distinguish key concepts from interesting details and to align specific experiments to fundamental microbiology statements. With each meeting, the time needed to thoroughly review each podcast decreased, and the student questions became more focused on experimental design and methodology.

At the end of the internship, we surveyed the interns to determine their reasons for applying for this atypical internship, challenges encountered during the process, and the impact of this project on their scientific thinking skills, as described by the ASM curricular guidelines. This survey was evaluated as exempt by Iowa State University's Institutional Review Board (IRB #20-350). While our sample size was small, with five of the six student interns completing the survey, we did see some surprising results (Table 1). Two students applied because they had lost their internships, two other students indicated that they simply wanted more experience with primary literature, and one wanted to "give back" to the microbiology community and help build a resource for teachers to use to help other students learn microbiology. Students listed several different challenges, the most commonly cited problem being thinking in terms of teaching rather than learning the material. Three responses referenced the challenges of writing learning objectives and difficulties identifying the main idea because "a lot of ideas are interconnected." The unusual nature of this internship experience and the flexibility with the process were listed as challenging for two students as well. When asked how they would apply the skills from this internship to their professional careers, all five respondents mentioned that this process improved their teamwork and collaboration skills as well as their ability discuss science with a variety of audiences.

At the end of the internship, we asked the students to self-report how working on TWiM podcast annotations had affected their scientific thinking skills from ASM's curricular guidelines on the following Likert scale (1 = greatly decreased; 2 = somewhat decreased; 3 = did not affect; 4 = somewhat improved; 5 = greatly improved).

We also asked students to provide examples of each of these categories. Their responses are paraphrased in Table 2. The three skills all the interns reported as being "greatly improved" were analyzing and interpreting results from a variety of microbiological methods, effectively communicating fundamental concepts in written and oral form, and collaborating with others. Students reported having

TABLE 1.
Intern feedback.[a]

Why did you choose to participate in this digital internship?	What was the biggest challenge?	What skills will you apply from this internship to your coursework and professional work?
Loss of internship (2)	New/unique experience meant uncertain expectations (2)	Teamwork and collaboration (5)
Wanted more experience with primary literature (2)	Thinking of podcasts in terms of learning objectives and general microbiology (3)	Science communication to a variety of audiences (5)
Wanted to "give back" to the microbiology community (1)	Isolating the main idea in terms of general microbiology and fundamental statements because a lot of ideas are interconnected (3)	Synthesizing and summarizing primary literature (2)

[a] At the end of the summer internship, we surveyed students, asking them three questions. Five of the six interns responded, with several giving multiple responses to each question. Their responses are paraphrased here. The numbers in parentheses indicate the number of responses.

TABLE 2.
Impact of the digital internship on scientific thinking competencies and skills.

	Mean Likert ratinga (SD)	Representative Student Responses
The ability to formulate hypotheses and design experiments	4 (0.49)	• Gained knowledge of microbiology techniques • Using "predict" and "design" as learning objectives helped think of the next experiment • Toward the end of the internship, we could predict what the next experiment should be (to support a paper's claims)
The ability to analyze and interpret results from a variety of microbiological methods	5.0 (0)	• Almost every podcast described many techniques • One podcast about VBNC bacteria described many different ways to count and culture bacteria • Techniques were often explained in the context of a research question
The ability to use mathematical reasoning and graphic skills to solve microbiology problems	3.8 (0.4)	• While mathematical reasoning wasn't improved, looking at graphs from the papers while listening to the podcasts helped understand them better • One podcast talked a lot about chemistry math because it was relevant to the research question
The ability to effectively communicate fundamental concepts of microbiology in written and oral form	5.0 (0)	• Evaluating the podcast independently, then meeting with peers led to understanding the fundamental concepts better • Communication skills improved as everyone in the group discussed their annotations • Writing each annotation improved confidence in communicating microbiology concepts to others
The ability to identify credible scientific sources and interpret and evaluate the information therein	4 (0.63)	• Reading the papers discussed in each podcast improved reading skills • The podcast hosts often commented on experimental design.
The ability to identify and discuss ethical issues in microbiology	3.6 (0.8)	• Some papers were about complex issues with multiple people being affected by policy change. For example, using less fungicides to protect bees, and the effects on crop yields • Hearing stories from other microbiologists has been enlightening
The ability to collaborate with others working toward a common goal	5.0 (0)	• Clear communication is important to produce the best end product • Working in a group where tasks are split so everyone contributes • Group members became friends and learned about how a good collaborative team can function

[a] Students were presented specific statements that were rated on a Likert scale, with 5 indicating greatly improved and 1 being greatly decreased.

positive collaborative experiences, which is remarkable, as group work is often avoided by high-performing students (20). Another side benefit is the sense of ownership students assumed with their group's annotations. They knew that their work would be used by others, and both groups took pride in their work. Students are listed as authors for each annotation they completed, providing documentation of peer-reviewed work for professional experience.

Benefits to faculty

The faculty working on this project have revised the learning objectives and written short exercises based on key figures from each paper discussed on the annotated podcast (Appendix 2). These can be used by microbiology faculty to actively teach scientific thinking skills in general microbiology courses taught either in person or through remote learning formats. With slight modifications, they can also be used as homework or virtual discussion forums that are typically integrated in learning management systems in asynchronously taught courses. These are also ready-made short exercises for a flipped classroom or as preparatory exercises for labs that highlight the same techniques (e.g., differential media, ELISA, etc.)

Meeting the challenge of COVID-19 restrictions

The loss of wet-lab internship opportunities due to COVID-19 restrictions in both industry and academic laboratories lead to the creation of a novel, digital internship for microbiology students. The internship itself, using the template provided in Appendix 1, can be duplicated in multiple settings, such as a senior capstone project or a digital internship with upper-level students wanting experience in hypothesis testing, use of different techniques, scientific communication, and collaboration with peers toward a common goal. In conclusion, this digital internship has addressed three serious challenges to both faculty and students: the loss of internship opportunities, the need to provide a remote means to achieve similar skills, and the needs of faculty to access active learning activities that can be delivered at a distance. We have combined these challenges to provide a unique learning opportunity for the student interns and to generate a free open education resource (OER) for faculty to teach science literacy using podcasts and primary literature with minimal time expenditure during this stressful period.

SUPPLEMENTAL MATERIALS

Appendix 1: Annotation template
Appendix 2: Sample annotation and accompanying figure-reading exercise
Appendix 3: List of completed podcast annotations aligned to ASM fundamental statements

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