

How Getting Friendly with Bacteria Can Promote Student Appreciation of Microbial Diversity and Their Civic Scientific Literacy

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ePortfolios are digital repositories where students can curate papers, projects, and reflections from individual or multiple courses across the disciplines and in a variety of formats to showcase their learning. This transparent and portable medium, which enables students to document their knowledge and abilities for assessment and career development, has been recognized by the American Association of Colleges and Universities as one of 11 high-impact practices. Using tailored rubrics, student assessment of learning gain surveys, and end-of-course exam questions, this study demonstrates how an ePortfolio assignment can be used in microbiology courses taken by majors and nonmajors to measure student learning outcomes in several course and program learning goals. Additionally, it helps students reflect on their learning and place it in a real-world context by connecting science, microbiology, and microbes with issues of social importance like cholera, gender equity, and antibiotic resistance. Writing from a first-person perspective and drawing on resources obtained in class and from their own research, students generate profiles for a chosen microbe and document the microbe's characteristics in creative ways. The ePortfolio assignment can also be partnered with creative work such as an art piece or a poem that highlights and showcases the microbe in a format that is accessible to the public to increase awareness of the role of microbes in our ecosystems. With careful design and construction of assignments, ePortfolios can also be leveraged to promote civic and scientific literacy by tying classroom content to real-world issues of civic importance.

KEYWORDS ePortfolio, diversity, real-world problems, civic scientific literacy, antibiotic resistance, literacy, microbes, SENCER

INTRODUCTION

ePortfolios are digital repositories of student work that have been recognized by the American Association of Colleges and Universities (AAC&U) as a high-impact practice (1, 2). Although more common in the humanities, the potential role of ePortfolios in science, technology, engineering, and math (STEM) is becoming increasingly recognized. For example, they have been found to be beneficial in summer research programs for underrepresented students (3–7). Other institutions that have used them throughout the academic year have found that they helped with student engagement and persistence

(8–11). Over the course of their academic careers, students can collect examples of their work, such as papers, projects, and reflections, and display them in digital format on their portfolios. The ePortfolio can serve as a student's website, where they can compile work from individual or multiple courses across the disciplines and in various formats. If made public facing, the ePortfolio can support the student beyond college by showcasing their work generated throughout their academic careers. Both during college and after graduation, students can display their learning in a transparent and portable medium, which helps document and demonstrate their knowledge and abilities for such purposes as graduate school and job applications. From a faculty perspective, ePortfolios can serve additional purposes beyond showcasing work. With careful design and construction of assignments, along with scaffolding and integration of ePortfolios into the curriculum, these transformative tools can be leveraged to promote student development in a variety of ways. For example, they can be used to promote civic and scientific literacy by tying classroom content to real-world issues of civic importance. ePortfolios can be used both in a variety of courses and across disciplines to encourage student reflections, data analysis, and engagement with real-world issues and to promote project-based learning (12).

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Teaching through issues with microbiology

Students take microbiology courses for a variety of reasons. Some plan to become health care professionals, such as nurses, veterinarians, doctors, and physician assistants. Others take the course as an elective, choosing to learn about microbes. Due to the different socio-economic backgrounds, interests, levels of preparation, and prior knowledge in microbiology, our classroom composition is often highly diverse. One way we can engage our students in the course material is by connecting it to issues of real-world importance. Most students know that microbes can cause infectious diseases, foodborne illnesses, and pandemics. What is challenging is helping students recognize the central role that microbes play in our world, from nitrogen and carbon fixation to decomposition and biogeochemical cycling, biotechnology, bioremediation, and antibiotic production. They often fail to identify the benefits that microbes play for our society and see them as abstract, distant, and not connected to each other or themselves.

Teaching science content through real-world issues is a central focus of the SENCER (Science Education for New Civic Engagements and Responsibilities) project. SENCER, which has been recognized as a Community of Transformation (13), has four main ideals:

- SENCER connects science and civic engagement by teaching “through” complex and unsolved public issues “to” basic science.
- SENCER invites learners to put scientific knowledge and methods to immediate use on matters of relevance to them.
- SENCER reveals both the power and the limits of science in addressing the great challenges of our time.
- SENCER helps all learners connect civic issues of local concern to national and global “grand challenges.”

Designing courses that align with the SENCER ideals entails choosing current and relevant scientific issues and using them as tools to engage students in learning and applying basic science. This practice allows students to integrate what they have learned and to understand that, although science does not have all the answers, it can be a tool for social good.

As students vary widely in their prior knowledge and preparation, the ePortfolio assignment can gradually expose them to relevant concepts throughout the semester, with the overarching goal of enabling students to demonstrate in their ePortfolio how they have integrated their classroom learning and their independent research. This ePortfolio project combines the ideals of SENCER with the ASM curriculum goals (see Table 1) (14). It introduces students to the wonder of microbial diversity while helping them connect real issues to microbiology to understand the relevance of the material to their own lives (15). “SENCERized” microbiology courses are centered around issues such as antibiotic resistance, climate change, and the impact of anthropogenic activity on ecosystems, as well as misinformation and disinformation as it relates to science (such as

vaccine hesitancy). These capacious, wicked problems, which can readily be described as “complex unsolved public issues” and global “grand challenges,” help realize the SENCER ideals and can easily be interwoven throughout the course in readings, assignments, videos, projects, and research activities, all designed to help students connect their coursework and content to the real world.

Intended audience

This assignment was originally designed for a standard microbiology course, taken after students (i.e., Veterinary Technology, Clinical Laboratory Sciences, Nursing, Biology, and Health Sciences majors) had completed either biology 1 and 2 or anatomy and physiology 1 and 2 at two minority-serving institutions. Class sizes ranged from 24 to 60. More recently, the assignment was implemented in a newly designed course called “Microbial Ecologies,” which had no prerequisites and served as a foundation course for an Interdisciplinary Science major (or an elective for nonmajors) at a private liberal arts college.

Prerequisite student knowledge

Although this assignment was originally designed for a course for science majors, it can be modified for majors and nonmajors with different levels of prior knowledge.

Learning time

As students varied widely in their prior knowledge and preparation, the assignment was designed to gradually expose them to relevant concepts throughout the semester. The timeline described below (see Procedures) shows how this assignment is scaffolded across the semester to give students ample time to complete it in its entirety.

Learning objectives

As the goal of this assignment is to improve student comprehension of microbial diversity (learning objective 1 [LO1], LO2, and LO4) as well as to engage the public with their creative works (LO3), it is tied to several of the Microbial Ecologies course learning outcomes.

Upon completing the course that this assignment is part of, students will:

- LO1: Comprehend the core concepts of microbial ecology and environmental microbiology at different levels of scale and space from individual cells to the biosphere.
- LO2: Recognize functional ubiquity and diversity observed among microbes in ecosystems and understand how these characteristics reflect their adaptation to varied and dynamic environments.
- LO3: Identify ongoing citizen science projects that involve microbial ecology and how they are promoting public engagement and participation in the process of science.

LO4: Understand how microbes, their processes, and products can be harnessed for social good.

The ePortfolio prompts on course content were designed to align with part I of the ASM Curriculum Guideline concepts and statements (Table 1).

Programmatic learning objectives

In addition, the ePortfolio assignment design helped students develop their civic scientific literacy. While there are several different definitions of civic scientific literacy (16–19), we define it as the ability to find, evaluate, and synthesize information about science and technology to make informed decisions as a consumer, as a citizen voting on STEM policy issues, and as an educated individual with an understanding of the scientific method (20). Student learning in literacy and communication is often tied to the general education outcomes of the program. The Microbial Ecologies course allowed students to demonstrate their improvement for the program outcome (PLO 1):

“The student can locate, analyze, synthesize, and evaluate sources of scientific information to address problems, make decisions, and take action. The student can communicate science effectively in a variety of forms and can work on a sustained project independently and in collaboration with others.”

To evaluate this form of literacy, we assessed writing mechanics and form, information synthesis, sourcing of information, and creativity (see Appendix S2 in the supplemental material; see also Fig. 3, below). Our assignment and rubric helped us to address part II of the ASM Curriculum Guidelines outline LOs related to scientific thinking that includes an ability to “effectively communicate fundamental concepts of microbiology in written and oral format,” and to “identify credible scientific sources and interpret and evaluate the information therein” and also an ability to “understand the relationship between science and society.”

PROCEDURE

Materials

Materials to support this activity are provided in Appendices S1, S2, S3, S4, and S5 of the supplemental material, which is available online.

Student instructions

After reading the assignment guidelines (see Appendix S1), students chose an organism from a list that was predetermined according to the course theme, such as a list of antibiotic-resistant bacteria (see Appendix S3) or general microbial diversity (see Appendix S4), and followed the instructions to set up their ePortfolios, creating their own layout and design. To populate their ePortfolios, students had to use their course notes, their textbook, and other resources to respond to assignment

prompts 1 to 9 (Table 1 and below) as if they themselves were the microorganism. (Questions 10 and 11 were optional and resulted in bonus points.). Creating their entries led to a “dating profile” of sorts, or a biography, like a Facebook page. Like Facebook, students had to send “friend” requests to “microorganisms” in their “family” (members of their genus) or their classification tree (such as alphaproteobacteria). Students were required to cite their sources in their posts and received help from librarians and others in creating a bibliography. These questions spanned the recommended microbiology curriculum, aligned well with the ASM Recommended Curriculum Guidelines (Table 1) and the key concepts from *Vision and Change* (21), and they encouraged the synthesis of ideas and concepts from the entire course from an entirely different point of view, that of the organism itself. Along with the instructions, students were given the rubric (see Appendix S2). This enabled them to understand how they would be graded. The design of the rubric was intentionally straightforward to ensure that the expectations were very clear and that students could achieve high grades by following the guidelines. The prompts that were given to the students along with the instructions are supplied in the supplemental material in (see Appendix S1 in the supplemental material).

Faculty instructions

The ePortfolio assignment is presented at the start of the course along with the creative work assignment. Students are encouraged to work on this assignment throughout the semester so that they have sufficient time to complete it without it becoming burdensome toward the end of the semester. Learning Management System (LMS) discussion boards and check-ins facilitate scaffolding of the assignment, and at the midpoint of the course students are asked to submit their work in progress. The scaffolded nature of the assignment flows well with the course content, as students are encouraged to relate what they are learning each day to their chosen microbe. The complexity of the problems we discuss, which are often anthropogenically driven and have no obvious solutions, helps promote student reasoning and critical thinking as well as revealing the power and limits of science. The ways that scientists, doctors, and public health professionals work together to define, characterize, and understand the nature of problems emphasize the power of science and the scientific method. By asking students to discover new knowledge about their chosen organism and apply what they have learned in class, students can synthesize their knowledge in a creative and exciting ePortfolio. The assignment also encourages responsibility as students comment on each other’s work and offer peer feedback. Several studies have shown the benefits of peer review (22, 23), and we have made use of peer mentors in several of our courses (12, 20, 24). This assignment can be followed by a project in which students generate an educational product for the public to promote awareness about microbes. Each student displays their product in a gallery walk along with their ePortfolio, allowing them to advocate for the

TABLE I
Alignment of prompts with ASM recommended curriculum guidelines and course LOs

No.	Assignment prompt	ASM concepts and statements	Microbial ecology course LOs addressed ^a
1	My cell wall structure and Gram stain reaction: What kind of cell wall do I have? Am I Gram-positive or -negative? Do I have a special type of cell wall?	Cell structure and function: Bacteria have unique cell structures that can be targets for antibiotics, immunity, and phage infection.	LO1, LO2
2	My type of respiration: Am I an aerobe or anaerobe. What final electron acceptor do I use? Does my type of respiration influence where I can be found or restrict me to specific habitats?	Metabolic pathways: Bacteria and Archaea exhibit extensive, and often unique, metabolic diversity (e.g., nitrogen fixation, methane production, anoxygenic photosynthesis). The interactions of microorganisms among themselves and with their environment are determined by their metabolic abilities (e.g., quorum sensing, oxygen consumption, nitrogen transformations).	LO1, LO2
3	My type of metabolism: Am I special in this regard? Can I metabolize special substrates? Can I break down novel substances like plastic? Do I have enzymes that allow me to do things that other bacteria can't do, like fix nitrogen? Am I essential because of this?	Metabolic pathways: Bacteria and Archaea exhibit extensive, and often unique, metabolic diversity (e.g., nitrogen fixation, methane production, anoxygenic photosynthesis). The interactions of microorganisms among themselves and with their environment are determined by their metabolic abilities (e.g., quorum sensing, oxygen consumption, nitrogen transformations).	LO1, LO2
4	Where do I normally live? Do I sometimes go on holidays (from a lake into someone's intestine)? While bacteria are adapted to habitats, they can migrate to new habitats and this usually requires adaptations and modifications in their gene expression, etc. Am I superflexible? If I do migrate can it be a bad thing?	Microbial systems: Microorganisms, cellular and viral, can interact with both human and nonhuman hosts in beneficial, neutral or detrimental ways. Metabolic pathways: The interactions of microorganisms among themselves and with their environment are determined by their metabolic abilities (e.g., quorum sensing, oxygen consumption, nitrogen transformations).	LO1, LO2
5	Am I a pathogen? Yes. Do I have virulence factors? What are they? Do I share my spoils? Or, if I'm not a pathogen, can I be used for something? Am I good or bad? Can I be both?	Microbial systems: Microorganisms, cellular and viral, can interact with both human and nonhuman hosts in beneficial, neutral or detrimental ways. Cell structure and function: Bacteria and Archaea have specialized structures (e.g., flagella, endospores, and pili) that often confer critical capabilities.	LO1, LO2, LO4
6	Am I resistant to antibiotics? Antimicrobials? Do I make them?	Evolution: Human impact on the environment influences the evolution of microorganisms (e.g., emerging diseases and the selection of antibiotic resistance).	LO1, LO2, LO4
7	Who are my family members (my genus)? If they are among your classmates, make friends with them. If not, put out a call to your family. Maybe you have a reunion coming up?	Evolution: The evolutionary relatedness of organisms is best reflected in phylogenetic trees. The traditional concept of species is not readily applicable to microbes due to asexual reproduction and the frequent occurrence of horizontal gene transfer.	LO1, LO2

(Continued on next page)

TABLE I (Continued)

No.	Assignment prompt	ASM concepts and statements	Microbial ecology course LOs addressed ^a
8	Who are my friends (in my classification tree)? Same as above, if they are among your classmates, say hi.	Microbial systems: Microorganisms are ubiquitous and live in diverse and dynamic ecosystems. Most bacteria in nature live in biofilm communities. Microorganisms and their environment interact with and modify each other.	LO1, LO2

^aLO1: Comprehend the core concepts of microbial ecology and environmental microbiology at different levels of scale and space from individual cells to the biosphere. LO2: Recognize functional ubiquity and diversity observed among microbes in ecosystems and understand how this reflects their adaptation to varied and dynamic environments. LO3: Identify ongoing citizen science projects that involve microbial ecology and how they are promoting public engagement and participation in the process of science (not applicable for this table). LO4: Understand how microbes, their processes, and products can be harnessed for social good.

problem and engage with the public beyond the course, which helps to address LO3.

The assignment is delivered in three main stages. In stage 1, the first day of class, students receive detailed instructions about the assignment and are required to choose their organism from a list that is shared with them, reducing the likelihood of their choosing an organism that they are already familiar with. At the start of the semester, students are introduced to the types and structures of microbial cells for the first time, the nature of the cell wall, their roles in ecosystems and biogeochemical cycles, and the ubiquity and diversity of microorganisms. They are provided with instructions on how to create the ePortfolio using online tutorials. In addition, a peer fellow (a student who has previously taken the class) helps with some in-class instruction on how to design the ePortfolio, and librarians show them how to create a bibliography using freely available citation managers such as Zotero. In addition, students are shown examples of poorly and well-designed ePortfolios from prior semesters. If necessary, instructional designers can be recruited to visit the class and answer questions. In stage 2, roughly 7 weeks into the semester, students upload their posts to the ePortfolio. The students are also paired up in class to discuss their ePortfolio progress with one another and to provide feedback. This provides an opportunity for constructive feedback from both their peers and their instructor and helps address any errors in their work. This is particularly important in the case of scientific nomenclature and creating the bibliography, and at the same time, the instructor can also draw attention to basic errors such as spelling and grammar. In stages 2 and 3, once the students have uploaded their portfolio and are commenting and “making friends,” the instructor can post comments and suggestions to encourage students to address specific issues. In the final stage, stage 3, students present their work to the class and comment and post on each other’s portfolios (Fig. 1).

The creative work that accompanies the portfolio is often the most enjoyable part of the course and it is the most reflective of the diversity of the students in the class. Students manifest their knowledge in a variety of ways, from pickles and

relish (fermented foods produced by their microbes) to videos and rap songs, comic books and paintings featuring their microbes, and even crocheted and knitted microbes. Different modes can be used to exhibit the works, from a gallery walk on campus to a Padlet gallery online. The creative aspect is tailorable to the institutional context and has the greatest capacity for broader impacts, as it can present the problem in a variety of different ways. Details of the creative works and exhibitions are shown in Fig. 2. While students learn about citizen science and outreach through the microbiology course content itself, this exhibition provides an opportunity for the students to engage with the public directly, which aligns with course LO3.

Suggestions for determining student learning

The use of stages in the assignment allows the instructor to give formative feedback throughout the semester and to give useful hints and pointers during lectures where information is pertinent to the assignment. The use of stages also enables students to gather information over a prolonged period and get feedback from the instructor and their peers. The grading rubric (see Appendix S2), which students receive at the beginning of the course, is also used to help assess the learning objectives (Table 1). Grading is not completed until the very end of the semester in stage 3, giving students plenty of opportunities to complete the exercise fully and to the best of their ability. In addition, a set of exam questions (see Appendix S5) can be added to help determine the extent of student learning from the activity. A SENCER-adapted version of the Student Assessment of Learning Gains (SALG) survey can be used to ascertain the students’ perceptions of the usefulness of the assignment and the class in general. Two versions of the SALG are used for this course and they function as a pre- and postassessments of students’ impressions of their own learning. The pre-semester SALG allows the instructor to determine the level of interest, preparation, and skills of the student in advance of the course in four main categories: understanding, skills, attitudes, and integration of learning. As the SALG is editable, the instructor

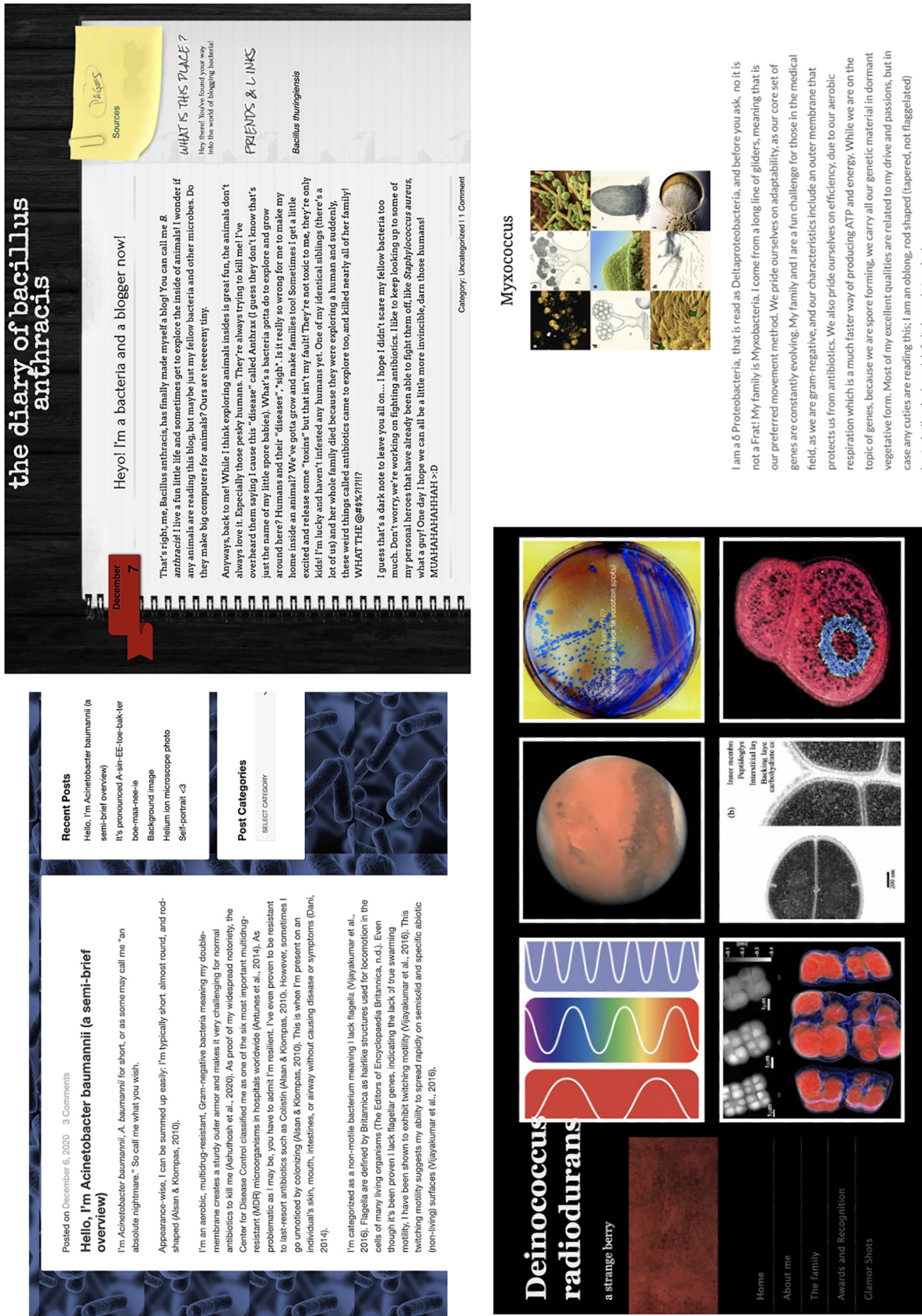


FIG 1. Examples of student work. Four snapshots of student ePortfolios are shown, each featuring a different microbe and style.

A PUBLIC PROGRAMS AND EVENTS



Marvelous Microbes
Eugene Lang College Building
GENERAL PUBLIC

Exhibition: February 17 - 28, 2020

Reception: Friday February 21, 2020 - 5:30 to 7:30pm

Marvelous Microbes the Exhibit will be held from the 17th to the 28th of February featuring the creative works of the Spring and Fall sections of Microbial Ecologies. The exhibit is a celebration of all things microbial, from art and comics to songs and push toys. Each creative work was designed by a student as part of an assignment called "Getting Friendly with Bacteria" and has an associated barcode that links to a website, designed by the student, to feature the microbes. Come learn about all the marvelous microbes, their amazing capabilities, and their roles in Earth's Ecosystems!

A reception will be held on the 21st of February where you'll be able to meet and mingle with the artists, designers, and scientists. Drinks and snacks will be served

Presented by the [Interdisciplinary Science](#) program at [The New School](#).

Getting Here

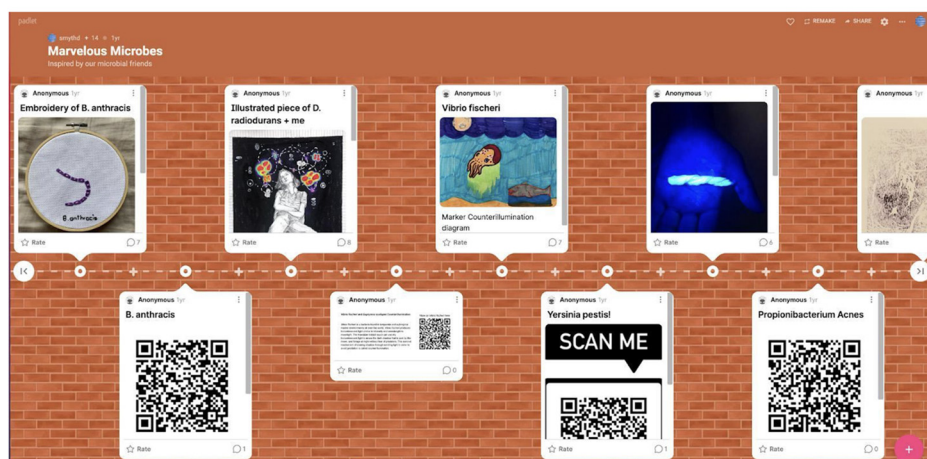
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C

- Anonymous** 1yr
love how symbolic!
- Anonymous** 1yr
really pretty gradient, I also like your concept of re-centering the frame onto the microbes!
- Anonymous** 1yr
I like how you framed the composition to highlight the edge of the hot springs to shift the focus to microbial communities
- Anonymous** 1yr
I really like this creative work. Your shading of the transition between the colors really shows off the bacteria's special qualities.
- Anonymous** 1yr
It reminds me of all the different versions of the world map to center/ cater to specific countries/continents!
- Anonymous** 1yr
I love how colorful this is! In my mind it accurately represents your microbes strong personality well!
- Anonymous** 1yr
I am not sure if we can be friends since I cannot come to the hot springs :(
- Anonymous** 1yr
really pretty use of color & representation of your microbe!!

FIG 2. (A) Announcement for the exhibition, open to the public, that was held on campus. (B) Alternative Padlet gallery walk, which was used during the pandemic as we moved to online instruction. The students uploaded images or links to the creative works along with QR codes that linked to the ePortfolio. During the exhibition, students could comment on the portfolio and get friendly with one another. (C) Comments made by the students on one of the student posts on Padlet during the Padlet gallery walk. This activity was aligned with LO3.

can add content-specific questions. The type of response is indicated under the category with either use of a Likert scale or a long answer provided by the student. The post-semester SALG builds upon the pre-semester one and enables the students to reflect on their learning gains and their experience of the course.

Sample data

Sample data are provided in the "Evidence of student learning" section of the Discussion.

Safety issues

This activity and associated research study were evaluated by the Institutional Review Board at each institution where it was conducted, and they were determined to be exempt. There are no safety concerns associated with this activity.

DISCUSSION

Field testing

As noted earlier, this assignment has been used by instructors in several sections over several semesters in three distinct institutions. It has always served to demonstrate student learning as evidenced by their portfolios. Through the design and use of the "first-person" voice, students critique, synthesize, and apply information from a variety of sources to make it engaging and accessible to the reader. Students have completed the assignment with full marks in almost all cases, owing to three critical components. (i) Students are given multiple reminders to complete the assessment and encouraged to review the rubric to understand how they will be graded. In addition, they receive ongoing feedback from the instructor on their portfolios right up until the end of the semester. (ii) They post on each other's assignments to provide one another with an additional source of feedback, giving them opportunities to learn from each other and guide each other. (iii) They have

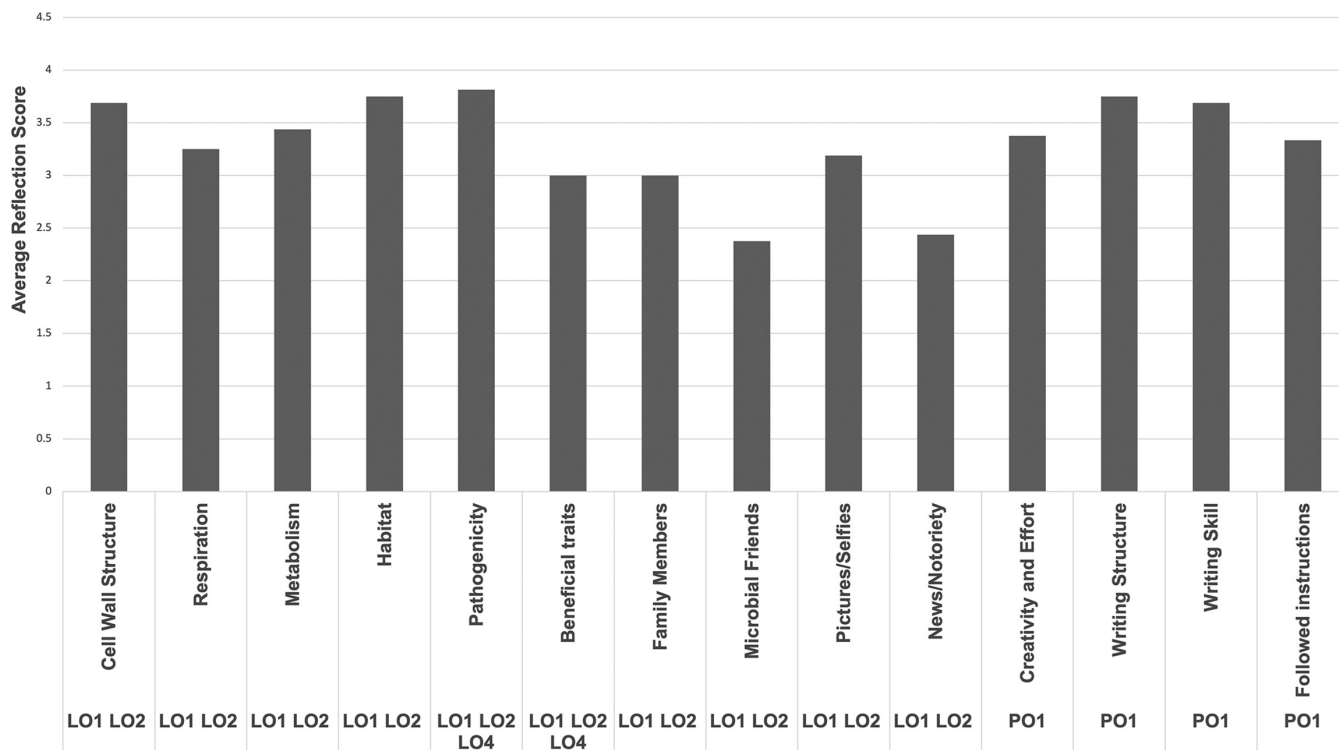


FIG 3. Student scores ($n = 16$) following assessment of the ePortfolio prompt responses (columns 1 to 8) with the rubric. While all the prompts address LO1 and LO2, only prompts 5 and 6 focused on LO4. The last four columns refer to creativity and the writing quality of the portfolio (columns 11 to 14) and help the students demonstrate improvement in the programmatic learning outcome. Students could score 8 bonus marks for adding pictures and stories from news articles (columns 9 and 10).

access to examples of poorly designed and well-designed ePortfolios from prior semesters and can view them as they build their own. Our most recent iteration in the new course Microbial Ecologies includes a creative component, which complements the ePortfolio and is designed to be completed by students outside of class time, thus saving class time. The creative component also adds to the excitement associated with the assignment and helps students meet LO3 (see above) of the Microbial Ecologies course.

An important resource that is often overlooked at institutions is a knowledgeable librarian. When designing projects that require bibliographies or literature reviews, the librarians have assisted instructors with generating LibGuides or have visited the class to instruct students about the library tools and resources. Information literacy is key to the development and completion of extensive assignments such as this one. Instructional designers are also very helpful and will often work one-on-one with the faculty and visit the class to instruct students in the use of ePortfolio tools and platforms.

For faculty who are new to ePortfolio usage, or at institutions where they are not widely implemented, support can be gained from joining a professional organization that promotes ePortfolio pedagogy, such as AAEEBL (Association of Authentic, Experiential, and Evidence-Based Learning) and AAC&U. Also helpful are comprehensive guides from leaders in the field (25–27).

Evidence of student learning

Data reported here are taken from the Microbial Ecologies course that was conducted in Fall 2020. While this course was designed to be a foundation course for the Interdisciplinary Sciences major, there are no prerequisites for the course and many students from other non-STEM majors signed up for it, many of whom were freshmen. Although this section was delivered in an online format owing to the COVID-19 pandemic, students performed remarkably well. Examples of student ePortfolios are shown in Fig. 1 and 2. A great variety of styles was evident, and each was complemented by the student's additional creative work. Student results scored with the rubric (see Appendix S2 in the supplemental material) are shown in Fig. 3. The alignment of each prompt with the course or program learning objectives is indicated below the chart. As mentioned above, the Microbial Ecologies course outcomes aligned with this activity and supported students in learning the core concepts of microbiology and the functional ubiquity and diversity of microbes, as well as how they can be harnessed for social good. The majority of students scored 3 and above on the rubric for the majority of the prompts, which demonstrated successful completion of the assignment and achievement of our goal for the assignment, to improve their learning of core concepts, of functional ubiquity, and of diversity of microbes (prompts 1 to 7), as well

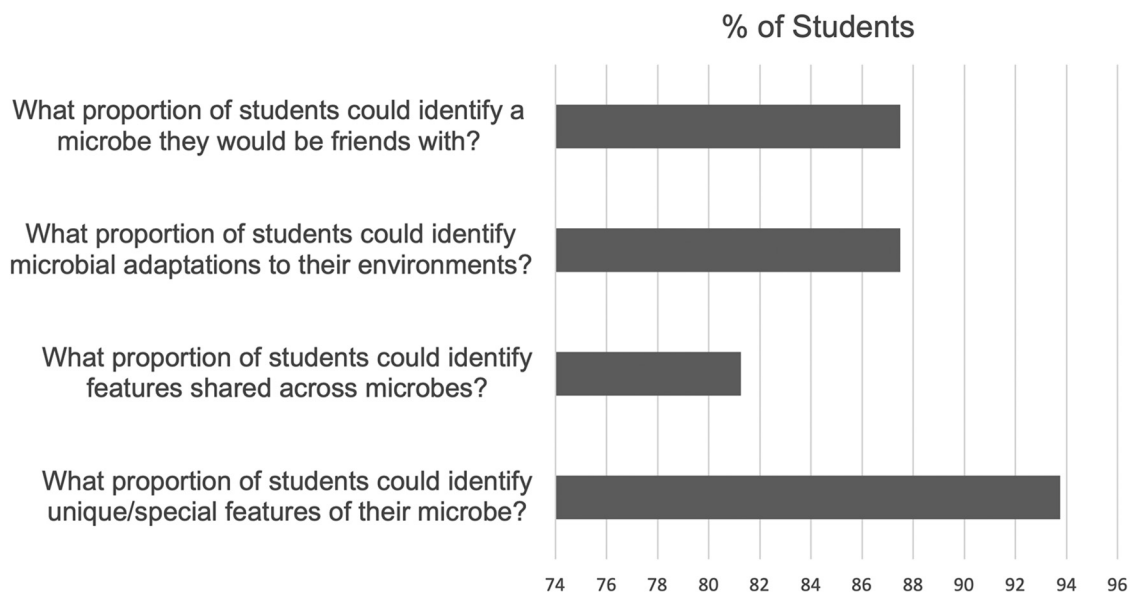


FIG 4. The proportions of students who responded accurately to the questions posed on the final exam. As the major goal of the course was to encourage student appreciation and knowledge of microbial diversity, these responses demonstrated student understanding and awareness of shared function and adaptability among microbes and progress toward LO2.

as how they can be harnessed for social good (prompts 6 and 11). While students struggled to identify their family members and microbial friends directly on the ePortfolio (prompts 8 and 9), most often by omitting this section, their responses to questions on the final showed that students could in fact identify microbes that shared characteristics and other properties with one another (Fig. 4). With respect to writing, students scored above 3 in the writing categories (prompts 12 to 15). By encouraging writing, we are helping students improve their communication and literacy skills, which aligns with program learning objective 1 (PLO1). Question 9 of Appendix S6 addresses LO3, with students noting that the creative project was helpful to their learning. Figure 2 also addresses LO3. We were able to determine that students engaged in LO3 through presenting and discussing their work at a public exhibition in person and virtually during COVID. Using embedded QR codes, students made their ePortfolios available for public online viewing and discussion. The sample comments show how they engaged enthusiastically with the other students' work. A selection of student responses to the SALG from Fall 2020 is shown in Appendix S6. Students commented on the impact of the ePortfolio assignment on their skills, and several noted it as being particularly enjoyable among the resources and instructional activities used in the class, with one student stating, "I actually enjoyed the ePortfolio more than I thought I would. It is a little weird being a microbe, although it did make them more personified and showed the importance of bacterial diversity." Another student commented, "The ePortfolio really emphasized how a singular bacterium interacts with the world around it. It also showed how there is so much bacterial diversity with different traits or abilities. Looking at everyone's works also was great for educating me about the different aspects of bacterial diversity." Two students did not like it, one stating that it "was good

but was stressful to put together in addition to other assignments during the weeks." Several students also made suggestions to improve future iterations of the assignments and gave advice for future students taking the course to "really internalize and listen to the timelines you provided regarding the assignments. I did by the end, and it was helpful to just get it done and split up the time. Also, give yourself time between long-term assignments like the ePortfolio because it gives you time to reflect and think about what you are missing, what you should add, what you may want to alter, etc." Additional sections of the pre- and post-SALGs are included in the supplemental material (see Appendices S7 and S8).

The areas that students struggled with the most included the use of in-text citations and citation format, as well as identifying the classification of the microbes, since these concepts were new to many of them (Fig. 3). Nevertheless, most students used online resources to identify their organism's classification and identified their "friends" and members of the classification trees when presented with their peer's portfolios at the end of the semester, showing growth in PLO1. The proportion of students responding accurately to questions on the final is shown in Fig. 4. It was clear that students were able to identify both unique and shared features of the microbes that had been characterized by their peers on their final exam, a measure of their improvement in LO2. Students were also able to identify adaptations, some in extensive detail (LO2). When it came to describing who they would be friends with and why, many chose reasons such as they were both pathogens or that they were symbiotic or extremophiles. Their responses demonstrated that they were not only able to express and synthesize what they had learned through the course materials and their own research, but also that they had also grown to understand and appreciate the shared features and functions of microbes and the diversity of microbial life. This directly ties to LO2.

Possible modifications

This assignment has been implemented on three different ePortfolio platforms, including CUNY's OpenLab, Digication, and the New School's Learning Portfolio. However, not all institutions have access to campus ePortfolio platforms. One Drive, Google Drive, and Dropbox are all useful for collaborative projects. Students can use Google Docs to share their work with one another and Google Sites to create websites. Other alternatives include free versions of commercial platforms, such as WordPress, Weebly, and Wix, which allow for comments and feedback throughout the assignment period by the instructor and peers. If the instructor prefers to complete this assignment as an in-class activity, students can make "friends" during class time by standing up and assembling themselves into groups. Post-Its could be used to label each student with their characteristics (examples could be "Gram-positive" or "Anaerobic" or "Like to swim"). The classroom furniture could also be arranged according to body sites, such as the skin or the large intestine. There are many ways that this could be adapted to be a fun in-class exercise to get students excited about microbiology.

SUPPLEMENTAL MATERIAL

Supplemental material is available online only.

SUPPLEMENTAL FILE 1, DOCX file, 1.03 MB.

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