Poster Development and Presentation to Improve Scientific Inquiry and Broaden Effective Scientific Communication Skills†

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We have redesigned a tried-and-true laboratory exercise into an inquiry-based team activity exploring microbial growth control, and implemented this activity as the basis for preparing a scientific poster in a large, multi-section laboratory course. Spanning most of the semester, this project culminates in a poster presentation of data generated from a student-designed experiment. Students use and apply the scientific method and improve written and verbal communication skills. The guided inquiry format of this exercise provides the opportunity for student collaboration through cooperative learning. For each learning objective, a percentage score was tabulated (learning objective score = points awarded/total possible points). A score of 80% was our benchmark for achieving each objective. At least 76% of the student groups participating in this project over two semesters achieved each learning goal. Student perceptions of the project were evaluated using a survey. Nearly 90% of participating students felt they had learned a great deal in the areas of formulating a hypothesis, experimental design, and collecting and analyzing data; 72% of students felt this project had improved their scientific writing skills. In a separate survey, 84% of students who responded felt that peer review was valuable in improving their final poster submission. We designed this inquiry-based poster project to improve student scientific communication skills. This exercise is appropriate for any microbiology laboratory course whose learning outcomes include the development of scientific inquiry and literacy.

INTRODUCTION

We introduced a team poster project into our general microbiology laboratory curriculum over 10 years ago. A team project was chosen for several reasons. Our lab is structured such that students work independently for all but one other exercise during the semester; the team project provides the opportunity to enhance interpersonal relationships and collaboration, important skills for students, whether they are pursuing graduate and professional study or heading directly to the workplace (1, 2). Various forms of small-group learning have been shown to improve academic performance and attitudes toward learning (3, 4). A team project spanning the semester reinforces laboratory skills and concepts introduced throughout the semester (5). The poster format for presenting undergraduate research has become quite common, used department- and university-wide, as well as for local, regional, and national conferences. Here we use an “in-class” poster presentation. Laboratory sections have individual poster sessions. Posters are projected one at a time as slides to the class, and student group members give oral presentation of the information. Posters provide an alternative to the lab report for fostering written scientific communication skills, as well as the opportunity to hone oral communications skills (6, 7). Poster assignments promote student engagement and help students make connections between lecture information and laboratory work (8–10).

When first introduced, the team poster project tasked students with exploring the factors that influence the growth of microbes in the environment. Students were assigned to groups, and each group was assigned an environmental factor (temperature, oxygen, water activity, nutrient level, pH). We felt that the exercise would be more valuable if it were inquiry-based, so students were challenged to formulate their own research question. The experiment to answer that question they designed within the context of the information provided in our lab manual (11, Appendix 1) and pre-lab presentation (Appendix 2). Guided, inquiry-based lab exercises improve science literacy and research skills (12). Efforts to reform science education curricula at all levels stress the importance of being involved in the research process (13). As stated in Vision and Change in Undergraduate Biology Education: A Call to Action, “learning
science means learning to do science” (14). Course-based research experiences engage students in the scientific process, improving student attitudes toward research and learning, and increasing self-confidence with respect to lab-related tasks (15–17). Providing more-authentic research experiences in introductory courses increases retention of STEM majors and improves critical thinking (18, 19).

Based on our experience with laboratory teaching, students have difficulty writing a purpose, hypothesis, and predictions due to the contrived “cookbook” nature of most lab exercises. Although many of our students have had some experience in presenting research, many have not. We considered revising our original “cookbook” poster project into an inquiry-based one. Such an exercise is among many “old standards” with the potential to be excellent inquiry-based exercises and there are guidelines and suggestions for such revisions (20, 21). However, we had piloted an inquiry-based exercise investigating physical and chemical methods for controlling microbial growth during several semesters and decided to make this the basis for the team poster project instead. Students take responsibility for formulating a hypothesis, experimental design, data collection and analysis, and time management. Applying the rubric provided by Buck et al. (22), the level of inquiry for this project is between inquiry levels 1 (guided) and 2 (open). Our students do formulate the question under investigation; however, student research questions and methods are derived from the information in the laboratory manual (11).

This change to an inquiry-based project addresses a course learning goal requiring students to “apply the scientific method to collect, interpret, and present scientific data in microbiology and related fields,” and aids in implementing the following action items in the Vision and Change report: integrating the scientific process into all undergraduate biology courses; stimulating the curiosity students have for learning about the natural world; demonstrating both the passion scientists have for their discipline and their delight in learning about the natural world; and increasing self-confidence with respect to lab-related tasks (15–17). Providing more-authentic research experiences in introductory courses increases retention of STEM majors and improves critical thinking (18, 19).

Prerequisite student knowledge

Before the start of the semester, students are trained in laboratory biosafety regulations (26–28; Appendix 3). The lab is a designated Biosafety Level (BSL)-2 laboratory though all organisms provided for students in the general microbiology lab are risk group I (RG-I) (Appendix 4). Before introduction of the poster project, students have practiced microbiological laboratory techniques, including aseptic technique, swab inoculations, alcohol and heat sterilization, and preparing dilutions. In addition, we highly recommend that students are computer literate and proficient in performing Internet-based research. We use PowerPoint and MS Word for poster preparation and design. Posters are presented as single PowerPoint slides.

Learning time

Our general microbiology laboratory runs three hours. The scope of the poster project is introduced during the first third of the semester, after students have been instructed in the biosafety rules and regulations of the lab (28) (Appendix 3) and have learned proper handling of cultures, culture transfer, pipetting, media preparation, and dilutions. The poster project is introduced to the students with a one-hour initial meeting session in which the students form their groups, formulate the research question, and discuss and plan their experiments. The following week, students perform inoculations (one hour) and the rest of the allotted “poster time,” spread out over the semester, is spent collecting and interpreting data, and designing, reviewing, and presenting the poster (Tables 1 and 2). Students are asked to manage their time appropriately so that no or minimal time is spent on the project outside of their laboratory. One related homework assignment requires students to perform guided peer-review of another student poster from a different laboratory section (Appendix 5).

Learning objectives

After this poster project, students will be able to:
1. formulate a purpose, predictions, and hypothesis for an original research question
2. design and execute an experiment
3. collect and interpret results
4. effectively communicate research findings in a scientific poster

Intended audience

We have incorporated this project into our general microbiology laboratory. This is a 300-level, required course for students majoring in the fields of animal science, microbiology, biology, biochemistry, and others. The enrollment during each fall and spring semester is about 200 students divided into 10 lab sections, and, during the summer, about 40 students divided into two lab sections; no lab section has more than 20 students. The instructional team per section consists of one full-time teaching faculty and one graduate teaching assistant. This poster project is appropriate for any lower- or upper-level microbiology courses that include the development of scientific inquiry and literacy in their curriculum learning outcomes.
TABLE 1.  
Timeline and required materials for poster project.

| Stage     | Topic                                         | Timea | Materials                                                                 |
|-----------|-----------------------------------------------|-------|---------------------------------------------------------------------------|
| Preparation | Basic Laboratory Techniques (Aseptic Technique, Culture Transfer Methods, Dilutions) |       |                                                                           |
| Stage 1   | Experimental Design                          | 1 hour| Cleaning products with varied active ingredients                           |
|           | Formulating a Hypothesis                     |       | Antisepsics and soaps (non-antibacterial and antibacterial)                |
|           | Establishing Group Rules                     |       | Antibiotic discs (BD)                                                     |
|           |                                               |       | Short wavelength UV light and index card                                   |
|           |                                               |       | List of available organisms (Appendix 2)                                  |
|           |                                               |       | Internet-connected computer or tablet (at least one to two per group)     |
| Stage 2   | Experimentation                               | 2 hours| Bunsen burners and/or incinerators                                         |
|           | Data Collection                               | 1 hour| Prepared tryptic soy agar (BD)                                             |
|           |                                               |       | RODAC plates                                                              |
|           |                                               |       | Petri dishes (100 × 105 mm /150 × 15 mm)                                  |
|           |                                               |       | 70% alcohol for sterilization                                             |
|           |                                               |       | Sterile swabs                                                             |
|           |                                               |       | Tweezers                                                                  |
|           |                                               |       | Sterile paper discs (6 mm)                                                |
|           |                                               |       | Bacterial cultures (Appendix 2)                                           |
|           |                                               |       | 50 mL beakers                                                             |
|           |                                               |       | Incubators and refrigerator                                               |
|           |                                               |       | Rulers                                                                    |
|           |                                               |       | Camera                                                                    |
| Stage 3   | Data Interpretation                           | 1 hour| Internet-connected computer or tablet (at least one to two per group)     |
|           | Poster Design                                 | 4 hours| with word processing and graphic presentation software (e.g., MS Word and PowerPoint) |
|           | Poster Presentations                          | 1 hour| Projector for presentations                                               |
|           | (~10 min/group)                               |       |                                                                           |

aThe times given for each stage indicate approximately how much time is spent on this project during each of the 6 lab meetings involved.

PROCEDURE

Materials

Materials are summarized in Table 1.

Student instructions

Instructions for the poster project are detailed in Appendix 2. A detailed outline can also be found in our General Microbiology Laboratory Manual (11) (Appendix 1).

Faculty instructions

In the weeks leading up to the first group meeting, students should be trained in the appropriate biosafety precautions and become proficient in basic laboratory techniques, including aseptic technique, alcohol sterilization, and inoculations of cultures with sterile swabs to grow bacterial lawns. Table 2 summarizes the semester schedule for the poster project.

Before students form groups and design their experiments, they should be given a brief introduction to the topic of controlling microorganisms (Appendix 2). Faculty can assign individuals to groups or allow students to form their own groups. We suggest that each group have three or four members. We have found that more than four students per group impedes a balanced distribution of work. Feedback from 155 students via SurveyMonkey showed that all preferred three or four students per group. Some comments from students: "It was very appropriate for the amount of work necessary for the assignment," "I thought this was an efficient number, allowing for the splitting up of the work and allowing for more results to be obtained," and "...yes, this number was great! Enough to get varied opinions and split up the work, but not too many that it could get confusing. I think groups of two to four are good, but it could get crowded around the lab bench/computers.
if there are too many people.” One group that only had two students commented “…and no I do not think it was appropriate because other groups had four people, so we had to do more work.”

Course instructors should guide students through the scientific process and support them in writing a testable hypothesis. Disinfectants, antiseptics, antibiotics, a list of available organisms (Appendix 4), and an Internet-connected electronic device should be available so that students can discuss their experiment and research background information. At the end of this initial meeting, each group should hand in an experimental plan containing a hypothesis and a methods section detailing the amount of media and types of organisms needed. This will allow the course instructors to provide specific materials to each group.

In addition to their experimental design, each group will be asked to write four or five “group rules” that they will follow throughout the semester. If a member does not follow the rules, they can be “fired” from the group and receive zero points for the project. This decision is made between the group members and the lab instructor after a discussion of the evidence.

In preparation for the next lab meeting, faculty should review all experimental designs and make comments as necessary. All requested media should be prepared. Organisms should be grown according to standard operating procedures of the lab. During the second group meeting, students will get back their experimental designs and follow their methods to inoculate and expose their plates to their microbial control factors and agents. Students should
label their plates with specific instructions regarding the length of time and temperature for incubation. Depending on the number of meetings for the lab per week, course instructors may need to remove each group’s plates and place them in a refrigerator until the next lab meeting for data collection. We encourage students to take pictures to be used for their posters. Biosafety regulations prohibit the use of cell phones, thus “lab cameras” should be available for student use.

After data collection, students work on creating their posters. Course instructors should first introduce the purpose and importance of creating posters for the scientific community (Appendix 6). Often, we present our own research posters to show the students a “real-life” research poster. We also display previous student posters in the hallway outside of the teaching lab and encourage students to study these examples. The poster guide (Appendix 7) will help to give an overview of the most important features of a scientific poster. Our teaching lab has 12 desktop computers available, so each group of four (five “poster groups” in total) may use two computers to research background information and design the poster itself. Most of our students are sophomores and juniors and we expect that they have some experience using university library resources and databases. We work on an individual basis with any student who has questions about where to search for information. Our desktop computers have appropriate software and an Internet connection. In addition, students keep an electronic notebook on iPads, which are also available for research. We suggest that posters all be the same size (36 inches by 48 inches). Each individual group makes font, layout, and design decisions.

Once posters are in their final draft phase, faculty should set up a peer review through a course website (such as Canvas or Blackboard) or, if permitted by your institution, a Google site. Feedback can be collected electronically, and faculty should compile the feedback for each poster in a single document if students don’t use an electronic learning platform that does this automatically. Students should then be given time to review the feedback and revise their posters before final submission.

Before poster presentations, students are asked to evaluate each other using the rubric for group member evaluation (Appendix 8). We allow 10 to 15 minutes before presentations begin for students to look over their posters and assign roles to each group member for their final presentations if this has not already been done. We also review the guidelines for presenting posters, which can be found in Appendix 6. As a fun, “competitive” addition, members of the group with the best poster (as judged by the teaching faculty) each win a “gold” (spray-painted) petri dish. Members of the next-best poster receive “silver” (spray-painted) petri dishes, and the group submitting the third-best poster is awarded “bronze” (spray-painted) plastic inoculation loops. The two best posters from our course are printed and displayed outside our teaching laboratory, serving as guides for students working on their poster project.

Suggestions for determining student learning

We have used the following strategies for grading and both formative and summative assessment:

**Formative assessment.** The experimental design and group rules developed and submitted by each group are used as formative assessment prompts for initial review of the group ideas and to provide feedback for the students early in the project.

**Summative assessment.** Appendix 9 offers a rubric for assessment of the completed poster project.

Additional suggestions for grading. Much time is dedicated to this assignment during the lab, and an appropriate number of points or final weight should be assigned to it. For example, it is worth about 13% of our final lab grade (Appendix 10). The rubric in Appendix 9 is used in grade-point assignment as indicated. For students to take the peer review assignment seriously, it is awarded 10, 5, or 0 points based on the following criteria: Thorough, helpful feedback would receive 10 points; some feedback showing lack of effort would receive 5 points; and late/no submission would receive 0 points. Group members are asked to score the other members of their group based on the rubric provided in Appendix 8.

Sample data

We have included two examples of final posters in the supplemental materials (Appendix 11).

Safety issues

Although our teaching lab is designated a BSL-2 facility due to the nature of the courses that are taught there, our general microbiology course in which this poster project was adopted only uses risk group 1 (RG-1) organisms (Appendix 4). The RGs of all organisms used in our courses are verified on the database of the American Biological Safety Association each semester to ensure proper handling and biosafety precautions. At the beginning of each semester, our students are instructed in biosafety rules and regulations set forth by the American Society for Microbiology (ASM) Biosafety Guidelines (27) and the Rutgers Environmental Health and Safety (REHS) regulations for teaching laboratories (28). Our faculty also presents a short lecture about the importance of biosafety and reviews all the rules and procedures (Appendix 3), after which students sign an agreement to follow all safety precautions. Students must wear lab coats and lab glasses at all times when present in the lab. These items are stored in the lab for the dura-
tion of the semester. American Society for Microbiology and REHS biosafety guidelines for BSL-1 are followed for hand hygiene (27, 28). Every student working in the lab uses an iPad to take notes and pictures, as well as keep an electronic notebook to minimize possible contamination (26). The iPads are provided for our students and remain in the lab. The organisms that we use in the lab are stored as frozen stock cultures at -80°C and freshly quadrant streaked before the start of each semester, and are maintained in tryptic soy agar (TSA) slants throughout the semester. Inoculated and used student cultures are discarded according to standard operating procedure of a BSL-2 laboratory (27, 28). No sub-culturing is done from organisms inoculated for the poster project.

**DISCUSSION**

**Field testing**

This poster activity was first developed over 10 years ago and, after many adaptations and redesigns, was introduced as an inquiry-based activity during the summer 2015 semester. We chose the summer semester as we offer a smaller course then—only two sections, with up to 20 students each. Unofficial student feedback showed that students felt they learned a great deal about their topic and had sufficient time to develop a good product during lab hours. Official feedback was collected from subsequent students anonymously—after obtaining approval from the Rutgers Institutional Review Board (IRB#E16-610)—via SurveyMonkey during the spring 2016 (29 students) and fall 2016 (70 students) semesters. Assessment of student learning was collected from poster rubric scores during the fall 2016 and spring 2017 semesters (n = 155). Faculty members involved in this project had strong backgrounds in microbiology research. Graduate students involved in microbiology-related fields served as teaching assistants (TAs) for this course. Teaching assistants and laboratory instructors meet each week to review learning goals and lab activities for the week as well as practice using rubrics to assess student work.

**Evidence of student learning**

Student learning was assessed as exemplary (3 points), competent (2.5 or 2 points), or beginning (1.5 or 1 point), over 10 scoring dimensions (Appendix 9). Specific, appropriate scoring dimensions from the rubric provided data demonstrating student achievement of each of the four learning objectives. Laboratory instructors scored poster rubrics for their assigned sections. All instructors were trained on objectively applying the rubrics to student work.

To assess Learning Objective 1 (formulate a purpose, hypothesis, and predictions for an original research question), we used combined weighted scores for the Abstract and Introduction scoring dimensions. The information required for these two sections relates to formulating a purpose, hypothesis, and predictions.

Learning Objective 2 (design and execute an experiment) was assessed using combined weighted scores for the Materials/Methods scoring dimension. The Materials/Methods section of the poster indicates ability to design and execute the experiment.

For Learning Objective 3 (collect and interpret results), we used combined weighted scores for the Results and Discussion/Conclusion scoring dimensions. Achieving this objective requires competence in collecting data for the results section and in interpreting those results in the discussion section.

Learning Objective 4 (effectively communicate research findings in a scientific poster and poster presentation) was assessed using combined weighted scores for all 10 poster rubric scoring dimensions.

For each learning objective, a percentage score was tabulated (learning objective score = points awarded/total possible points). A score of 80% was our threshold for achieving each objective. We chose this threshold because each semester the lab average is approximately 80%, which is our standard for successfully completing the lab portion of our general microbiology course. Overall results are summarized in Table 3. At least 76% of the student groups participating in this project over two semesters achieved each learning objective. This percentage is well above the Rutgers University threshold that requires at least 65% of students to achieve the learning outcomes for any course (29).

**Student perceptions**

After project completion, students were asked to participate in an anonymous survey to provide feedback on their experiences with the project. Almost 90% of students responding indicated they learned a great deal about formulating a hypothesis, designing an experiment, and collecting and analyzing data (89% in each category; see Fig. 1). Students agreed or strongly agreed (72% combined) that this project improved their writing skills (Table 4).

When asked about perceived skill gains, 65% of the class had previous experience with poster design and presentation (Fig. 2); 70% of experienced students indicated they had improved related skills from this exercise. Of the students polled, 35% had no prior experience with poster design and presentation and all of these students felt their gained skills they would use in the future.

We were interested in the perceived value of peer review, as peer review was only recently implemented (spring 2017 semester). Most students agreed or strongly agreed (84% combined) that they received valuable feedback from peer review (Fig. 3). Although peer review was not directly assessed in this project, studies have shown that including a peer review component has increased student learning as well as quality of writing and scientific content (23, 24).
Possible modifications

This project could be adapted for undergraduate microbiology and biology courses, for majors and non-majors, at all levels. The poster topics can be varied; possible topics include, but are certainly not limited to, the influence of environmental factors on microbial growth (temperature, pH, water activity, oxygen, or nutrients), identification of unknown microbes, or topics on selection and differentiation. The organisms provided may be varied to include organisms in your course collections, or RG-2 organisms. In addition to having students do computer research only during the laboratory, instructors of smaller-size courses could also organize sessions with a research librarian at their school to introduce students to all resources and databases available through their library. This could be scheduled during the lecture portion of the course or outside of classroom time. The poster presentations could be hosted in a larger venue outside of scheduled lab time, either during lecture or as a separate event.

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TABLE 4.
Student feedback collected via SurveyMonkey (n = 155).

| Evaluation                                | Assignment Improved Scientific Writing Skills | Learning Goals Were Clearly Outlined | Group Had Enough Time to Complete Assignment |
|-------------------------------------------|-----------------------------------------------|--------------------------------------|---------------------------------------------|
| Strongly agree                            | 13                                            | 34                                   | 43                                          |
| Agree                                     | 59                                            | 59                                   | 41                                          |
| Disagree                                  | 23                                            | 6.4                                  | 13                                          |
| Strongly disagree                         | 5                                             | 0.6                                  | 3                                           |

Data shown in percentages.

FIGURE 2. Student perception of skills gained after the poster project (n = 155). The statement “I have designed and presented a poster before; however this project did not teach me any new skills” received 20% response.

FIGURE 3. Student assessment of peer review. Students (n = 57) were surveyed via SurveyMonkey on whether they thought the peer review process was helpful and provided valuable feedback.

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