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| Tips and Tools

# Teaching transferable skills in teamwork, accountability, goal setting, writing, and problem-solving in a non-major microbiology lab: the unknown bacteria experiment redefined

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**ABSTRACT** College to Career is a phrase that we often use to describe the skills and abilities that students should achieve while preparing for college and/or careers. To help prepare our students for their future careers, we developed a microbiology laboratory curriculum based on factors identified to improve college-to-career readiness. These factors include content knowledge, analyzing and interpreting data, accountability, goal setting, and teamwork. At the core of the design are inquiry and problem-based learning. This approach allows students to actively engage in the scientific process while collaborating with classmates and learning technical and transferable career skills. The curriculum includes microbiology laboratory skills, including plating, serial dilutions, and biochemical tests, with integrated opportunities for students to engage in critical thinking, analysis and interpretation of data, teamwork, goal setting, decision-making, and scientific writing.

**KEYWORDS** transferrable skills, inquiry-based learning, problem-based learning, microbiology lab curriculum

In the past decade, there has been a shift in science education, with greater emphasis on skills such as analyzing and interpreting data. Problem- and inquiry-based teaching emphasizes these skills along with critical thinking, problem-solving, collaboration, application of new information, and written and oral communication (1–5). With these teaching techniques, students actively engage in the scientific process and learn transferrable skills, thus bolstering a college-to-career learning environment.

Our goal was to transform the non-major microbiology laboratory course with an emphasis on transferable skills to better prepare students for their prospective careers (6–8). At the core of the redesign are assignments that align with problem- and inquiry-based learning. Student activities and assessments include a challenge boot camp and bacteria identification project, which require critical thinking and encourage students to actively engage in finding a solution, making decisions, and justifying their choices; a lab report boot camp to learn and practice effective communication of research findings; time management activities, which include an experimental design outline; and a weekly plan of action reports, which encourage students to consider resource allocation and develop a coherent plan to guide their work. Throughout the semester, students work in groups of 3–4. The aforementioned assignments are completed during the first 8 weeks of the semester and are designed to prepare students for a problem-based bacteria identification project. For this project, students are presented with a scenario based on a human or non-human animal infectious disease concern, derived from peer-reviewed journal articles (Appendix 4). Students are required to apply knowledge and skills learned during the first 8 weeks to develop a hypothesis and design experiments to determine the causative agent of infection. Students are given ~4–5 weeks to complete

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Jeanetta H. Floyd was previously a faculty member at the University of West Florida, where the activity was conducted in addition to being conducted at Georgia State University.

the identification project. Project results, along with prevention and treatment options, are presented by each group in the last 2 weeks of the course.

This curriculum provides students with a laboratory experience that teaches microbiology laboratory skills but also reinforces career readiness skills, such as critical thinking, problem-solving, applying new information, self-directed learning, and making evidence-based decisions (9–12). This course is completed in 15 weeks (Appendix 6). The prerequisite for this course is Biology I; students who register for this course are sophomores and above.

## PROCEDURE

### Challenge boot camp

For the first 8 weeks of the course, students engage in the challenge boot camp. These are assignments completed outside of the lab as homework; students use a curated library to search for and find appropriate protocols to solve a problem (Appendix 2). The challenges represent a different approach to teaching basic microbiology lab techniques such as Gram stains and serial dilutions. After selecting the appropriate protocol, the principle and rationale for choosing the protocol must be explained as part of the assessment. Students receive feedback from teaching assistants (TAs). The correctly identified protocol is implemented in the lab.

### Lab report boot camp and reports

The lab report boot camp begins with a PowerPoint presentation (Appendix 1) presented during class that provides examples of items that should and should not be included in a lab report. Students then use a rubric (Appendix 5) to grade two mock lab reports, one that earned an "A" and one that earned less than a "C." The students are instructed to use the rubric as a guideline for their feedback. TAs then lead a discussion on the merits of each of the papers.

Students are required to submit two lab reports. The first lab report is on the Gram stain. Students complete a peer review of the lab report, again using the Appendix 5 rubric as a guideline for their feedback. Accountability is incorporated into this assignment, as students are required to provide a short rationale for why they chose to use or ignore feedback given in the peer review. Although students work in groups of 3–4 throughout the semester, lab reports are submitted individually. Students are encouraged to visit the university writing center as well as meet with TAs for writing support.

The second lab report is based on the bacteria identification project. The lab report is scaffolded, with introduction, methods, and results sections submitted individually as low-stakes assessments with feedback provided by TAs to aid in writing the final lab report, which is due at the end of the course (Appendix 5).

### Scenarios experimental design outline and weekly plan of action

Following the challenge boot camp, groups of 3–4 students complete a culminating project to identify a bacterium. Each group is provided with a scenario derived from peer-reviewed journal articles that describes a short medical history of a human or non-human animal and a specific set of signs and symptoms caused by a bacteria of public health significance (Appendix 4). Groups conduct background research to write a short proposal to outline how they plan to identify the organism. The proposal includes a hypothesis for the causative agent, the public health significance of the scenario, and an outline of the biochemical tests/experiments to be performed (Appendix 3). After submitting the proposal, each week groups are required to submit a plan of action, which provides accountability for supplies used and ensures adequate materials are available. The results of the identification project, along with public health impact, treatment options, and prevention strategies, are formally presented by each student group via PowerPoint or Prezi presentation in the last 2 weeks of the semester.

### Safety issues

The lab protocols and bacteria used were designed for a BSL-1 environment. Students are introduced to aseptic techniques and basic microbiological protocols using distilled water before using organisms. Students wear appropriate personal protective equipment (PPE), including lab coats, gloves, and goggles. Lab safety training and assessments of learned safety procedures are carried out at the beginning of each semester. Test results are maintained for institutional compliance. The lab biosafety manual complies with the *American Society for Microbiology* (*ASM*) Guidelines for Biosafety in Teaching Laboratories (13).

## CONCLUSION

Our primary goal was to transform the microbiology lab course to embrace the evolving landscape of science education by prioritizing transferrable career skills and the *ASM* curriculum guidelines (14). We did this by engaging students in problem- and inquiry-based learning, which fosters critical career skills such as data analysis, problem-solving, critical thinking, information organization, evidence-based decision-making, and effective communication. Student evaluations indicate that they have enjoyed the structured interactions and ability to take ownership of their experiments. Students have commented that "*I believe what I have learned will truly benefit me in my future endeavors*" and *"we were able to grow and shape our experimental ideas."* While this curriculum design is for undergraduate non-majors, it can easily be adapted for an advanced microbiology course.

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### ADDITIONAL FILES

The following material is available online.

#### Supplemental Material

**Supplemental instructional materials (jmbe00135-23-s0001.pdf).** This file contains six instructional supplement documents.

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