Making an Introductory Tissue Culture Lab Course Accessible to Novice Students (Work in Progress)

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Work-in-Progress:
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The ability to culture and manipulate mammalian cells in a sterile environment is a valuable skill for all bioengineering and biomedical engineering students. However, many students and instructors do not find tissue culture lab courses appealing due to cost, space, time, and safety constraints. To address this, in the Department of Bioengineering at the University of Washington we expanded the reach of an existing tissue culture lab course to make it more accessible to students with no prior tissue culture or "wet lab" experience, such as early undergraduate bioengineering students and graduate students who transitioned to bioengineering PhD programs from other science or engineering disciplines without strong biology backgrounds.

In this work-in-progress, we describe the first offering of Introduction to Tissue Culture Laboratory Techniques. In this lab makeover, we significantly changed expectations, lab format, lecture content, lab protocols, and grading policies in order to engage novice students. The instructor observed striking improvements in overall student engagement, mastery of techniques, preparedness, and confidence in lab performance. These observations are supported by student feedback in written reflections, informal communication, and end-of-course student surveys. Briefly, the course learning objectives include:

1) Demonstrate ability to work safely with animal cells and mastery of aseptic technique
2) Perform laboratory techniques essential for establishing and maintaining cell lines *in vitro* (feeding, counting, passaging, freezing/thawing, etc.)
3) Properly use equipment commonly found in tissue culture labs, including automatic pipettors, centrifuge, spectrophotometer, etc.
4) Collect raw data and perform calculations (e.g. cell density)
5) Justify the use of particular lab procedures to answer specific scientific questions

Lecture and lab topics include: sterile technique, characteristics of cultured cells, counting cells with a hemacytometer, feeding and passaging cells, thawing and freezing cells, measurement of cell proliferation, effects of antibiotics, cell fusion, and transfection. Most course content involves methods described in Culture of Animal Cells: A Manual of Basic Technique.[1] The course consists of one 50-min lecture and two 2-hour lab sessions per week. In its first offering, twelve students were enrolled: 9 undergraduate bioengineering majors, 2 MS students (material science or bioengineering), and 1 PhD student in bioengineering. The course was taught by the author with no TA support, which the author notes was an extraordinary effort.

Innovations in the tissue culture lab course for novice students

The innovation of this work-in-progress is its focus on teaching fundamental techniques to novice students, which is in contrast to courses geared toward advanced students offered in other highly ranked programs such as Rice University,[2] UC San Diego,[3] and MIT.[4]

We implemented several innovations aiming to increase student engagement, preparedness, and confidence in the lab. The following innovations were assessed by instructor observations, excerpts from student reflections, informal student feedback to instructor, and student comments in end-of-course evaluations. Instructor prompts for each activity are shown in Table 1.

1) In pre-lab written reports, students are required to draw a figure similar to the "graphical Table of Contents consisting of a colorful figure that represents the topic of the review" required for reviews submitted to the *American Chemical Society* (pubs.acs.org).[5] This "snapshot" conveys the student's overall plan or strategy for the lab and notes any important volumes, time limits, etc.
2) The instructor provides guided post-lab analysis, including asking students to analyze hypothetical results or asking students how the results would have been affected if they had made a hypothetical mistake in the procedure.
3) Students reflect at the end of every lab report on what learned and feel confident about, and also anything that is still unclear. This is an application of the "muddiest point" exercise that has been used extensively in assessment of undergraduate education,[6] and was recently implemented in a project-based bioinstrumentation lab at Rice University.[7]
4) Instructor emphasizes the experimental process rather than results, and makes it clear that mistakes are an inevitable and acceptable part of the learning process.

Table 1. Prompts for activities to increase student engagement, preparedness, and confidence.

Graphical Snapshot	Please draw a figure describing what you plan to do in this lab. You may include any type of schematic (flow chart, diagram, etc.), but include only minimal text.
Guided Post-Lab Analysis	Describe each control in this experiment, and why each is positive or negative. Briefly describe at least one additional control, and how it would be informative. What are some sources of error, and how could you prevent this in the future? Considering the mechanism of action of each antibiotic or antimycotic used in this lab, does the data make sense? Explain briefly.
Post-Lab Reflection	What did you like MOST and LEAST about this lab? Why? How would you approach this experiment differently? How would the results be affected if you made any of the following mistakes?

Pre-Lab Report: Graphical Snapshot

In previous offerings of the course with a different instructor, students were not required to submit anything before the lab. Often, this meant that students were unprepared and would even use the printed protocol (provided by instructor) to take notes instead of recording in their lab notebook. In the revised course, students submitted a pre-lab report at the beginning of each lab period (carbon copies from lab notebook submitted to instructor). In the pre-lab, students wrote a brief description of the objective, a detailed lab protocol, and provided a graphical snapshot of the lab similar to the "graphical Table of Contents" required for reviews published by the *American Chemical Society* (pubs.acs.org).[5] Student feedback on the pre-lab figure was mostly positive. Some students clearly enjoyed making this snapshot, and the instructor used the relevance and level of detail of the information included to gauge student preparedness and understanding. Most students reported that the overview figure was useful and referred to it during the lab, but some students thought the figure was redundant to the written procedures.

Guided Post-Lab Analysis

In previous offerings of the course, students wrote a brief post-lab analysis describing the major results and conclusions. In the revised course, the instructor designed questions to guide the students to conclusions and help them apply experimental strategies. As a result of this change,

the instructor observed that overall student post-lab analysis was more thoughtful and conveyed a better understanding of the labs. Student comments on end-of-course surveys included "Post labs required thought" and "Good post lab questions."

Post-Lab Reflection

The instructor also employed reflection in the post-lab reports to help the students feel ownership and confidence, and apply their knowledge to new situations. The reflections provided valuable formative assessment for the instructor (excerpts will be presented at conference).

Lab Culture and Impact

In addition to providing students with a unique learning opportunity, a main goal was to make the lab a welcome and non-intimidating environment for all students, regardless of their prior lab experience or knowledge. The instructor emphasized the experimental process rather than the results and made it clear that mistakes are an inevitable and acceptable part of the learning process. This encouraged students to develop a healthy appreciation for the challenges of working with living cells.

The instructor's observations and student feedback indicate that students felt comfortable in the lab environment and felt the lab was useful, regardless of their prior experience in tissue culture. Student comments in end-of-course evaluations include:

- "Things are taught at a pace that I can understand and ask questions."
- "Extremely dedicated and caring teacher that made sure everyone understood what was being taught and went out of her way to emphasize the scientific process rather than perfection and good grades."
- "Unexpected experimental results → fun troubleshooting."
- "Helps me brush up on cell culture techniques and fix my mistakes as well as showed me techniques I had never used."
- "When I first learned these techniques, I didn't understand the reasoning and biology behind them. So this class helped me understand the fundamentals."
- "I had zero TC [tissue culture experience] coming into this lab. The level of instruction was perfect for someone without experience…really has benefitted me now that I'm in a research lab that does TC."

Finally, the following comment in student end-of-quarter evaluations illustrates the need for introductory tissue culture training in undergraduate biomedical engineering programs:

- "I loved learning about tissue culture. I think that's a huge gap in our core curriculum so I'm glad I got it here."

Conclusion

Introduction to Tissue Culture Laboratory Techniques provides training in fundamental tissue culture techniques and is intended for students with no prior tissue culture and/or wet lab experience. This work-in-progress introduces several examples of tools for increasing engagement, preparedness, and confidence in novice students.

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