Scaffolding a Course-Based Undergraduate Research Experience in Microbiology Using Disciplinary Communication Assignments

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Overview

In 2001, Professor of Teaching Emeritus William Ramey spearheaded the creation of a team-based undergraduate course (MICB 421 and MICB 447) in microbiology that immerses students in authentic scientific research. A new phase of development began in 2014 which enhanced course structure and created new opportunities for student engagement.

This course has become a sophisticated model of a **Course-based Undergraduate Research Experience** (or a CURE) (Auchincloss *et al*).

CUREs have been defined as broadly accessible undergraduate research courses where students:

- Engage in scientific practices
- Experience the process of discovery
- Do meaningful work
- Collaborate
- Experience and appreciate the iterative nature of scientific research

Our course is scaffolded on a series of disciplinary communication assignments strategically deployed throughout the term to guide the student-teams through the research process.

The assignments follow the conventional process of science (*planning, doing, sharing*):

- 1-page letter of intent
- A comprehensive research proposal
- Bi-weekly executive summaries of research progress
- An oral presentation
- A draft original research paper
- A revised original research paper

and
- A symposium presentation (poster or talk)

or
- A technical video or paper

or
- A Q&A video response to questions from their peers

Each communication assignment is assessed against a rubric and detailed formative feedback is delivered in a timely manner.

Projects

Course projects have mainly centred around topics related to bacteriology and bacteriophage (i.e. viruses that infect bacteria) biology using the model bacterium *Escherichia coli* and its well studied viruses. *E. coli* and bacteriophage are suitable models for an undergraduate research lab since they can (1) be grown quickly (overnight) using relatively inexpensive media, (2) they are of no risk to human health, (3) we know a great deal about their biology (including genome sequences and freely available gene knock out libraries), and (4) there are still lots of important unanswered questions to be addressed related to their microbiology, biochemistry, and genetics.

Some of the general topics that our students have investigated include:

- Antibiotic resistance
- Cell stress responses
- Protein structure and function
- Gene regulation
- DNA structure
- Biofilm formation
- CRISPR
- Membrane structure
- Bacteriophage life cycle
- Bacteriophage resistance

Projects most often derive from research results, models, or suggested future directions published in JEMI, although new projects are sometimes introduced into the course via the broader scientific literature. We have recently initiated a new project using *Caenorhabditis elegans* (the worm) as a model host to study a host-pathogen interaction, thereby bringing some immunology to the course.

Similar to any scientific research field, successive questions link together. New models are developed, tested (and re-tested), supported refuted, *rinse, repeat*.

As an example, here are titles of four related JEMI studies:

Deletion of the *Escherichia coli* K30 Group I Capsule Biosynthesis Genes *wza*, *wzb* and *wzc* Confers Capsule-Independent Resistance to Macrolide Antibiotics

Sandra Botros, Devon Mitchell, Clara Van Ommen
Department of Microbiology and Immunology, University of British Columbia

Deletion of the Group 1 Capsular Gene *wza* in *Escherichia coli* E69 Confers Resistance to the Antibiotic Erythromycin on Solid Media but not in Liquid Media

Su AM, Wang A, Yeo L
Department of Microbiology and Immunology, University of British Columbia

Single Deletion of *Escherichia coli* K30 Group I Capsule Biosynthesis System Component, *wzb*, Is Not Sufficient to Confer Capsule-Independent Resistance to Erythromycin

Gurneet Rana, Yuree Jang, Paul Ahn, Jeremy Nan
Department of Microbiology and Immunology, University of British Columbia

Macrolide Structures Can Confer Differential Susceptibility in *Escherichia coli* K30 Deletions of Group 1 Capsule Assembly Genes

Jady Chiu, Gloria Han, Kevin McCrystal, Michelle Zuo
Department of Microbiology and Immunology, University of British Columbia

Course Structure

The course operates over a 16-week academic term.

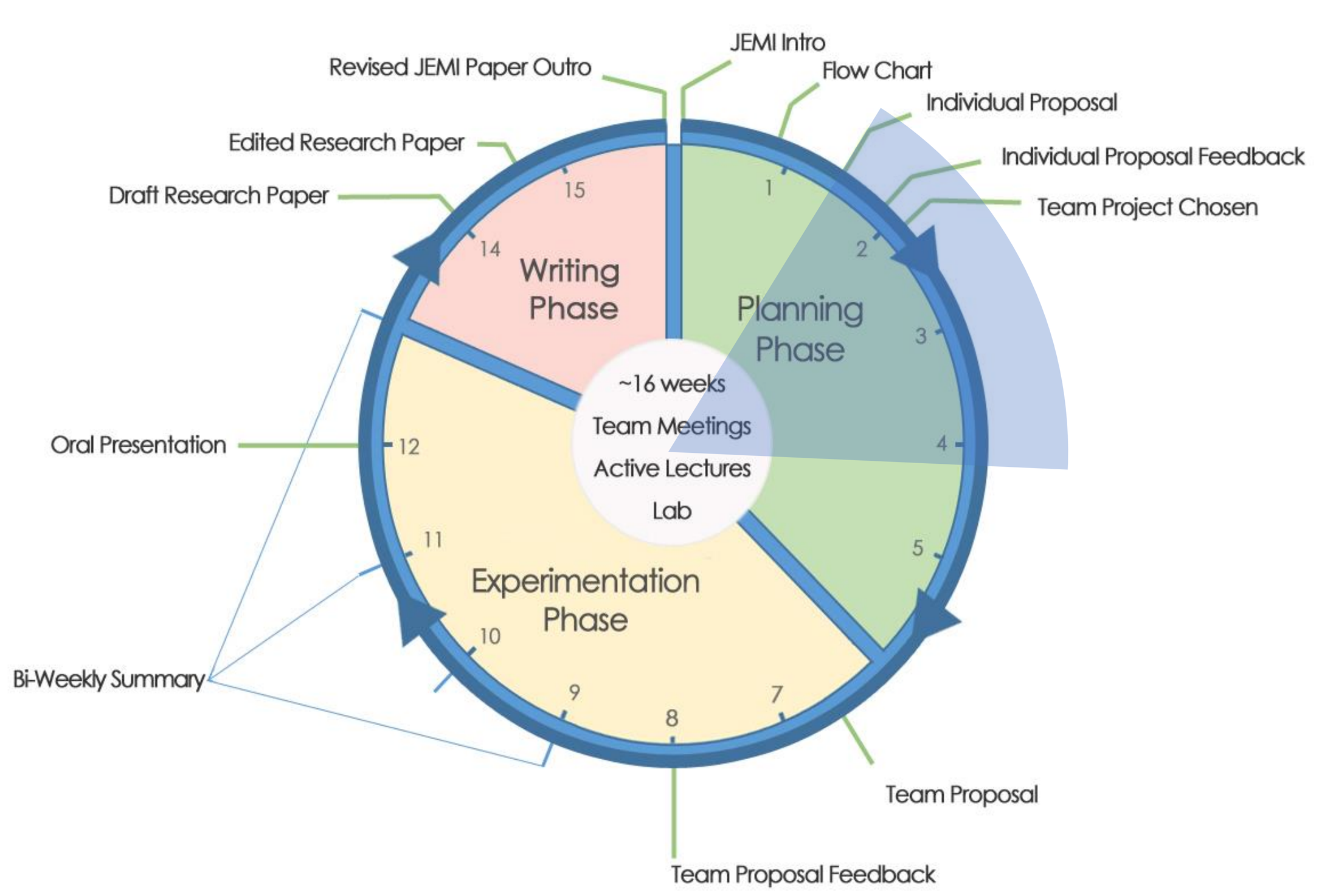
The goal is to produce an original research paper for publication in our online course-based Journal of Experimental Microbiology and Immunology.

The experience is supported by tightly orchestrated student-centered lessons that link engaged classroom activities and lectures, small team-based meetings, and the laboratory.

The term can be roughly divided into three phases:

Weeks 1 – 6: Planning Phase (green)
Weeks 6 – 13: Experimentation Phase (yellow)
Weeks 13 – 16: Writing Phase (pink)

Communication assignments within each phase stimulate project development, drive progress, and facilitate reflection and self-directed inquiry.



Highlighting the Phases

Planning Phase – *focus: designing a scientific research project*

Students begin by reading papers published in JEMI describing studies conducted in previous terms. Students individually derive new research questions and document their idea in a 1-page proposal. Teams of 3 or 4 students then choose a lead project and draft a long-form research proposal. This process is supported by weekly team-meetings with the Instructor and a TA. The **team proposal** includes well referenced background information, a research question, and a testable hypothesis. The proposal is structured with defined experimental aims that align with protocols, detailed methods, a budget, a timeline (below), and safety considerations.

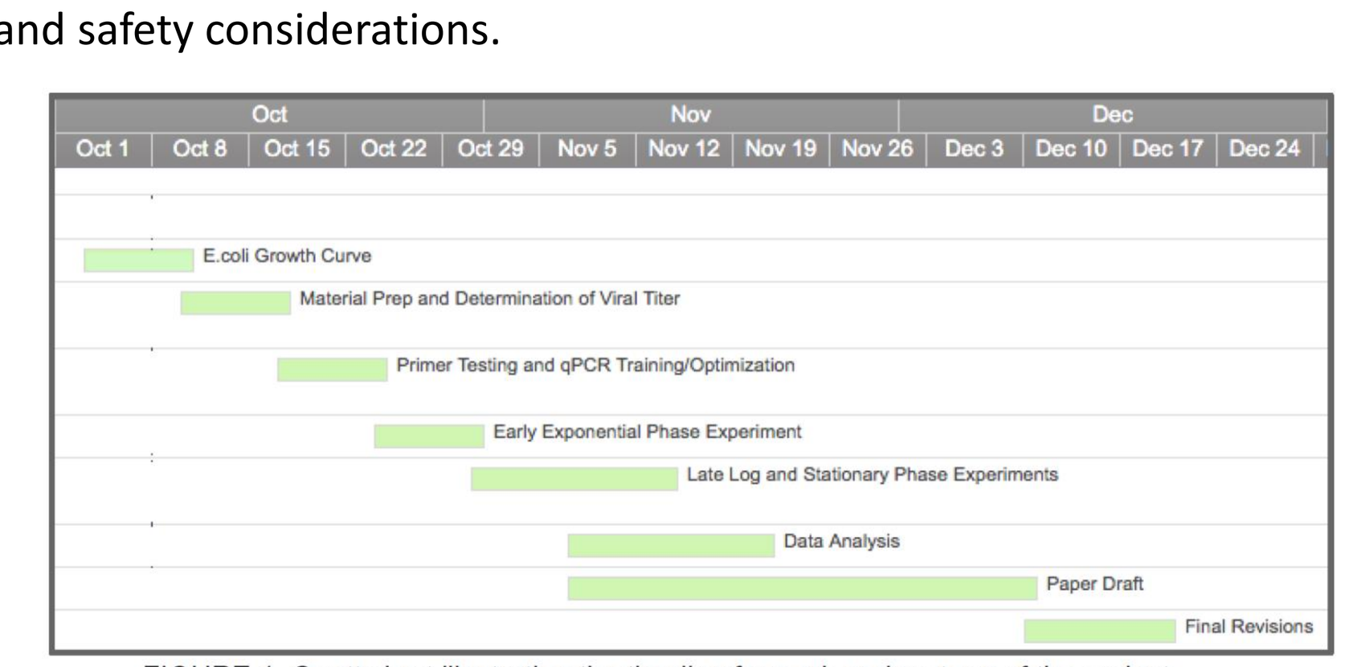
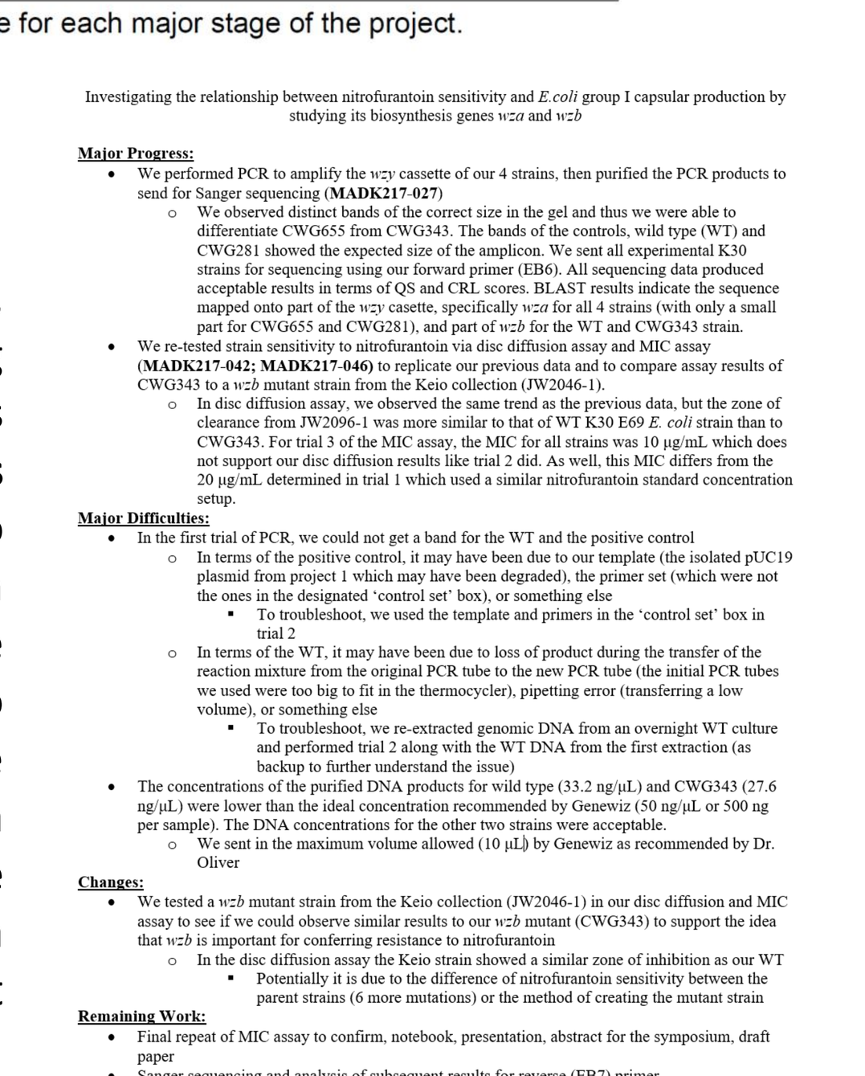


FIGURE 1. Gantt chart illustrating the timeline for each major stage of the project.

Experimentation Phase – *focus: rigour and problem solving*

Work in the laboratory involves piloting, optimizing, executing and replicating experiments. Rarely (*if ever*) do experiments work the first time. **Executive summaries** (left) are submitted on bi-weekly basis to facilitate reflection which aids in troubleshooting and prioritizing. The document also communicates progress to the course Instructor (or lack thereof in the case of technical set-backs) and provides a time-based check point as students move through the project. It also serves as a useful summary for students in subsequent terms following up on the project.


Investigating the relationship between nitrofurantoin sensitivity and *E.coli* group I capsular production by studying its biosynthesis genes *wza* and *wzb*

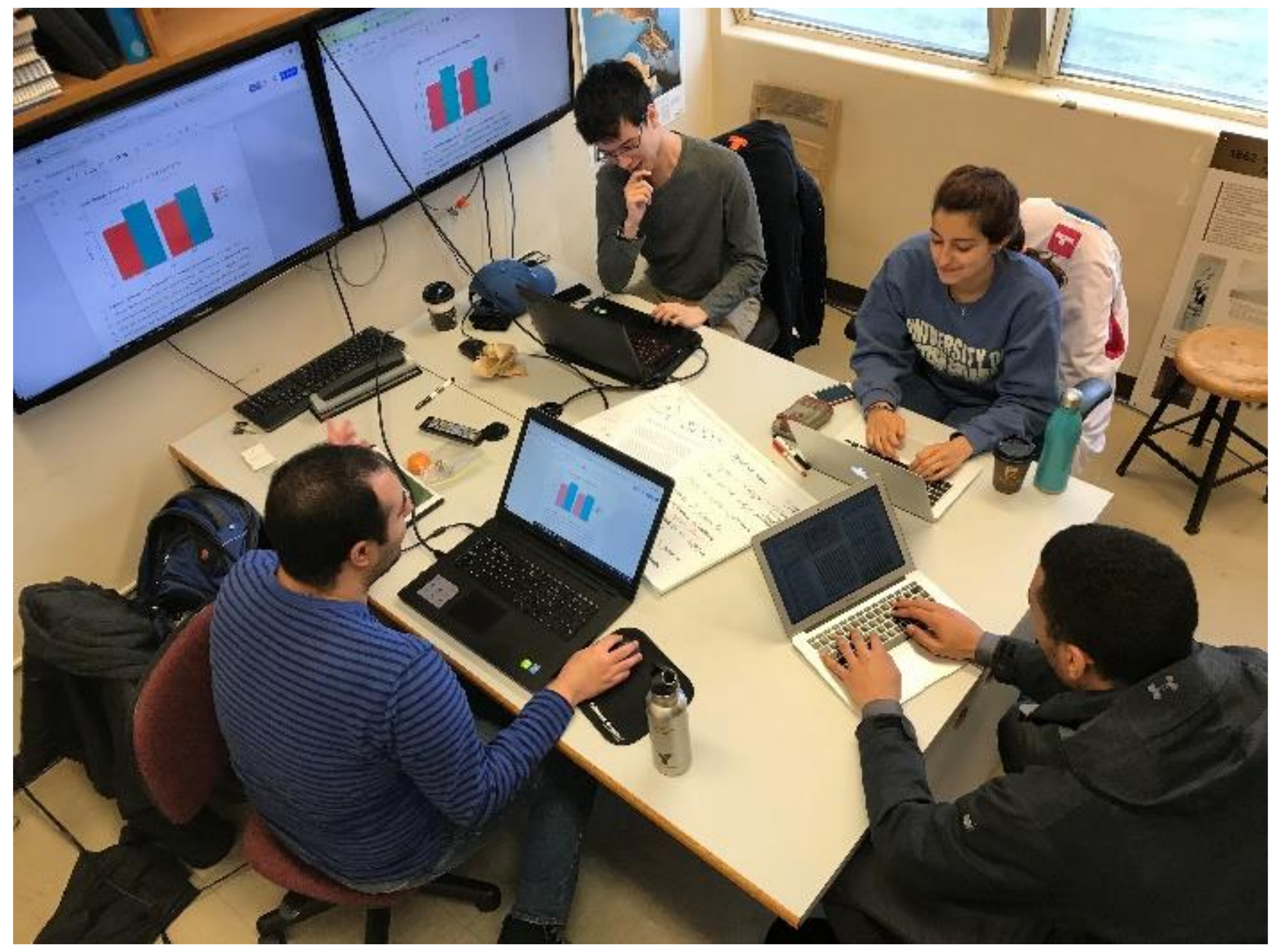
Major Progress:

- We performed PCR to amplify the *wzy* cassette of our 4 strains, then purified the PCR products to send for Sanger sequencing (**MADK217-027**)

Highlighting the Phases

Writing Phase – *focus: contribution, community, and integrity*

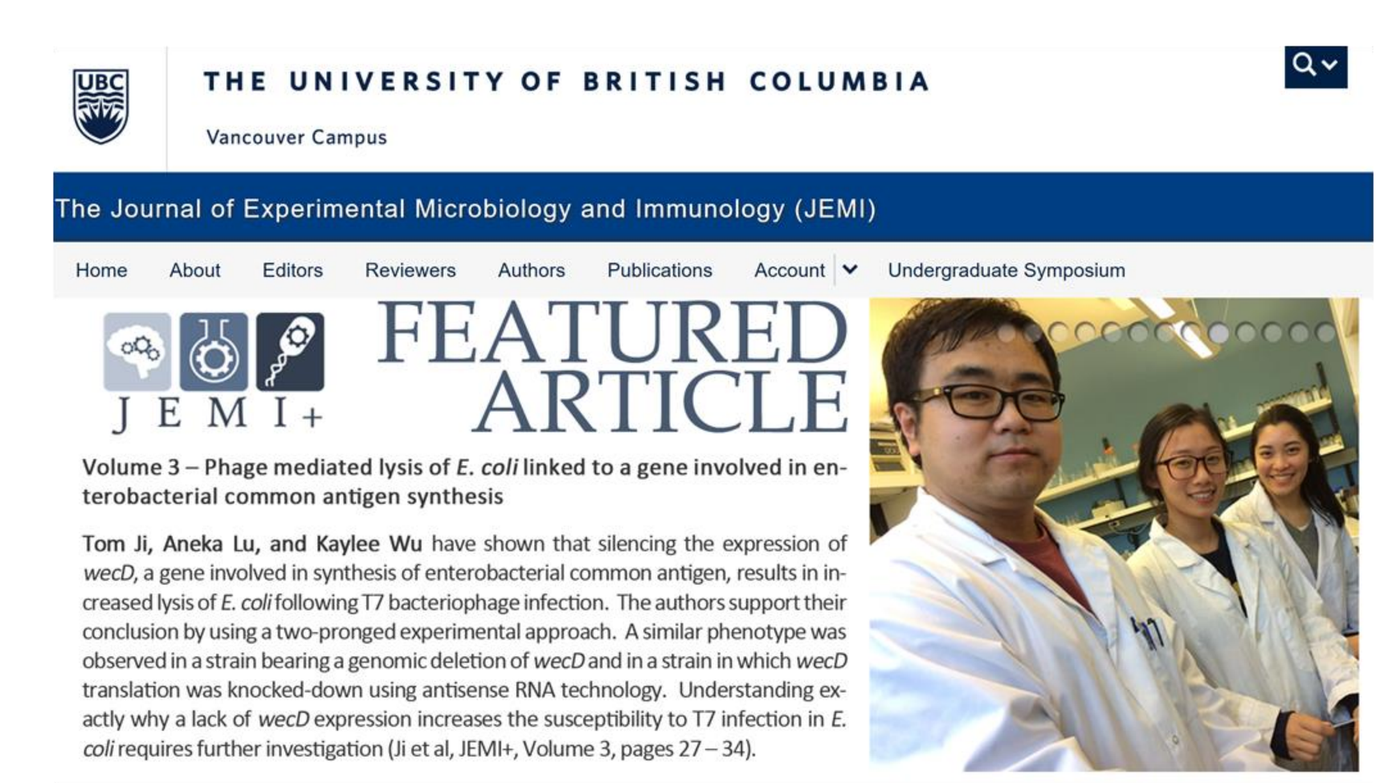
In-class **oral presentations** serve to guide writing of the team's **draft paper**. Team discussions often include understanding the structure and function of a paper, intended audience, peer review, data analysis and presentation, and statistics. Teams receive feedback on their paper and carry out **revisions** before final submission for publication.



Publish @ JEMI

The goal of each research project is to yield a research article that will be published online in our online course-based Journal of Experimental Microbiology and Immunology (JEMI).

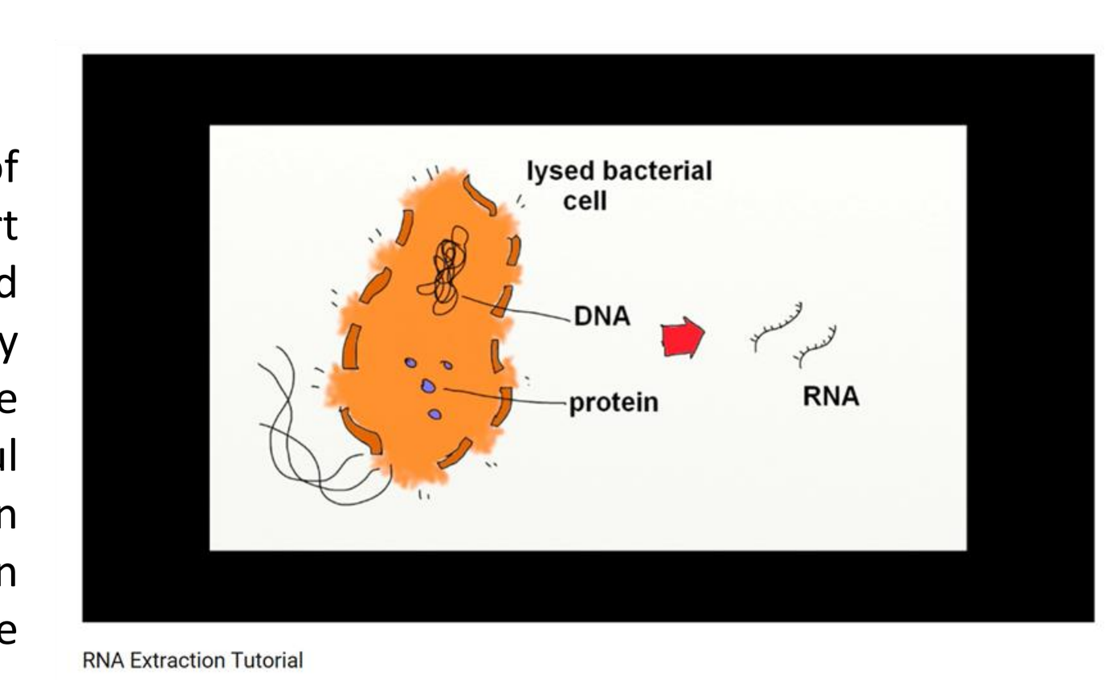
http://jemi.microbiology.ubc.ca/



Each paper is reviewed and revised at the end of the term. Papers reporting results considered a "work in progress" (i.e. insufficient data to answer the question) are published in JEMI. Papers reporting a clear finding (i.e. robust well-controlled experiments) are advanced to peer review for possible publication in JEMI+ (Skylight project seed funding, 2014). Post-doctoral fellows, senior graduate students, and faculty with subject matter expertise serve as reviewers. A graduate student TA manages the peer review process in May – June each year.

JEMI-methods

Students have the option of creating a technical video or short paper explaining the theory and practice of something that they have learned in the course. The goal is to contribute a useful resource. This RNA extraction video (to the right) has been viewed > 74,000 x on YouTube (authors Chang, Tsui, and Ray).



Undergraduate Research Symposium

On Thursday April 26th 2018 we will hold or department's first undergraduate research symposium featuring the work of students working in the fields of microbiology and/or immunology.

The event will provide students with:

- an opportunity to share their research findings with the scientific community
- practice communicating in a disciplinary setting,
- opportunities to Interact with practicing scientists.

Students will give talks and/or present posters.

To date, we have 43 abstract submissions and 63 registrants, suggesting a desire to participate and contribute. Abstracts submissions include directed studies and co-op projects as well as student-driven projects from our cutting-edge experiential learning courses (MICB 406, MICB 421, MICB 447).

An organizing committee of undergraduate students, graduate students, post doctoral fellows, staff and faculty are working towards bringing this together.

Perspectives on Learning

While seemingly complex courses with several high-level multifaceted learning outcomes, the systematic application of communication assignments can be used to apply sufficient (i.e. enough without being too much) structure to guide students through a process of practical inquiry leading to meaningful results and exciting new scientific discoveries!

The development of communication skills is a key learning outcome. The following attempts to highlight some of these.

1. Disciplinary communication skills.

Attention is given to disciplinary conventions associated with communicating in different mediums (e.g. proposals, papers, talks, posters, meetings). The American Society for Microbiology style is used as the standard. Professional skills such as writing executive summaries, careful documentation, peer review, chairing meetings, and public speaking are integrated as well.

2. Understanding the iterative nature of learning to communicate effectively.

Practice, practice, practice. Several communication assignments are intentionally revisited during the term in slightly different permutations.

- Individual proposal → team based proposal
- Bi-weekly summaries → total of three submissions
- In-class oral presentation → symposium
- Draft paper → revised paper

By revisiting these assignment the students are given opportunities to reflect on feedback and improve. Multiple low impact assignments are key here.

3. Communicating with purpose.

Since each communication assignment has a defined purpose, students must carefully consider their audience. By crafting each communication piece to engage the intended readership, students develop a sense for the scientific community in which they are working. As students become of aware of their community their scientific contribution becomes more relevant, underscoring the importance of rigour and integrity in research.

Auchincloss, L.C., Lausen, S.L., Branchaw, J.L., Eagen, K., Graham, M., Hanauer, D. I., Lawrie G., McLinn CM, Pelaez N., Rowland S., Towns M., Trautmann N.M., Varma-Nelson P., Weston T.J., Dolan E.L. (2014). Assessment of Course-Based Undergraduate Research Experiences: A Meeting Report. CBE–Life Sciences Education, 13, 29-40. doi:10.1187/cbe.14-01-0004.