NC STATE

Cultivating Critical and Creative Thinking in a First-year Undergraduate Research Course

Susan Carson, PhD

The Research Question

American Foulbrood Disease (AFB) is the leading bacterial cause of honeybee colony loss in the US and worldwide. The etiologic agent of AFB is the bacterium, *Paenibacillus larvae*. First-year students in previous years isolated and genetically characterized bacteriophages (viruses that infect bacteria) that are able to infect and lyse *P. larvae*.

Students in the current semester are addressing research questions that were formulated by the students who took the course last year:

1. Can we develop a phage buffer in which these phages are stable?
2. What is the host range of the various phages?
3. Are the putative lysins predicted on the various phage genomes active? Can we produce them recombinantly?

Intellectual Standards of Critical Thinking[3]

Clarity	Could you give me an example or elaborate further? Could you illustrate what you mean?
Accuracy	How could we check on that? How could we verify or test that?
Precision	Could you be more specific? Could you give me more details?
Relevance	How does that relate to the problem? How does that help us with the issue?
Depth	What are some of the complexities of this question? What factors make this a difficult problem?
Breadth	Do we need to look at this from another perspective? Do we need to consider another point of view?
Logic	Does all this make sense together? Does what you say follow from the evidence?
Significance	Is this the central idea to focus on? Is this an important problem to consider?
Fairness	Do I have any vested interest in this issue? Am I sympathetically representing the viewpoints of others?

NC State Standards of Creative Thinking

Originality	Did the idea arise from constructive imagination and independent thought?
Flexibility & Adaptability	Did you adjust your thinking to changes in the situation or context?
Appropriateness	Is there a good fit between the constraints of the problem and the properties of the solution?
Contribution to the Domain	Is the new idea of value to the discipline?

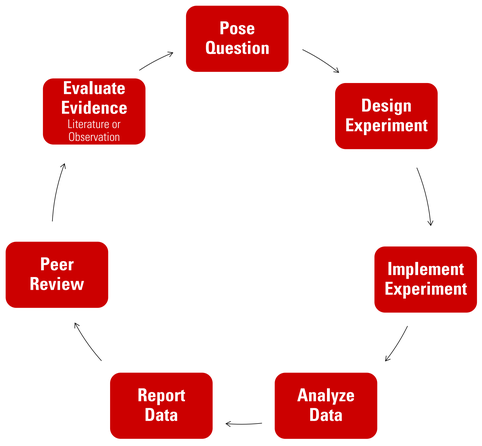
Reporting Data and Peer Review

Students each write an original midterm and final lab report on their research findings that includes **title, introduction, materials and methods, results, discussion/future work, and reference** sections. Instructions map to specific skills/behaviors/standards (available upon request).

Each lab report is subject to peer review by a classmate using a rubric based on the intellectual standards of critical and creative thinking (available upon request). Students receive peer feedback, but peer revaluation of lab reports do not affect report grades. Peer reviews, themselves, are graded by the instructor. For the final report, students evaluate their own work using the rubric, in addition to the work of a peer.

Lab reports are assessed by *the instructor* using a rubric based on skills and behaviors of critical and creative thinkers that was developed in conjunction with the NC State QEP (available upon request).

The Research Method



Evaluating Literature and Formulating Questions

Student Assignment Prior to Journal Club

1. What was the overall question/problem addressed by this paper? Define the scope of the problem that was explored (depth, breadth/perspective)?
2. Select one experiment detailed in the results section of the paper, and summarize:
   a. What question was addressed? How was it significant to the study?
   b. What was done (broadly, not specific protocol steps)? Were the methods employed appropriate to address the problem/question?
   c. State the result obtained and its relevance to the overall question addressed by the paper.
3. Who is the intended audience for this article? Was this article written with clarity for the intended audience?
4. Did the conclusions follow logically from the data? Provide an example.
5. Did the authors consider alternate conclusions of the data? Provide an example. Are there any interpretations that you thought about that the author did not consider?
6. Given the findings and approach taken in this work, what questions does it lead you to with respect to our *P. larvae* phage research project? List as many research questions as you can think of. Select one and briefly provide a possible methodology to pursue. Explain why you selected the above research question from among your alternatives.

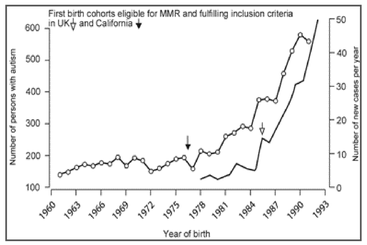
References

1. AFB-infected comb http://www.theabk.com.au/article/american-foulbrood-%E2%80%93-disease-can-be-eradicated
2. AFB-infected larva http://www.mol-ecol.uni-halle.de/research/genomics/honeybees_6/
3. Intellectual Standards of Critical Thinking adapted from *The Nature and Functions of Critical and Creative Thinking*, Richard Paul and Linda Elder, 2012, Tomales, CA: Foundation for Critical Thinking Press. www.criticalthinking.org

Student Learning Outcomes

1. Evaluate the work of others using the *intellectual standards* for critical[3] and creative thinking.
2. Apply critical and creative thinking *skills* and intellectual standards in the process of solving problems and addressing questions.

Critical Thinking Scenario Example



Wakefield AJ. *Lancet* 1999;354:949-50

1.What does the author of the graph want you to infer? Does the data strongly support the conclusion?

2.Give an alternate explanation for the data shown in the graph.

3.Suggest further data that you could gather to investigate the alternatives above.

Acknowledgements

Thank you to the students, past and present, in the Phage Hunters and Phage Genomics courses. Thanks to Eric Miller, Jake Dums, Shelby Roland, and Adam Groth for their part in teaching this course. Thank you to the Bayer Crop Sciences Bee Care Center, the Howard Hughes Medical Institute, and the NC State Biotechnology Program for financial support of this course. Thank you to Meredith Davis and other members of the QEP planning team who worked on the student learning outcomes and common rubric based on the skills and behaviors of critical and creative thinkers.

NC STATE THINK

Higher-order Skills
in Critical and Creative Thinking