Supplemental Materials

for

Targeting Critical Thinking Skills in a First-Year Undergraduate Research Course

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Appendix 1: Additional critical thinking scenarios used during the course.

Scenario 2: Neonicotinoid pesticide and honey bee colony collapse

The 2014 publication by Lu et al entitled “Sub-lethal exposure to neonicotinoids impaired honey bees winterization before proceeding to colony collapse disorder” in Bulletin of Insectology has received considerable media attention. In the study, the researchers set up an experiment with 18 bee colonies. All 18 colonies are fed a constant supply of either a sucrose or high fructose corn syrup over a period of 13 weeks from July 2 – Sept 17. In 12 of the colonies, neonicotinoid pesticides were added to the syrup in a sub-lethal dose of 0.74 ng/bee/day.

Bees were permitted over-winter, as normal. The researchers observed no difference in the treated versus non-treated hives during the summer and fall months. However, in April, 6 of the 12 neonic-treated colonies were dead, and 1 out of 6 non-treated colonies were dead. Furthermore, in the neonic-treated hives that had not successfully overwintered, few dead bees were found in the hive (as occurs in Colony Collapse Disorder), whereas many dead bees were present in the one control hive that did not successfully overwinter. The authors state that the data strongly support the idea that neonicotinoid poisoning is the primary cause of Colony Collapse Disorder.

1. How strongly does the data support the conclusion that neonicotinoid poisoning is the cause of the widespread problem of colony collapse?

2. Describe any problems you see with the experimental design or conclusion reached in the paper.

3. What further information would you need to assess the veracity of the conclusion (either known information or further experimentation that could be pursued)?

Scenario 3: Influenza vaccine

"But my Dad had the vaccine and still got the flu"

1. Does this statement strongly support the idea that flu vaccines are not effective?

2. What are some alternative explanations for Dad getting the flu, besides that flu vaccine is not generally effective?

3. What other information would you need in order to support or oppose the different explanations?

S. Carson. Critical thinking scenarios enhance higher-order cognitive skills.
Scenarios 4 and 5: Recombinant bacteriophage lysin

Note: this scenario was based on a real experiment students planned to implement without appropriate controls. Use of this scenario guided them to plan and implement experimental controls.

The amazing first-year undergraduates on Dr. Carson’s research team cloned the lysin gene from two different bacteriophages that infect Paenibacillus larvae into an expression vector in E. coli. They used IPTG to induce recombinant protein expression, lysed the cells, and then spotted the cell homogenate onto a plate with P. larvae seeded into top agar. They then observed whether P. larvae became lysed where the cell homogenate was spotted. Consider the two following experimental outcomes.

Outcome 1

P. larvae grew as a confluent lawn that showed no zone of clearing where the cell homogenate was added.

1. What are possible explanations for this result? Provide as many alternative explanations as you can.

2. What experiments would you perform in order to either confirm an explanation or to test for lysis in a different way.

Outcome 2

P. larvae grew as a confluent lawn but showed a zone of clearing where the cell homogenate was added.

1. The students interpreted this to mean that the recombinant bacteriophage lysin is active and able to lyse P. larvae. How strongly does the experimental outcome support their conclusion?

2. What alternative explanations are there for the experimental outcome?

3. How can they test or control for the alternative explanations?
Appendix 2: Student responses to “Please describe the single most important assignment, strategy, or other course aspect that made a meaningful difference to your higher order thinking abilities.”

Reflections were collected through an online system, but were not anonymous. Student responses are complete and have not been modified or corrected.

The Article write ups made the most difference in my thinking. I thought they were relevant and interesting in all aspects which really made me want to understand all conclusions fully.

In writing the analysis of experiments in my lab notebook has had a major impact because with each entry I was analyzing my own results. This meant that I had to think about what I may have done wrong or possible alternative reasons for the results I found.

Writing my research papers made the biggest difference in my higher order thinking abilities. In the discussion sections of the papers, I thought of every possible explanation for each observation and planned many future experiments. This allowed me to be more open-minded, find sources of error, and determine how to change future experiments.

I think that the lab reports actually enhanced my higher order thinking abilities the most. In high school, most of my lab reports were on cut and dry lab procedures that simply required me to regurgitate the answer that decades of students before me had answered. It was not difficult to analyze a situation that was basically summarized and explained for me from the beginning of the lab. With this course, we actually had to design many of our own experiments, so there was no preconceived idea of what the "right" discussion of conclusion was. When writing my lab reports for these experiments, especially the discussion section, I actually had to think about why we did something, and what the results meant. I feel that practicing that skill has actually really helped me prepare for my future lab courses and possible research experiences.

The final paper was the most important and meaningful assignment to me in terms of organizing information and higher order thinking. All of the assignments we completed throughout the semester required higher level thinking, but the final report incorporated all of the skills I gained from the different assignments. In particular, I felt the discussion section of the paper required the most critical thinking in terms of incorporating all of our findings from the semester and drawing conclusions.

I think the Critical Thinking Experiment Scenarios we worked on and discussed in class improved my higher order thinking skills the most, although I learned the most from lectures, working on our experiments, and writing in my notebook. The Critical Thinking Experiment
Scenarios made me consider alternate explanations for patterns, trends, and experimental results. I had to think about how to explain certain observations and how to make sure my assumptions and conclusions were right. This helped me when I was writing my midterm and final lab reports.

The most important aspect of the course that made a meaningful difference to my higher order thinking abilities were the class discussions about the experiments. Hearing the thoughts of other classmates pertaining to the possible experiment ideas, conclusions, implications and significance as well as other alternative future experiments plans, helped me learn a lot more. Being exposed other points of view and opinions made me think more in-depth about the experiments. Critically thinking about the experiments before performing them, allowed me to better understand the significance of our research and possible opportunities for further research.

I saw the most improvement in my thinking abilities after completing the second article review. I found it helpful to consider comments from the first article review and improve my weak parts. Dr. Carson’s suggestions helped me to evaluate my personal way of thinking and how it may be improved. When writing the second review I made sure that I corrected my previous mistakes, and I succeeded. Taking the feedback and applying it to the second assignment was very important to my growth. The article reviews also encouraged me to critically evaluate another person’s thinking. I realized the blind trust I gave to authors, and how little I stopped to question their methods and logic. I saw a huge improvement in my critical thinking abilities after one article review, and even more after the second article. The reviews also helped me apply the critical and creative standards. After the assignments I was able to spot examples more easily. Also by using the standards to evaluate others, I found myself trying to think according to the standards in order to eliminate the weak places in my conclusions and arguments.

Analyzing the journal articles throughout the semester definitely helped me to develop use of the intellectual standards. The questions prompted me to look at the articles in a detailed manner and improved my ability to catch its strengths and weaknesses. Each article was also discussed amongst the entire class; this gave me others’ opinions on the articles and helped me see different aspects of each article that I may not have paid much attention to earlier. This helped me catch those details during the analysis of the next article. This activity was definitely the most important assignment that made a meaningful difference to my higher order thinking abilities.
The in class article analysis helped make a meaningful difference in my higher order thinking abilities.

Quite honestly, the lab techniques that were instructed to us I thought particularly served to prepare me for a career in my intended field, and placed me in a higher category for potential positions than other peers of mine who have not had such relevant experience.

The exercise we did in class where we develop our own version of the experiment was the most beneficial to me hen considering critical thinking. This was important to me because it is one of the few times in a science based class that I have been able to design my own experiment rather than in pervious education where all of the steps and instructions were laid out for me. I think this is good because in the future I will have to do the majority of my experimentation on my own, or with minimal background instruction so it is important that I develop these necessary skills now. Also hearing ideas of others and critiques of these plans was beneficial as it allows me to see how I can change my plans for potential future experiments.

I think that the assignment that most allowed me to develop and improve my higher order thinking abilities, was developing our own procedures for our experiments. We were required to do this for at least two experiments, one of which was the replication, expression, and isolation of the lysin protein. Developing our own procedures for this experiment required me to think about what needed to be done, as well as the resources I had and the best way to accomplish my goal. It also required us to think about isolating a single variable using controls in order to account for possibilities that may have caused false positives in our data. This level of thinking about the implications of my work was high and above any other experience in my prior education.

The scenarios that we discussed in class were the most helpful in enhancing my critical thinking skills. They prompted me not only to think of alternate explanations for results but to design controls that would eliminate those alternate explanations. It also helped develop my creative thinking skills because we had to propose unique solutions to problems occasionally.