Scientific Teaching and Engaging Pedagogies: “OK, We Know We Should, but How?”

Ellen Goldey
Workshop Agenda
subject to change based on your interests

I. Scientific Teaching
   – What is it? What might it entail within courses?
   – Work with examples

II. Engaging Pedagogies
   – Examples to apply content to real-world problems
   – Examples for traditional content
### Engaging Pedagogies

<table>
<thead>
<tr>
<th>Faculty Development</th>
<th>Assessment</th>
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<tbody>
<tr>
<td>Faculty members are unfamiliar with Gen Ed Goals.</td>
<td>Some members of the department are seeking new knowledge/skills needed for reforming their program, but lack support/time/incentive for this work.</td>
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<tr>
<td>There is no structure/support/incentive for transforming programs</td>
<td>Faculty learning community and/or Center for T&amp;L may aid cadre of practitioners in building knowledge, skills, and leadership capacities. ADMINISTRATIVE SUPPORT IS MINIMALLY SUFFICIENT.</td>
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<tr>
<td>Faculty members (full or part time) are unaware of general education (GE) goals, institutional mission (IM), or how the department supports these broader issues.</td>
<td>The assessment portfolio may emphasize quantitative, direct measures (e.g., Major Field Test) and lack insight from qualitative measures (e.g., surveys, interviews).</td>
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<td>The department chair or a committee determines which courses fulfill GE requirements, but instructors may not know, or know how to achieve, GE goals. IM is rarely considered in department's program.</td>
<td>Pockets of reform may be under heightened scrutiny, thus increasing anxiety. Retrenchment may occur without encouragement and opportunities to learn from early failures. The ethos may reflect both anxiety and distrust.</td>
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<td>The department's faculty members work to align courses to meet GE learning goals, but IM goals may be overlooked or perceived as outside the department's duties.</td>
<td>GE goals are well integrated, and some courses target the capacities valued in the institution's mission (e.g., civic engagement, advancement of knowledge; cultural pluralism; social justice).</td>
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### Faculty and Administration Dispositions Toward Change

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<th>Integration of Department Program with Gen Ed Goals &amp; Institutional Mission</th>
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<td>All instructors are attempting to adopt best pedagogical practices, and lecturing for 50% or more of class time is rare. Students actively learn on own and from each other in most classes/labs.</td>
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### Students

Students are engaged in discussion, guided inquiry, and other activities in classes/labs, and instructors intersperse brief lectures if needed. Knowledge is actively constructed by students. Instructor is "coach." Professional behaviors are valued.

### STEM Department Evaluation Rubric*

*For sample discussions of core competencies, see the 2009 reports of the AAMC-HHMI Committee Scientific Foundations for Future Physicians and AAAS' Vision and Change in Undergraduate Biology Education: A Call To Action.*

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What is “Scientific Teaching”?

Engage students in *doing* science.

Apply research standards to our teaching:

- Learn from experts in the field
- Test new strategies
- Gather evidence of outcomes
- Use evidence to inform next steps
- Share what we learn with others
How do STEM Scholars/Professionals Spend Their Time?

- Read primary literature (a lot of it!)
- Listen to/learn from other scholars
- Conduct research to advance knowledge
- Analyze data, interpret results
- Communicate findings (write, present)
- Collaborate and cooperate
- Help solve “wicked problems” (at least our grads would, right?)

How can we help undergraduates achieve these core competencies -- even first year students?
Gap Analysis

Undergraduates typically do not read primary research literature, especially in their first year.

What knowledge, skills and/or dispositions are students likely to build if we bridge the gap?

How might/do you engage first year students with primary literature?

Scientists spend a lot of time reading primary research literature in their field.
One Model for Introducing 1° Literature to First-Year Students

• In advance, select brief straightforward articles (each with at least one graph).

• Devote lab time for each team to digest their article.

• Ask students to consider:
  “What new knowledge does the study contribute?”
  “Does it challenge any prior assumptions?”

• Have each team portray the research in a skit and describe the graphs.

• Repeat throughout the course, with increasing article complexity

An Example:
A glimpse into our first lab session

Each student team has an hour to digest one of six ecology-related articles – each article is ~2 pages and has two graphs.

You will see just the abstract and a graph from one of the articles, which is about piranha (*please imagine you’re a freshman again*).

You will have two minutes to consider the questions:
- How does this study challenge assumptions and contribute new knowledge?
- How would you teach your peers about the study through a skit?
A couple of helpful terms.

Shoaling = swimming in groups
What does *everybody* “know” about piranha?

How does this study challenge what we thought we knew? What new knowledge is constructed?

How would you teach this experiment through a skit for your peers?

variety and abundance of piranha predators in the flooded forests of the Amazon in which they live indicate that an important reason for shoal formation may be predator defence. Experiments using wild-caught piranhas supported the hypothesis that individual perception of risk.

2. METHODS

(a) *Experiment 1: safety in numbers*

We tested the prediction that piranhas perceive larger shoals as safer by measuring the opercular rate of fish as singletons and in shoals of two, four and eight individuals. The investigation took place at Flutuante Arapaima in the Mamirauá Reserve, Amazonas.
Wofford College First-Year Students Perform Skits to Describe Primary Research Literature to Peers

What do you notice about these students during their first college biology lab?
Sample student feedback

“At the beginning of our first lab, I was initially intimidated because it was my first college lab and it was three hours long. I was surprised at how much fun I had working with my group to create a “skit” for our presentation because we all worked so well together. My lab group was supportive and everyone listened to each others ideas so we were able to perform as well as I thought we could. I learned the most about my topic during lab by standing in front of the class and exploring the graphs from our study. It helped me to better understand the experiment. Also by constructing the play-dough snakes and creating a visual for our project helped reinforce the results of the study.”
An aside: End of course 1° literature is more complex
How do STEM Scholars/Professionals Spend Their Time?

- Read primary literature (a lot of it!)
- Conduct experiments to advance knowledge
- Analyze data, interpret results
- Communicate findings (write, present)
- Collaborate
- Helping solve “wicked problems” (grads would, right?)

How can we do this with undergraduates - even first-year students?
Our “requirements” for Authentic Inquiry

• Open-ended/unknown outcome
• Contribute to construction of new knowledge
• Scalable to large numbers of students at low cost
• Data adequate for robust quantitative analysis
• Students must work as team to prepare, predict, collect data, analyze, interpret and communicate findings
Factors beyond natal experience appear to influence bean beetle ovipositioning

Annamaria Hidalgo, Carson Martin, Chandler Stokes, Ashleyanne Stratas
Wofford College, South Carolina

Methods

We used less adzuki beans in order to approximate the size of cowpeas (3). We believe this may be due to the smaller size of mung beans, and showed that the bean beetles preferred cowpeas which could be due to the larger size of cowpeas (3). In another experiment, Messina and Jones reared bean beetles on lentils for several generations, and they became well adapted to this undesirable host (2). We hypothesize that bean beetle’s preference for oviposition would be influenced by natal experience and genetic adaptation to a preferred host. We also predicted beetles raised for multiple generations on a host would be more attracted to the natal bean than beetles raised on a new host for a single generation.

Results

Our second experiment would use equal-sized glass beads that would be coated with adzuki or mung extract. This would determine if the beetles preference was based on odor of the bean. From these results we would be able to determine whether size and smell are determining factors of oviposition. This research is economically significant because the studied beetles are common pests of many seed crops post harvest and these findings could help enable manipulation of the parts of the beans that attract these pests in order to prevent crop damage. This would decrease the amount of pesticides needed, boosting the agricultural market.

Discussion

Contrary to our predictions, bean beetles reared on cowpeas preferred cowpeas (3). In another experiment, Messina (3) tested a deterrent odor of mung. Parr (4) has shown that bean beetles avoid laying eggs on seeds that are already infested by larvae. In another study, Messina (3) tested beetle preferences of seed beetles.

Figure 1: This figure shows where each type of bean beetle preferred to lay their eggs. Adjacent columns with the same letters are not statistically different. The p values and chi squares for each treatment group comparison were MGA p<.0001 and chi square 40.9585, MGM p = .2096 and chi square 1.5741, SGA p<.0001 and chi square 42.1501

Our first experiment would use equal surface area. We tested 60 beetles from each population. After one week we counted the eggs that were on each bean type. We performed a contingency analysis followed by Chi Square analyses of each population’s preference.

The data was analyzed with SGA p<.0001 and chi square 42.1501, MGM p = .2096 and chi square 1.5741, SGA p<.0001 and chi square 42.1501

Acknowledgements

We would like to thank all the Bio 150 professors and students.
Sample student feedback

The assignments in this class were above anything I expected. While I hated with a passion working on the research posters, they were a great help. I know so much about the topics we did our posters on. This was one major change from high school; working with a group.

Also, I have studied more for this class than any other science class. In high school, I was used to not studying until the night or morning of a test and making A’s. In this class I have learned to study a little each day and know the material inside and out. The assignments were much more challenging and required an actual thought process rather than just a regurgitation of facts. (Anonymous, 2010)
Collaboration and teamwork

Essentials of good teamwork?

(share handout)
How do biologists approach their scholarship?

• Read primary literature (a lot of it!)
• Conduct experiments to advance knowledge
• Analyze data, interpret results
• Communicate findings (write, present)
• Collaborate
• Helping solve “wicked problems” (at least our grads would, right?)

How can we do this with undergraduates -- even first year students?
TACKLING WICKED PROBLEMS
THROUGH THE TRANSDISCIPLINARY IMAGINATION

Valerie A. Brown  
John A. Harris  
Jacqueline Y. Russell
Learn and apply biology *through* the study of malaria

*SENCER (Science Education for New Civic Engagements and Responsibilities)*

Every year, nearly 2 million people die of Malaria
Engaged/Active/Problem-based Learning: Study of malaria through Guided Inquiry

- Ecology and Phylogeny: (e.g., global distribution of malaria species and their hosts – mosquitoes, birds, mammals – it’s not just a human disease)
- Cell Division/Reproduction (e.g., life cycle of Plasmodium – meiosis does not produce the gametes!)
- Molecular evolution (e.g., of Plasmodium, Anopheles mosquitoes, sickle cell trait in human host)
- Current control efforts (e.g., Gates, etc.)
This is a figure from the textbook showing terrestrial biomes.

This is a figure from the 1° literature on the distribution of *Anopheles* mosquito species.

Sample questions from their guided inquiry handout:
• In which biomes are *Anopheles* absent?
• What factors in these biomes may account for this?
A glimpse into the inquiry-based classroom
Engaging Ideas for Traditional Content

Example activity:

• Snap beads for Meiosis and Mitosis
  – Identifying and correcting misconceptions in real time for Cell Cycle
  – DNA replication is not immediately followed in real time by transcription and translation!
Meiosis misconceptions come from textbooks...

What are the inaccuracies in this figure that we understand as “simplification” that students could misinterpret?
Active Learning – David Marcey PULSE Fellow

• [https://www.youtube.com/watch?v=Q_jzkT0d5kg&feature=youtu.be](https://www.youtube.com/watch?v=Q_jzkT0d5kg&feature=youtu.be)

“Transforming the lecture hall into an arena of learning”