



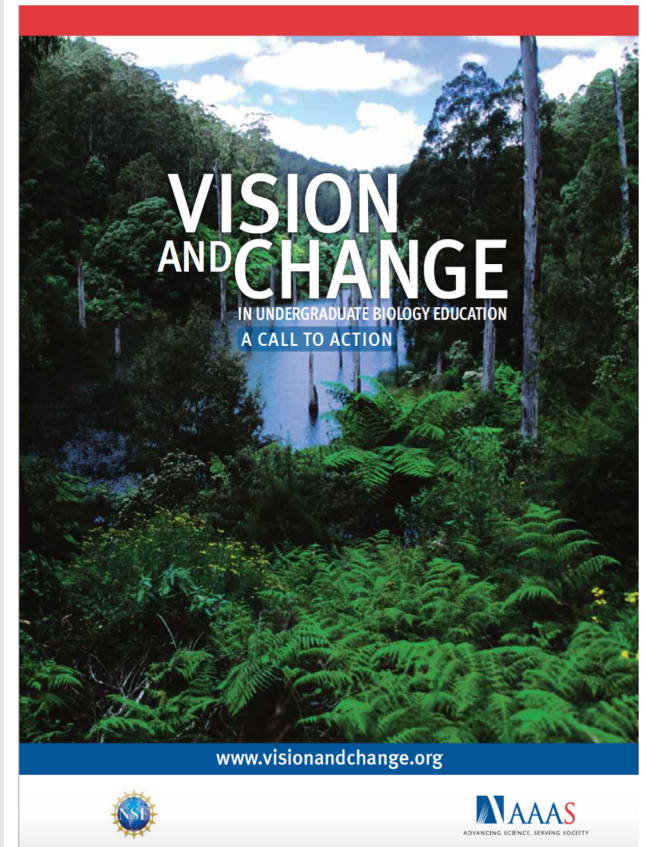
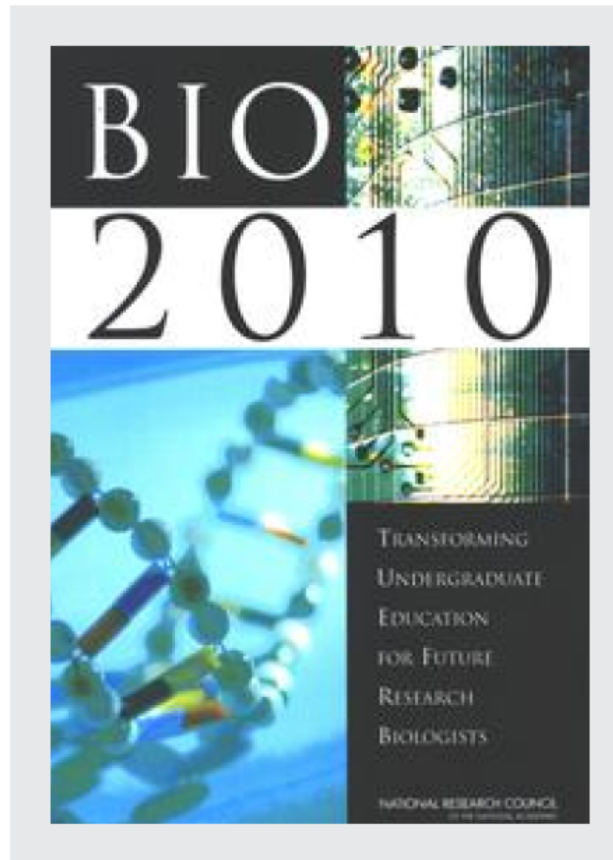
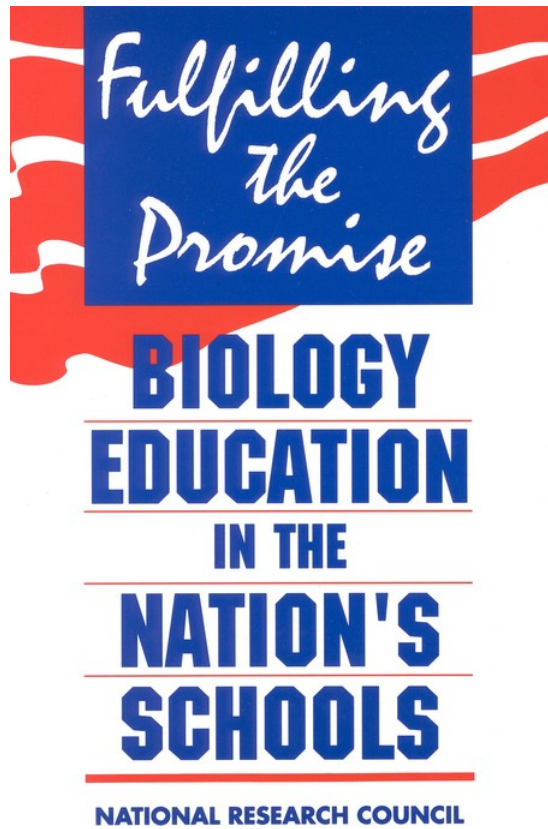
# Is Biology Education Evolving?

Critiquing three cases of high school and undergraduate biology education reform.

Matt Kloser  
CREATE for STEM Institute Seminar Series  
December 12, 2018



# Toward Biology Education Reform

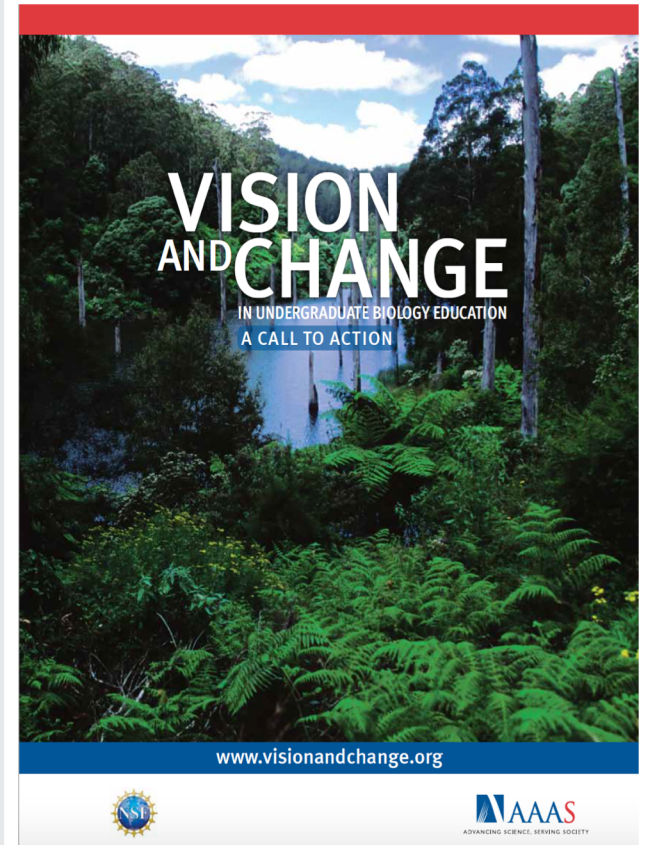
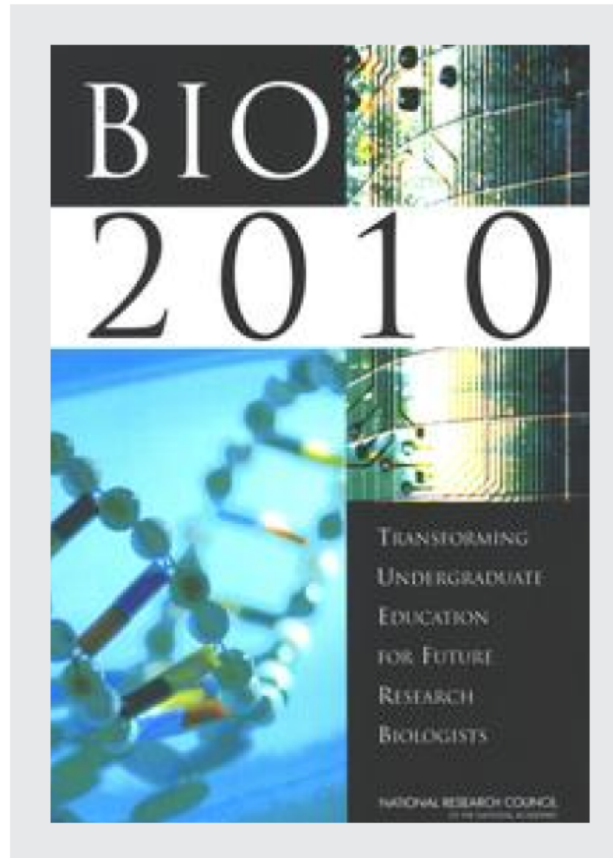


# Toward Biology Education Reform

*Fulfilling  
The Promise*

- **Small Set of Core Ideas**
- **Examining Why We Believe What We Believe**
- **Application to Student Lives**

IN THE  
SCHOOLS  
NATIONAL RESEARCH COUNCIL





# Toward Biology Education Reform

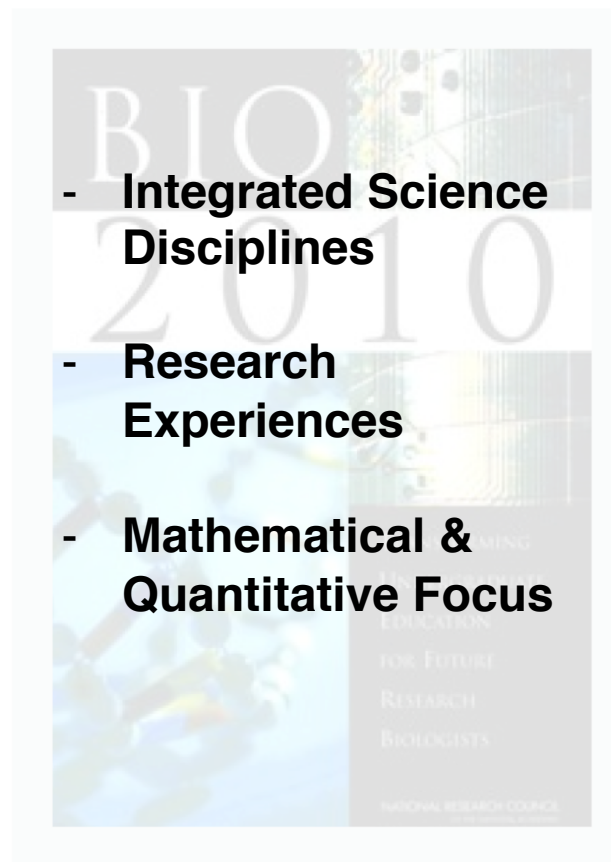


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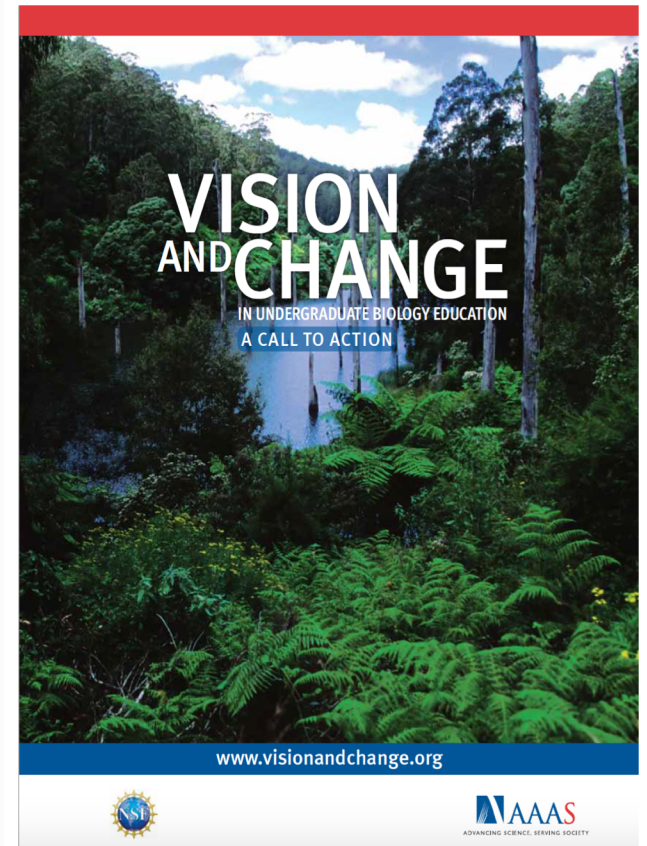


BIO 2010

- Integrated Science Disciplines
- Research Experiences
- Mathematical & Quantitative Focus

FOR FUTURE RESEARCH BIOLOGISTS



NATIONAL RESEARCH COUNCIL



VISION AND CHANGE

IN UNDERGRADUATE BIOLOGY EDUCATION  
A CALL TO ACTION

[www.visionandchange.org](http://www.visionandchange.org)



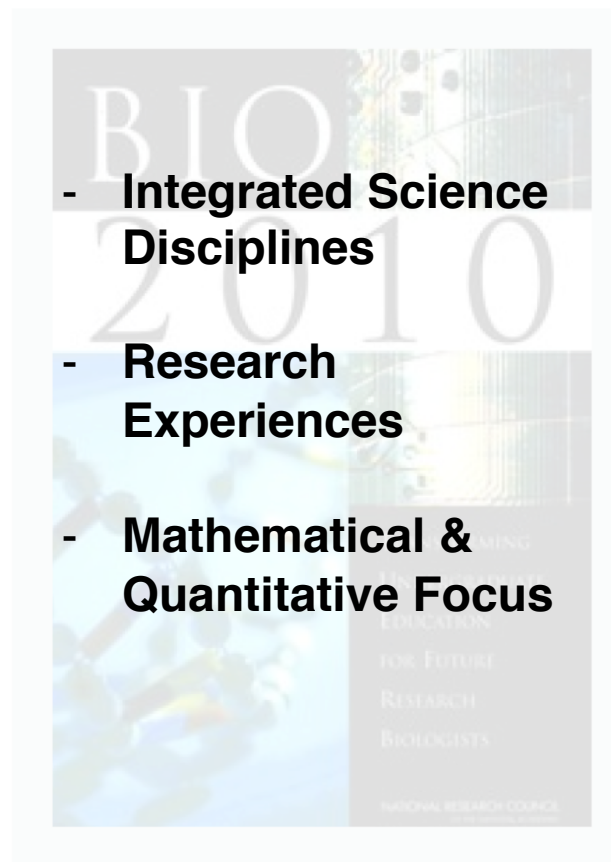
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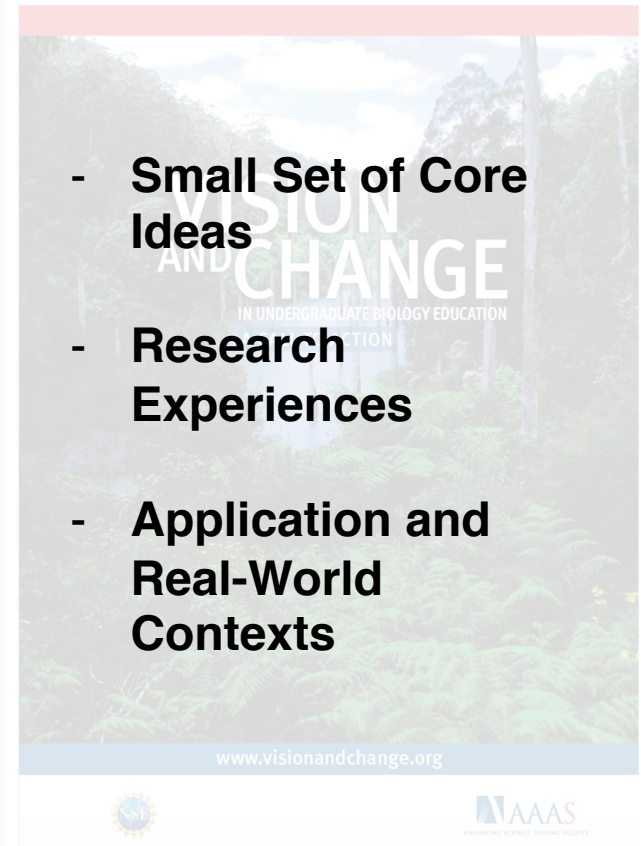
# Toward Biology Education Reform



*Fulfilling the Promise*  
**Small Set of Core Ideas**  
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**Application to Student Lives**  
NATIONAL RESEARCH COUNCIL



**BIO 2010**  
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How do we engage young people  
in the *story* of the living world?

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# Plot:

Epistemically considerate texts in high school biology classrooms

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It is a rare textbook, indeed, which supplies enough of the structure of the discipline to let the student know that he is dealing with a model [and] not with a literal truth [or] falsehood.

- Schwab, 1978

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## Traditional Textbook Excerpt

### 57 Section 3: Costs of Invasive Species

58 Estimated damage and control cost of invasive species in the U.S. alone amount to more than  
59 \$138 billion annually. Invasive species can affect industries such as timber, fishing, plant, and  
60 tourism. In the timber industry, the Asian long-horned beetle has changed forest ecology (Figure  
61 2). First introduced into the U.S. in 1996, this insect infected and damaged millions of acres of  
62 hardwood trees. By 2005, thirty million dollars had been spent in attempts to eliminate the beetle  
63 and protect millions of trees in the affected region.



Figure 2: An Asian long-horned beetle eats the tissues that transport water and nutrients in the tree.

64

65 Similarly, the fishing industry in the Great Lakes Region has declined with the introduction of  
66 the sea lamprey. In its original habitat, the sea lamprey used coevolution to act as a parasite  
67 without killing the host organism. In the Great Lakes Region, however, the sea lamprey acts as a  
68 predator and can consume up to 40 pounds of fish in its 12-18 month feeding period. Sea  
69 lampreys prey on many types of large fish that are essential to the Great Lake fishing industry.

70

71 The cost of invasive species is not limited to finances. Throughout history, there have been  
72 multiple instances of diseases spreading through invasive species. Birds, rodents, and insects can  
73 be carriers of viruses. For example, the Chinese mitten crabs are carriers of Asian lung fluke.

74 In addition, the efforts to control invasive species can have long-term public health implications.

75 Waterborne disease agents, such as cholera bacteria, are often transported via ballast water.

76 Pesticides applied to treat a particular invasive species pollute soil and surface water.

## Epistemically Considerate Excerpt

### 75 Do social groups provide animals other benefits that might increase their survival rate?

76

77

78 Powell thought that if foraging in flocks resulted in more eyes to watch for predators, then  
79 individual birds might not have to spend as much time looking for predators and could spend  
80 more time feeding. The higher number of birds would ensure that at each moment, some  
81 birds were watching for predators. Powell used the same experimental set-up with the cage,  
82 model hawk, and starlings to investigate the effect of different group sizes. This time he  
83 observed three different conditions. He made 60 observations of single starlings in the cage,  
84 58 observations of 5 starlings in the cage, and 117 observations of 10 starlings in the cage. For  
85 each observation he picked one bird in the cage and timed how long it kept its head down  
86 (foraging) and how long it kept its head up (surveillance – watching for predators) while it  
87 was in the feeding area. He calculated the average percent time that the starlings spent  
88 foraging and watching for predators in each group size shown in Figure 4.

88

FIGURE 4 Foraging Behaviors of Groups of Starlings

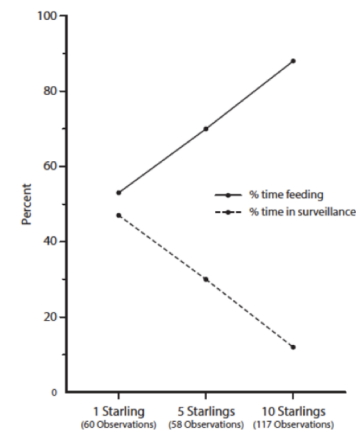


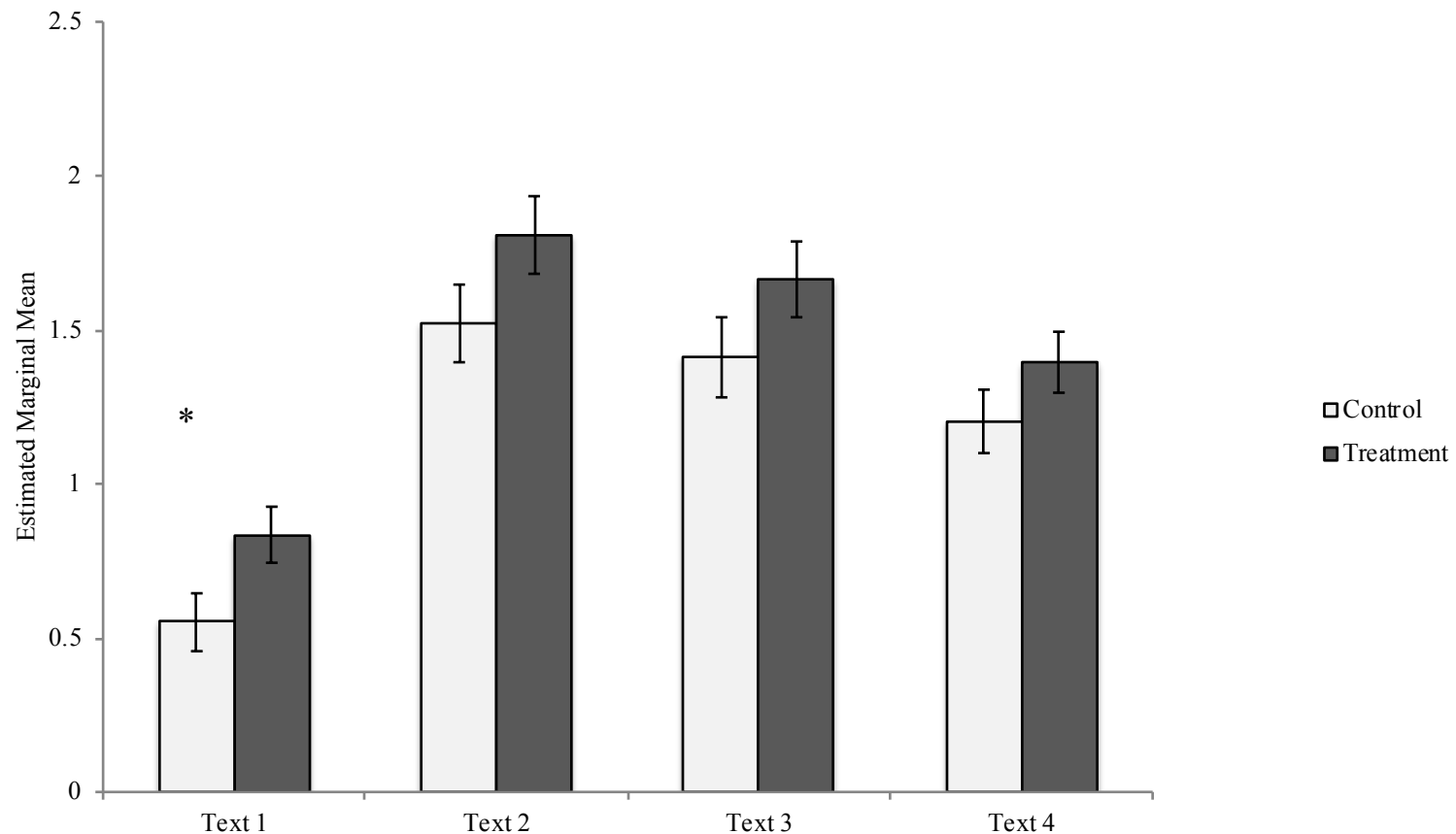
Figure adapted from Powell, 1974



# Selected Results: Experimental Design

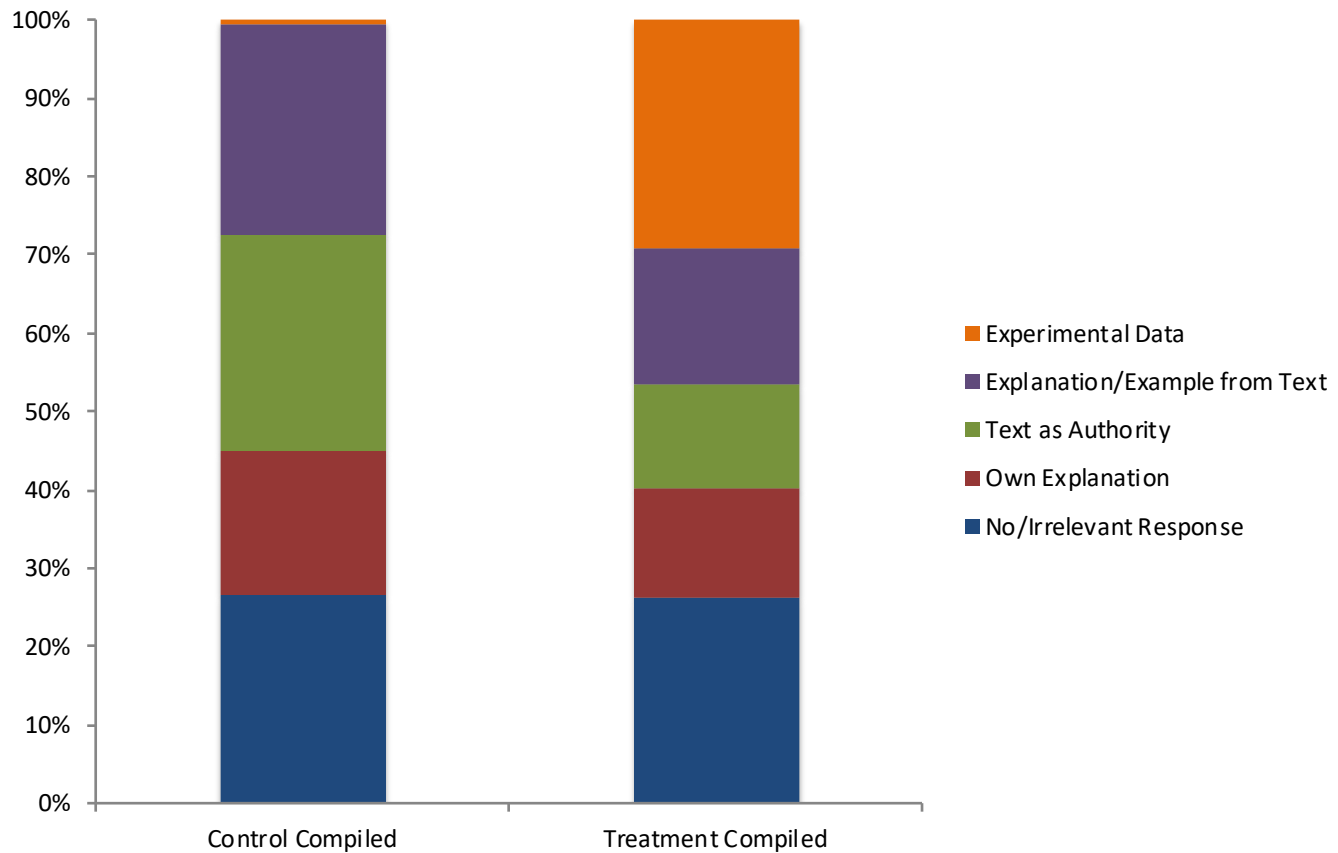
Estimated marginal means:

Experimental design transfer task score by condition



# Selected Results: Epistemic Foundations

Proportion of cited source of justification for 'big idea' claims on post-test by condition ( $n_c=890$ ;  $n_t=930$  responses over 4 repeated measures)



Carlos:

“You can easily look at the graph for easier learning. I mean, if you really just wanna learn what the – the text is reading – you read a little, you look at the graphs [and] on the [control text], there’s, there’s nothing that shows you what you’re – what you’re learning, you just have to go ahead and read.”

---



Participant text preference for different purposes (n=24).

Text	Interest	Trustworthy	Comprehension	New Information	Study for Class
Control	6	3	9	5	13
Treatment	18	18	14	17	11
No Choice	0	3	1	2	0

Bill:

“[The author of the control text] didn’t include an actual experiment, but that was pretty nice that he didn’t...He just – he actually just gave us the information, which is much nicer and easier...I don’t think our teachers really need us to know [who] did this...So that was easier, and probably easier to take notes on later.”

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# Community Critique: Plot

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- In what ways might alternate text types evolve the way in which students think about the oft-hidden epistemic foundations of biology?
  - What are the major limits of these text types to changing the nature of how young people might engage the living world?
-



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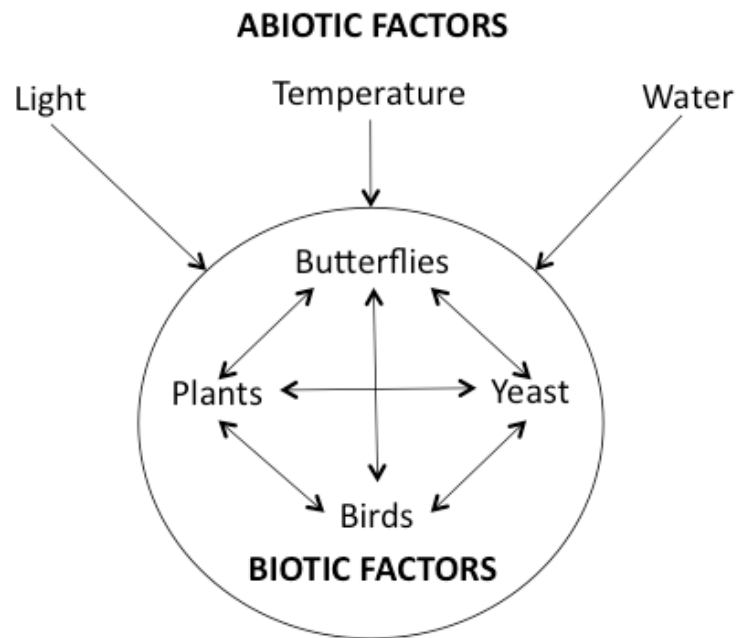
# Setting:

Course-based Undergraduate Research Experiences  
(CUREs) at Stanford University

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# Introductory Biology Lab (Eco/Evo) Stanford University

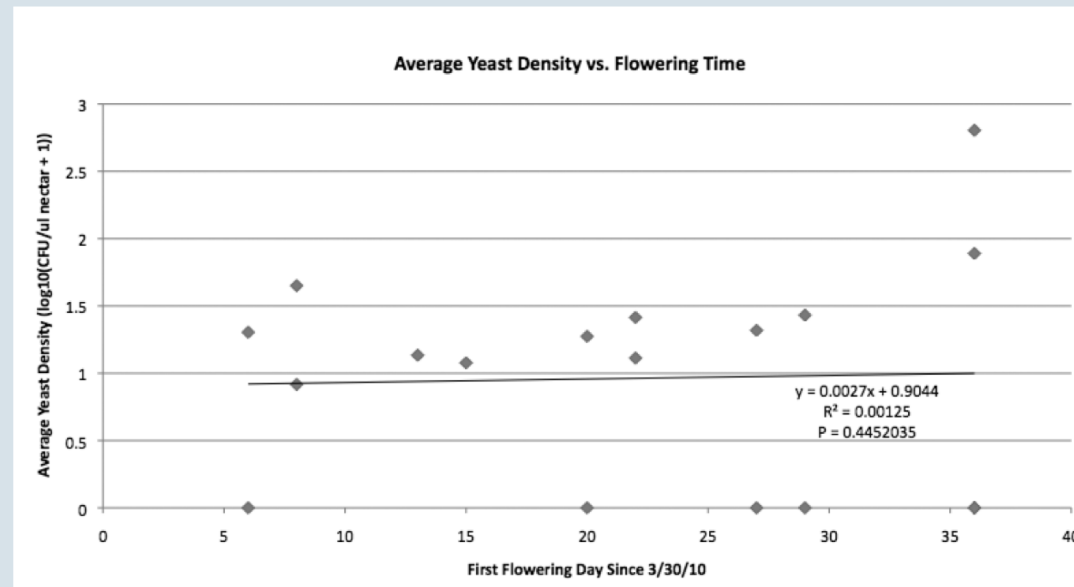
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# Selected Student Work

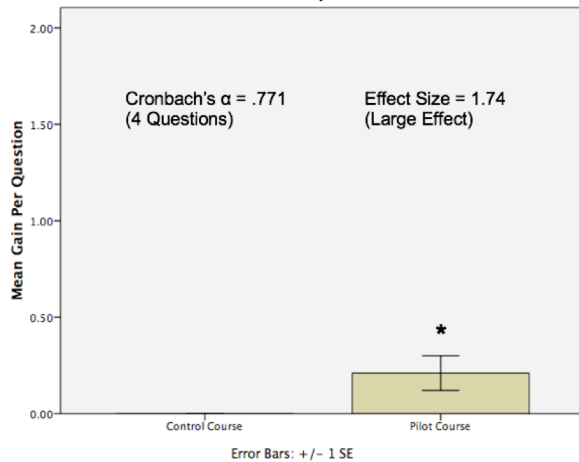
“We hypothesized that plants with earlier first flowering date (FFD) would consequently yield higher yeast density due to increased pollinator visits, attracted by greater number of flowers. Therefore, our null hypothesis is that there will be no correlation between FFD and yeast density.”

**An example of results from one lab pair based on their hypothesis that a relationship exists between yeast density and flowering time.**

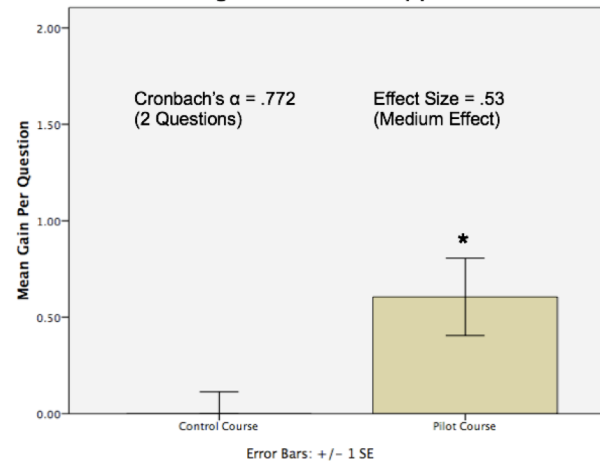


# Selected Results

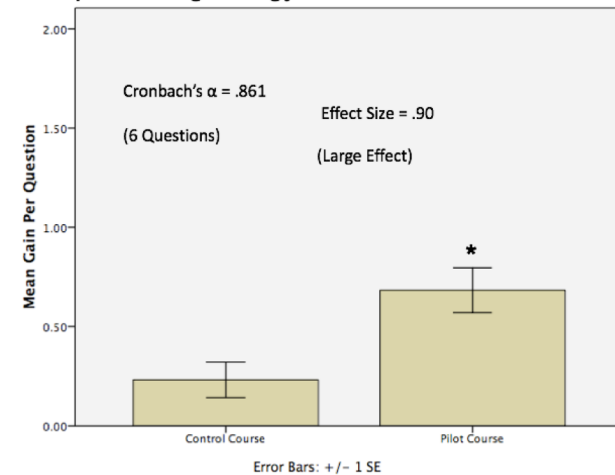
**Figure 1:** Student attitudes toward authentic research experiences



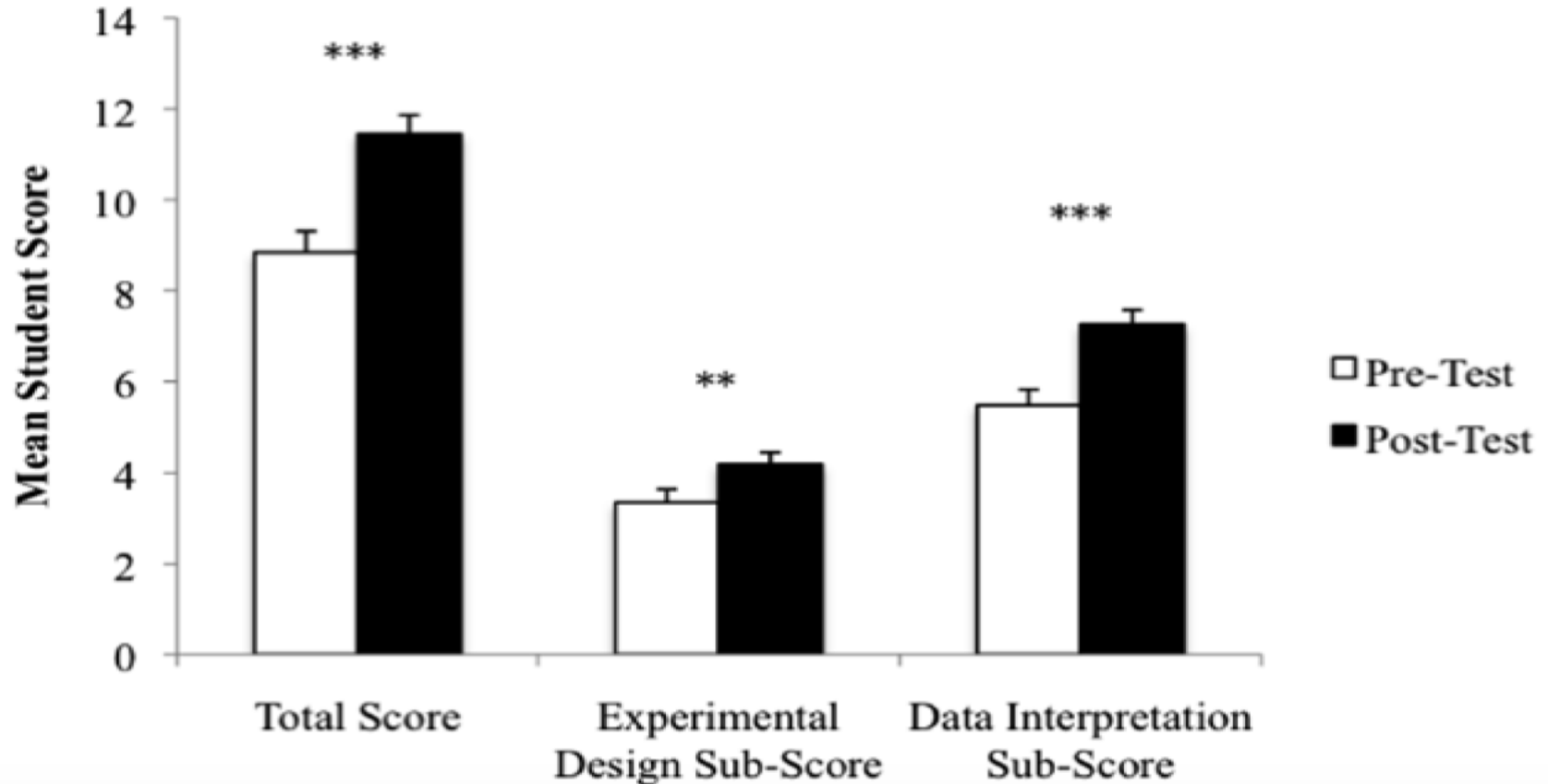
**Figure 2:** Student short-term interest in pursuing further biological research opportunities



**Figure 3:** Student self-confidence in performing biology lab-related tasks



**Performance assessment pre/post results ( $n = 33$ ). Total possible points = 18. Tests were scored blindly by two independent raters who reached 80% agreement on 25% of the sample before scoring tests individually. Scores were analyzed using a randomized blocks ANOVA with two factors, occasion and subscale. Significant results for the main effect of occasions are shown followed by the disaggregated subscores for the experimental design and data interpretation portions of the assessment. \*\* =  $p < .001$ . \*\*\* =  $p < .0001$ .**



# Community critique: Setting

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- In what ways have the development of CUREs evolved undergraduate biology lab experiences for effective student outcomes?
  - What are the limits to CUREs' impacts?
-







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# Characters:

”Big Questions” Intro Biology Sequence, University of  
Notre Dame

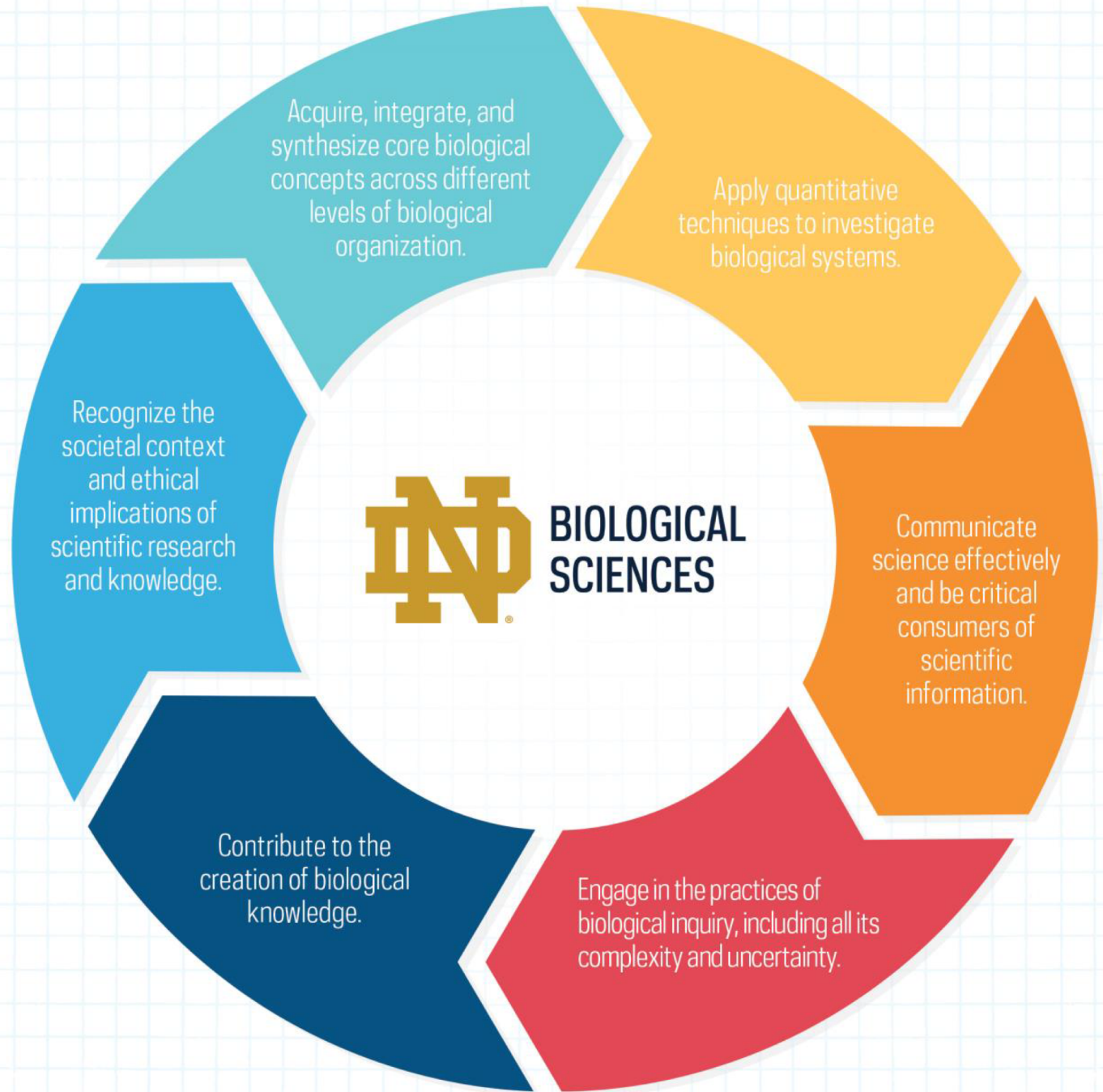
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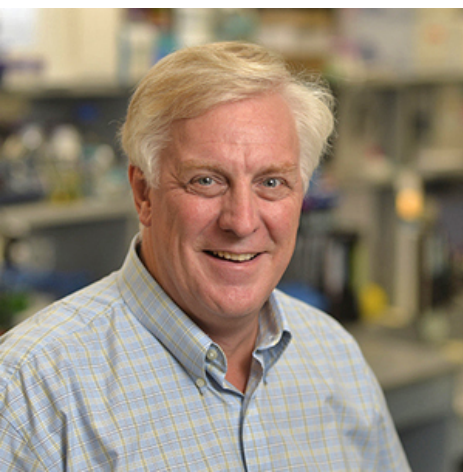
# PILLARS

Build Foundational Knowledge

Foster Thinking Like a Biologist

Develop Enthusiasm for Biology





## Blindness: Can We See Potential Gene and Stem Cell Therapies?

Dr. David Hyde



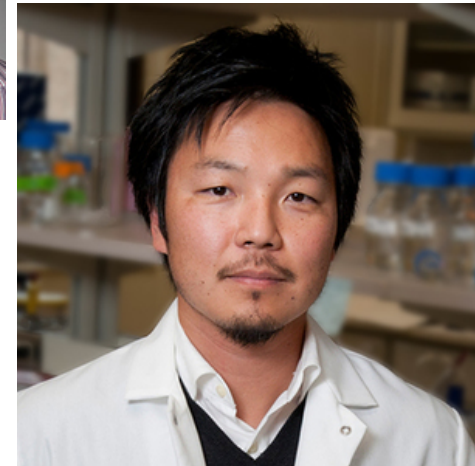
## What Powers Life on Earth?

Dr. Jeanne Romero-Severson



## Hero or Villain: How Might Earth's Ecosystem Resolve the Climate Question?

Dr. David Medvigy



## Who's in Control? The Role of Microbiomes in Our World?

Dr. Shaun Lee

*[For full syllabus, see:  
[biology.nd.edu/undergraduate](http://biology.nd.edu/undergraduate)]*

## **Core Concepts (All)**

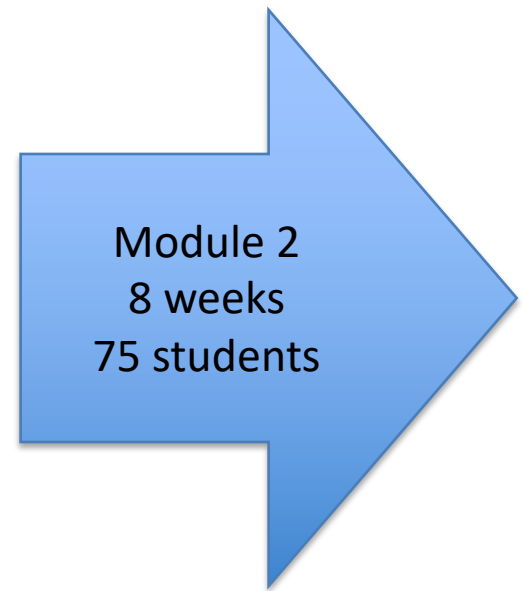
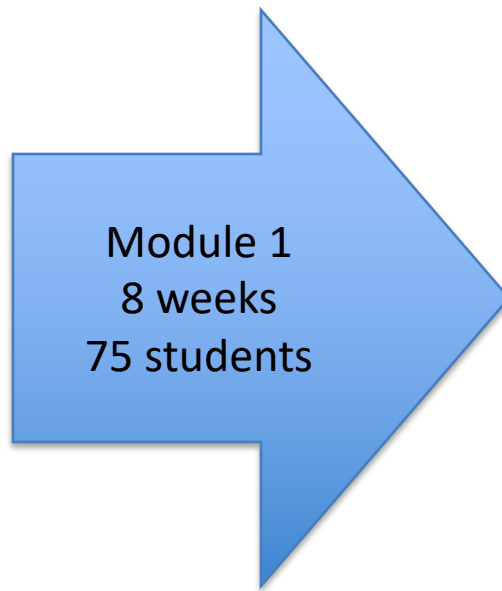
- Evolution
- Biological Information & Flow
- Structure-Function
- Transformations of Energy & Matter
- Systems

## **Levels of Organization (3)**

- Molecules
  - Cells
  - Organisms
  - Populations
  - Ecosystems
-

# Course Structure

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# Community Critique: Characters

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- In what ways does this reform suggest that ‘characters’ in this story must evolve to meet students’ learning needs?
  - What are the limits or constraints to this approach?
-

# Questions and Discussion

- 
- What parts of the biology “story” might have more or less impact on engaging young people in doing and thinking about biology?
  - What major assumptions about biology education should we revisit in order to think about reform?

