Research on a Laboratory Curriculum for NEXUS/Physics

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Why create a new laboratory curriculum?

Traditional labs, following given protocols, do not engage students in sense-making and do not improve students' understanding of course content. [1]

Reform labs, such as ISLE and UMd's SCL, show dramatic improvement, but fail to engage students' primary interests and do not help prepare them for their future careers.[2]

Our Challenge: Can we create labs that students see as relevant to their interests and career goals while maintaining an epistemological focus?

Our Goals:

Competency E2 of the HHMI-NEXUS project:

> Demonstrate understanding of the process of scientific inquiry, and explain how scientific knowledge is discovered and validated. [3]

Engage in Sense-making in a Realistic Science Environment

- Experimental Design (Protocol Development)
- Modeling (Conceptual, Physical, Diagrammatic, Graphical & Mathematical)
  - How to make a model?
  - Use of models?
  - Where and why a model breaks down? (Limitations.)
- Multiple Representations
- Scaling Arguments
- Error Analysis
- Technical Skills for Biological Applications
- Advantages of Group Work and Discussion
- Quantification yields more Productive Biological Information than Observation

What did we do?

1. We **changed the content** in order to focus on physics applicable at biological scales.
2. We **chose a lab format** to promote coarse-grain lab skills (e.g. sense-making, exp. design, epistemological focus).
3. We **chose high-tech equipment and modern analysis tools** to promote fine-grained lab skills (useful to professional biologists).

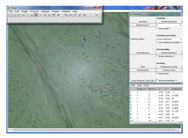
These three goals are often in tension.

Lab Equipment: High-Tech Equipment with Modern Analysis Software

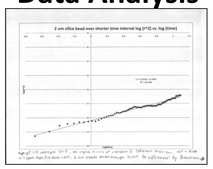
Microscopes

Spectroscopes

Image Analysis



Data Analysis



We want to know: How do students see the labs?

Do students see applications to 'biology'? Are they learning useful skills to prepare for their future?
How do students perceive the emphasis on experimental design / protocol development?
How does this lab curriculum compare to other labs?

We have gathered survey and video data from two small test classes (max N = 31) to answer these questions.

How do students orient to the 'biology' in the labs?

> I find that I am learning a lot about how to discover and think through biology problems better.

> Critical thinking and communication between peers are definitely valuable skills in the realm of biology. Using tracking programs, excel, and also using microscopes are definitely beneficial skills to have in biology.

> Labs such as the neuron lab which **relate to background knowledge** we already know are especially interesting because we are **exploring and proving an area of a subject we did not completely understand**.

Prompt: Are you learning lab skills relevant to biology?	Middle of 1st Semester (N = 22)	End of 2nd Semester (N = 31)
Yes	68%	64%
Somewhat	18%	36%
No	14%	0%
Gaining Skills in: ImageJ	8 (of 22)	16 (of 31)
Excel	4	9
Microscopy	5	4

Perception of Experimental Design / Protocol Development:

Prompt: To the extent possible, rather than giving you a protocol, we have allowed you to develop and test your own protocol. Do you see this as beneficial? Is it a hindrance? As you see it, what are the advantages and disadvantages of our laboratory approach?

Response to Prompt (N = 31)	Middle of 2nd Semester	End of 2nd Semester
Beneficial	64%	86%
Neutral	36%	14%
Con: Makes the lab rushed	10 (of 31)	4 (of 31)
Pros: Better Methodology	9 (of 31)	4 (of 31)
Better Content	8	---
Prepare for Career	---	7
Reflective of Real Science	4	7
Problem-solving Skills	4	7

> I find that I am **paying attention** to every step and can **explain the experiment** from beginning to end, with an **understanding of why things happened** and **how the results change** when a variable is manipulated.

> I definitely see it as beneficial because a large part of science and especially biology is how to create an experiment so this is **great practice for the future**.

> I learned how to approach a problem by designing our own experiments and interpreting data our own way. **These labs taught me how to think for myself.**

Comparison to ISLE labs:

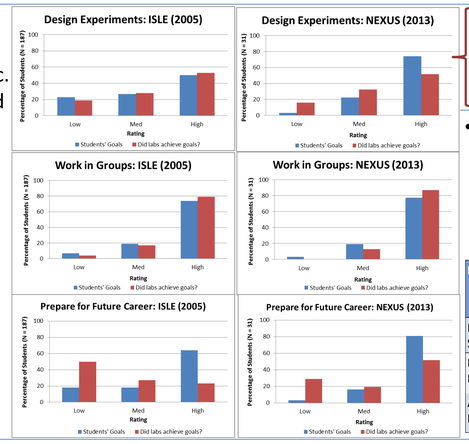
Rutger's ISLE labs have a similar student demographic. We used one of their assessment tools and compared our data to theirs. [2]

Students were asked two questions:

1. **How important is each goal FOR YOU?**
2. **How successful were the labs in terms of achieving each goal?**

Goals:

- Learn to design your own experiment
- Learn to interpret experimental data
- Prepare for your future professional career
- Understand concepts better
- Learn to work with other people
- Learn to communicate ideas in different ways



- Results for the other three goals were comparable to the ISLE results.
- We find the results for 'Prepare for your Future Career' especially promising.

- When asked to list three things they had learned in the labs, responses from students in ISLE, UMd's SCL and NEXUS/Physics included these sense-making goals with the following frequency:

Learning Goal	SCL (2003)	ISLE (2005)	NEXUS: Middle of 1st Semester	NEXUS: End of 2nd Semester
Number of Students	~200	~200	22	31
Design Experiments	14%	24%	14%	**35%**
Analyze and Interpret Data	8%	11%	24%	**29%**

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REFERENCES

[1] E.F. Redish & D. Hammer, Reinventing College Physics for Biologists: Explicating an Epistemological Curriculum, *Am. J. Phys.*, v. **77**, pp. 629 *ff* (2009)
[2] E. Etkina & S. Murthy, Design Labs: Students' Expectations and Reality, *AIP Conf. Proc.*, v. **818**, p. 97 ff (2006)
[3] AAMC-HHMI committee, *Scientific Foundations for Future Physicians* (AAMC, 2009)

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