Interactive Engagement and Biological Relevance: Success at a Large Institution

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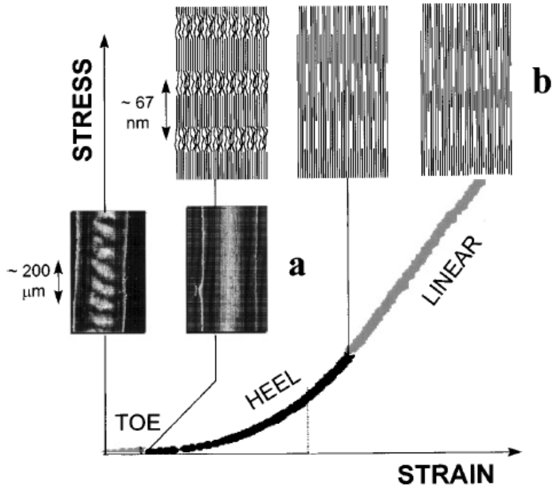

The *Status Quo Ante*

R1 university, ~ 30 faculty members, ~ 100 grad students

- No engineering school, so IPLS is largest "service" course
- Biology graduates ~ 400 majors/year
- IPLS enrollment > 500/semester
- Traditional format: 3 lectures and 1 lab each week
- Little or no interactive engagement in lecture

The Team

Project director:

Physics and Astronomy Education Research (PAER) group faculty:

Alice Churukian (PER from KSU)

Duane Deardorff (PER from NCSU)

David Smith ‡ (PER from Dublin)

‡Now at UW

Colin Wallace (AER from Colorado)

Also:

Jean DeSaix (Biology)

David Guynn (PER grad student)

Motivation and Design

- National reports supporting change in undergraduate biology
- Learn from leaders in the community
- How could we better meet the needs of our students?
- How can we make the changes sustainable?

Motivation and Design

National reports supporting change in undergraduate biology education

- *BIO 2010*

- *Vision and Change*

- *Scientific Foundations for Future Physicians*
- Can the quantitative skills increasingly being used in biology research begin to trickle down to undergraduate education?

Motivation and Design

Learn from leaders in the community

- Joe Redish & Physics Education Group, Univ. of Maryland
- Dawn Meredith and Jessica Bolker, Univ. of New Hampshire
- Catherine Crouch, Swarthmore College
- Ken Heller & Physics Education Group, Univ. of Minnesota

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Motivation and Design

How could we better meet the needs of our students?

- Detailed discussions of course content and course goals with faculty from Biology, Chemistry, Physics & Astronomy
  - Focus on skills rather than specific topics or concepts
  - Emphasize logical and critical thinking
- Decided on lecture-studio format
- Adapt other IPLS resources and design new materials

Motivation and Design

How can we make the changes sustainable?

- Make it “instructor resistant”
  - Lecture slides and studio activities prepared for “turn-key” operation
  - Instructors concentrate on delivery rather than creation
- Team teaching and mentor-apprentice model
  - Experienced faculty “rotator” + studio coordinator + novice instructor
- Infrastructure as for previous “traditional” lecture/lab model
- Transform ***all*** sections
- TA training

Design Process

- Began with a blank slate: “blow it up and start over”
- NSF funding: *Physics and Biology Partnership for a New Learning Environment*, TUES Type 2, 2013-2016, $499,000
- Identified topics to be included
  - Authentic biological relevance (from biology literature)
  - OR foundational for such a topic
- Focus on conceptual understanding and quantitative reasoning/problem solving rather than lab technique or lab report rhetoric

Design: Course Content

Topics added	Topics revised	Topics eliminated
Allometry – Biological Scaling	Forces and kinematics	Planetary Motion
Stress and Strain	Torque and its role in biomechanics	Rotational Kinematics
Diffusion	Thermodynamics	AC Circuits
	Fluids	

Design: Course Structure

- Research-based and research-validated teaching methods
- Fit administrative constraints of department
  - Revenue-neutral (same number of instructional staff)
  - Any faculty member can teach it (in principle)
- *New Studio* model developed at Kansas State University and Colorado School of Mines (we call it "lecture/studio")
  - All students meet for interactive lecture
  - Students divided into multiple sections for studio
  - Warm-up + lecture + studio + homework = module
  - 2 modules/week
  - Occasional mini-lectures from guest biologists to reinforce relevance

Design: Lecture/Studio Model

- Lecture = 50 min, studio = 110 min.
- Studios: hands-on activities, tutorial exercises, simulations, group problem-solving
- 1 studio instructor per ~30 students
- Lectures and studios tightly coupled (lecture prepares for studio); eliminates incoherence between lecture and lab material
- If multiple lecture sections needed, same lecture given back-to-back
- All HW, exams, grading same for all students

Mon	Tues	Wed	Thurs	Fri
Morning Lecture Afternoon Studios	Morning Studios Afternoon Studios	Morning Lecture Afternoon Studios	Morning Studios Afternoon Studios	Review session or exam

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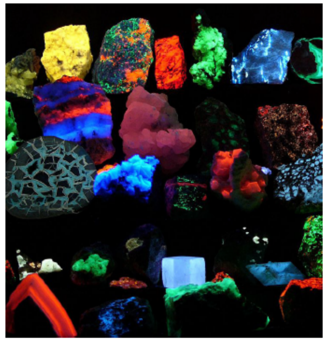
Design: Instructional Materials

- 54 interactive studio activities
  - Designed for 110-minute sessions but many could be divided for use in shorter recitation or lab sessions
  - Mixture of pencil and paper activities (tutorials), experimental explorations, simulations, group problem-solving
- Accompanying lectures, warm-up assignments, clicker questions, homework assignments and exams
- Instructor preparation
  - Weekly faculty meeting (exams, course procedures)
  - Weekly meeting with all instructors to prepare for next week's studios

Studio activities for IPLS

Absorption and Fluorescence



Introduction

The energy in a molecule is *quantized*, meaning it can only have certain discrete values and not any values in between. Thus a molecule can only absorb and emit energy in amounts equal to the difference in energy between two allowed states. Since the energy of a photon (in electron volts) is related to its wavelength (in nanometers) by $E = hc/\lambda$ (where h = Planck's constant and c = speed of light and hc = 1240 eVnm), this means that a molecule will only be able to absorb specific wavelengths of light. The color we perceive in a material (biological or otherwise) is determined by the wavelengths of light that it absorbs (and the wavelengths it does *not* absorb). Specific biomolecules absorb specific wavelengths of light, resulting in a variety of biological effects from photosynthesis to concealment.

Learning Goals

At the end of this activity, you should be able to…

- Relate the perceived color of an object to its absorption spectrum.
- Explain why the emission wavelength is larger than the absorption wavelength in a fluorescence process (Stokes shift).
- Using the transmission spectrum of the eye lens and the absorption spectra of the visual pigments, determine the range of wavelengths that an organism can perceive.
- Relate absorption and emission wavelengths to differences in energies of quantum states.

Newton's Laws: Jumping Grasshoppers 2

Introduction

This activity is a follow-up to Grasshoppers 1, and expands upon that activity in two ways. First, while Grasshoppers 1 explored the forces on a grasshopper during a *single* jump, today's activity will compare key dynamical features such as mass, maximum force, and maximum jump distance across *multiple* jumps. Second, while in Grasshoppers 1 we assumed that the grasshopper jumped straight upward, in today's activity we will explore a grasshopper jump in two dimensions, allowing us to draw conclusions about jump distances.

Learning Goals

After completing this studio, you should be able to…

- Analyze the motion of connected objects.
- Apply Newton's laws to reason about the changes in the maximum jump distance of a grasshopper.

A. Exploration 1: Deducing position from velocity, and taking a graphical perspective

First, some unfinished business from Grasshoppers 1, we will use numerical integration again, this time to find the position of the grasshopper from its velocity.

1. Complete the blanks in the following sentences:
   a. $v(t)$ is the ___(1)___ of $a(t)$, so to get $v(t)$ we need to look at the ___(2)___ of the $a(t)$ graph.
   b. $y(t)$ is the ___(3)___ of $v(t)$, so to get $y(t)$ we need to look at the ___(4)___ of the $v(t)$ graph.

Fluid Dynamics III: Reynolds Number

Introduction

The motion of an object in a fluid is controlled by its *Reynolds number*, a dimensionless quantity that is the ratio of the inertial forces acting on the object to the drag forces it experiences. For a sphere of diameter d moving at speed v the Reynolds number can be expressed as:

$$Re = \rho d v/\eta$$

where ρ is the density of the fluid and η is its viscosity (sometimes called its *dynamic viscosity*).

Learning goals

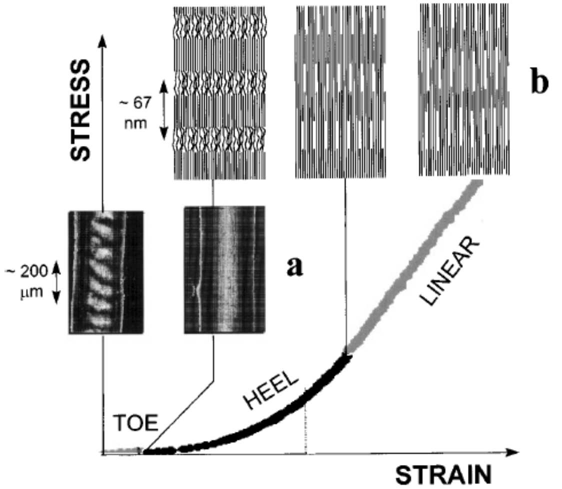
After completing this activity, you should be able to…

- Calculate the Reynolds number for a particular fluid and flow speed, using parameters provided.
- Use the Reynolds number in a particular situation of fluid and flow speed to determine whether inertial or drag forces dominate.
- Specify and calculate the forces on a sphere moving in a fluid, including the drag force.
- Use Newton's laws and the drag force to determine the terminal speed of a sphere falling in a fluid.
- Apply dynamic scaling to determine appropriate values of size, speed and viscosity for a scale model.
- Describe the motion of an organisms in a fluid under conditions of very low Reynolds number.

http://paer.unc.edu/projects/ipls/

Biologically-Relevant Topics: Examples

- Newtonian Mechanics
  - Jumping Grasshoppers
- Impulse and Momentum
  - Collisions and concussion (with college football data)
- Chemical Energy
  - Potential energy of chemical bonds, ATP
- Nonlinear stress and strain
  - Tendons, resilience



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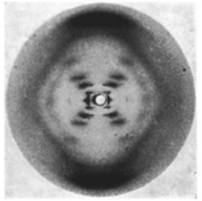
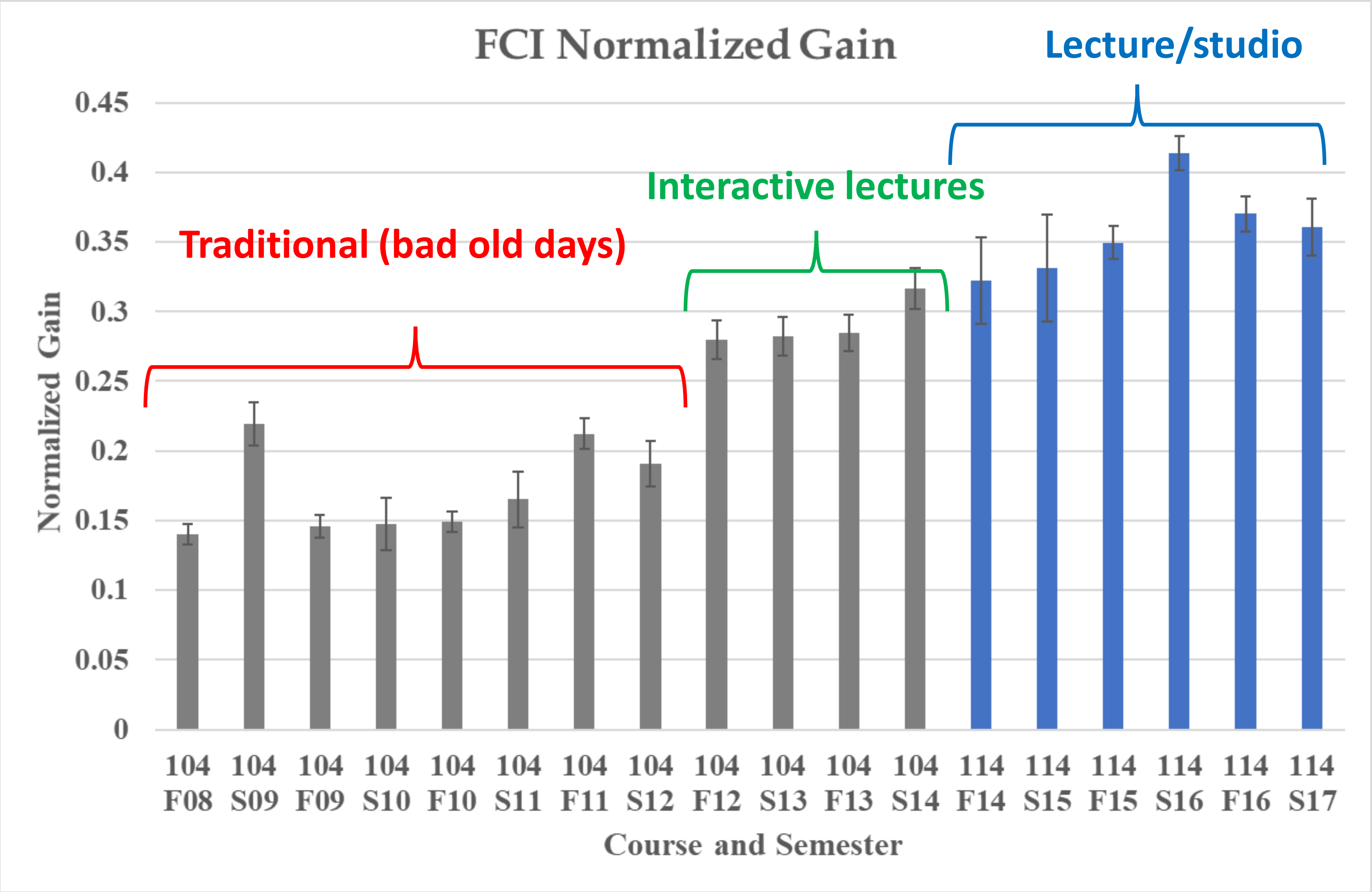
Biologically-Relevant Topics: Examples

- Fluids
  - Viscous fluids and Poiseuille’s Equation (blood flow)
  - Reynolds number
- Electric Potential and Circuits
  - Electrocardiogram
  - Nerve signal propagation
- Magnetism
  - MRI
  - Magnetotaxis (with sea turtle videos!)

- Optics
  - Optics of the eye (ophthalmology and giant squid!)
  - Diffraction of DNA



Results: Force Concept Inventory



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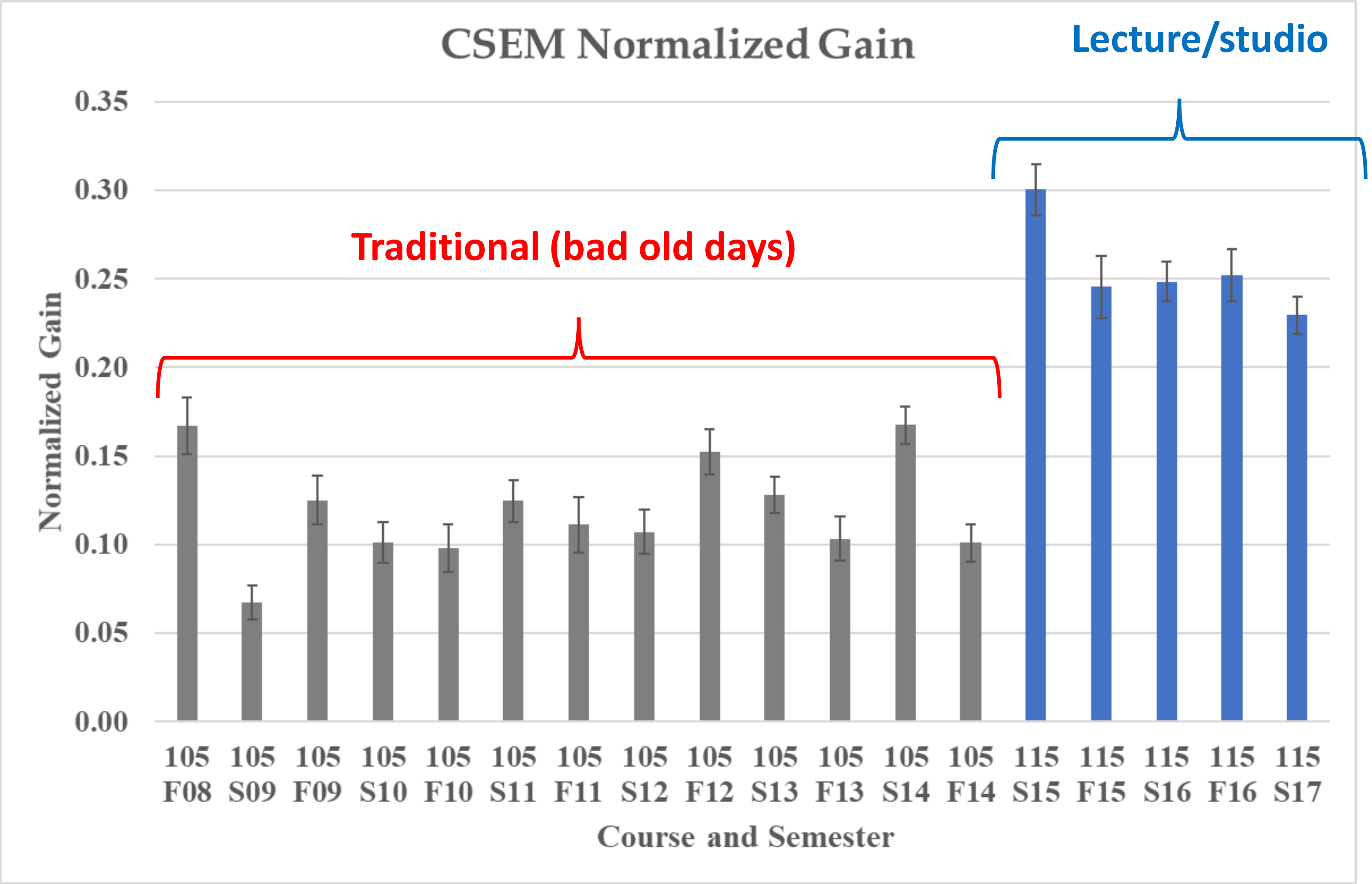
Results: Concept Survey in E&M



Results: Student Comments

- “I think studio is one of the best working environments I have ever been in.”
- “I really enjoy the class and the fact that it is specifically targeted at those who have a biology background. Many of the examples tie-in some sort of biology, making learning more interesting.”
- “The information about fluid dynamics was especially relevant to my interests in hydrology and stream ecology systems.”
- “This class is very difficult. The pace is extremely fast and seems like it takes up a huge majority of time with lecture and studios back to back throughout the week.”
- “Sometimes TAs in studio do not answer questions well. Students are sometimes left feeling confused.”

Results: Sustainability

- Faculty not involved in development have taught course
  - Teaching Assistant Professor (1)
  - Assistant Professors (3)
  - Professor (1)
  - Distinguished Professor (1)
- Teaching a large-enrollment course now a prerequisite for tenure
- 27 graduate TAs and undergraduate LAs have taught studios
- Over 4000 students taught since Fall 2014
- Biology faculty: “Our students *love* this course”
- Additional room renovation will be complete by May 2018

Overall Messages

- Studio-style teaching is feasible at a large institution
- Additional instructional staff not needed if conversion is complete
- Learning gains are dramatically improved
- Student attitudes and interest level also improved
- Separating development from implementation helps with sustainability
  - Faculty members don’t have to be “true believers,” only trainable
  - Large-enrollment teaching feasible for beginning faculty
- TA training very important
- Renovated rooms not necessary (but helpful)

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Want to join the party?

- All course materials available for widespread dissemination
- Studio materials: PALS – Physics Activities for Life Sciences
- Website: paer.unc.edu
- Contact us: paer@unc.edu
- All materials will appear on comPADRE in due time
- Continuing to improve current material, explore additional topics and concepts, improve assessment
- For more detail, see http://arxiv.org/abs/1709.05229 (under review at *Am. J. Phys.*)

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