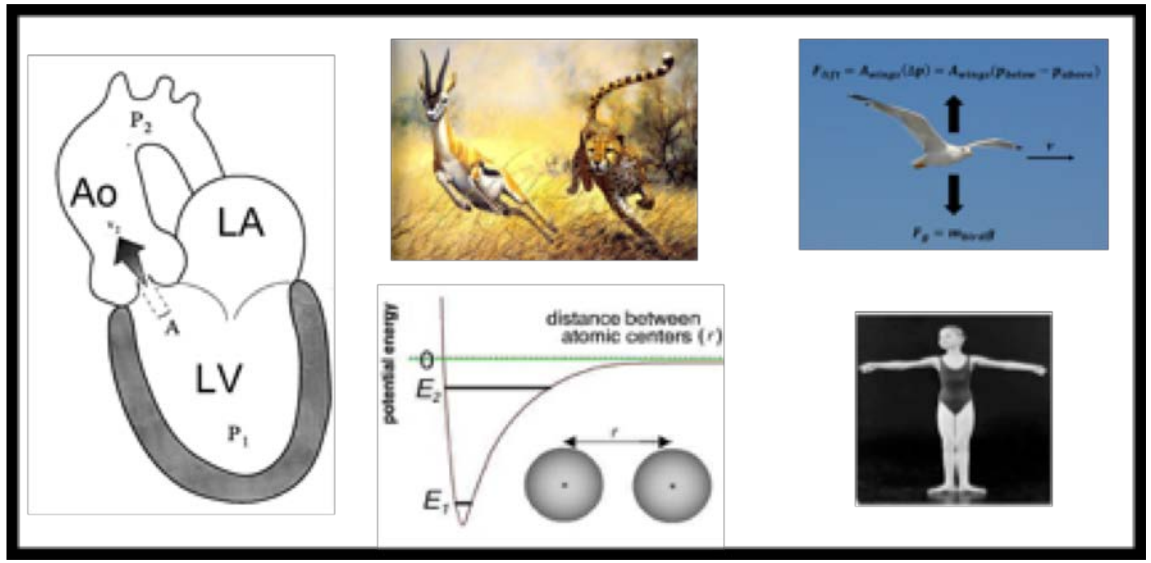

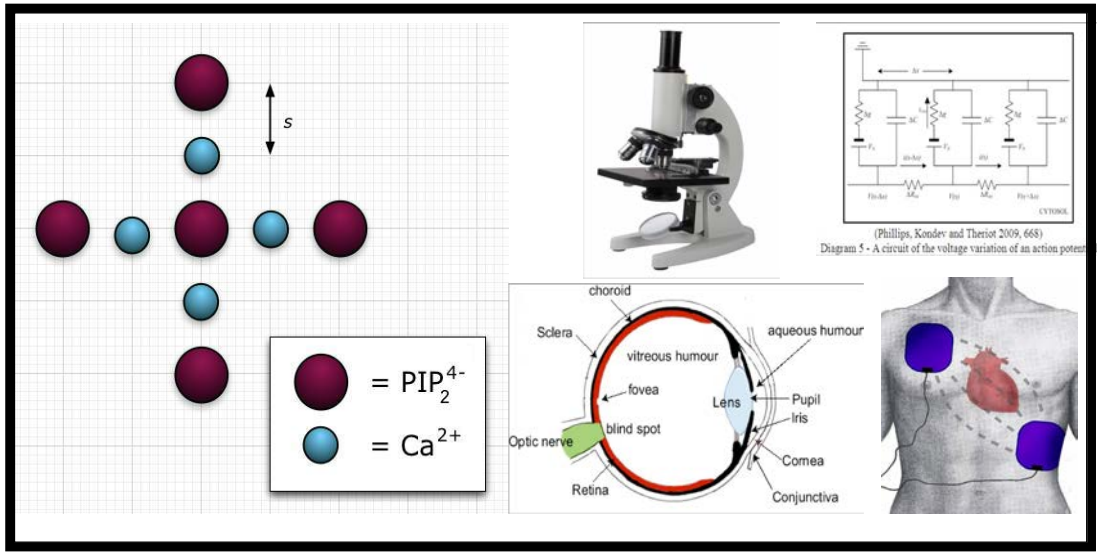

Assessing the Lasting Impact of IPLS

Ben Geller, Swarthmore College

AAPT – Provo, UT
July 22, 2019

Thank you to my collaborators and funders


Jonathan Solomon ’20


Nathaniel Peters ’18


Haley Gerardi ’17


Aqil MacMood ’20

- **Nathaniel, Aqil, and Haley are all giving talks this afternoon in Session CB.**
- **We will also have posters at PERC on Wednesday!**


Catherine Crouch


Chandra Turpen


Sara Hiebert Burch

Advisory Board:

Eric Brewe
Todd Cooke
Brad Davidson
Eric Kuo
Sanjay Rebello

NSF 1710875

Talk Outline

- Motivation for a Pilot Longitudinal Study at Swarthmore

- Preliminary Results from Years One and Two of the Study
  - What attitudes do students express?
  - What skills do students exhibit?
    - ❖ Core methodological challenges encountered in assessing skills

- Preliminary Conclusions and Unanswered Questions

Talk Outline

- **Motivation for a Pilot Longitudinal Study at Swarthmore**

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A (the?) central goal of IPLS:

Make physics relevant to life science students.

But relevance has multiple dimensions…

“Relevance” goals in the context of IPLS

1. Developing relevant **skills**: Equipping future life science professionals

[e.g., Meredith & Redish (2013); Redish et al. (2014)]

- ✓ Quantitative reasoning
- ✓ Coordinating across representations
- ✓ Using simple physical models

2. Developing **attitudes** about relevance: Interest and engagement

[e.g., Hidi et al. (2006); Van Ness and Widenhorn (2012), Crouch et al. (2017); Geller et al. (2018) etc.]

- ✓ Epistemological view of physics
- ✓ Affective response to physics

Both the SKILLS and ATTITUDES goals require that we consider how the IPLS learning environment connects (or does not connect) to the other biology and chemistry learning environments that our students encounter…and how we can explicitly support our students in navigating these environments.

Navigating these different learning environments is complicated, in part because:

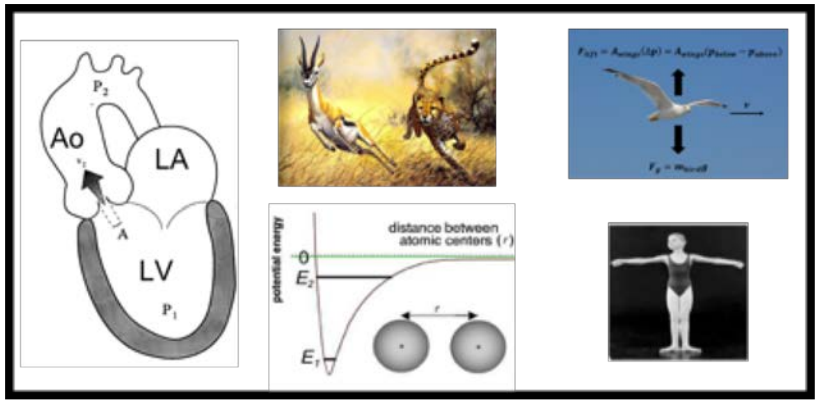
- Students have **expectations and anxieties** that can make transfer between disciplines especially challenging [Bialek (2004), Watkins et al. (2012), Kuo et al. (2014)].
- Introductory science classes communicate different **disciplinary epistemologies** [Redish et al. (2013), Meredith et al. (2013), Gouvea, Sawtelle, and Nair (2019)].
- A student's **personal identity as a disciplinary scientist** shapes how he or she views their work in different disciplines [Hall et al. (2011), Sawtelle et al. (2015)].
- **Curricular sequences that develop cross-cutting concepts** such as energy and entropy in IPLS are possible [Dreyfus et al. (2015), Geller et al. (2015)], but require **iterative communication** with faculty members from biology and chemistry.

How have we tried to support students in navigating these disciplinary boundaries within IPLS at Swarthmore?

IPLS course design at Swarthmore: Make the content relevant

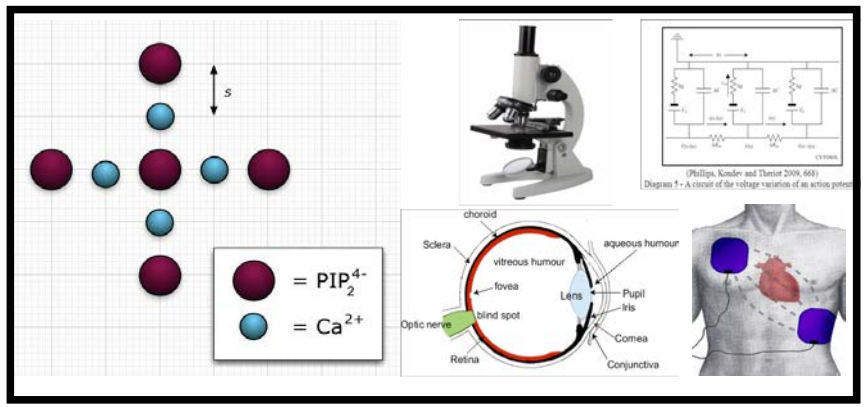
IPLS Mechanics

- Kinematics and Dynamics: ***random vs. coherent motion, biomechanical stability***
- Energy: ***chemical energy***
- Fluids: ***cardiology and flight***
- Thermo: ***heat conduction and free energy***



IPLS E&M

- Electricity/circuits: ***cell membrane, nerve signaling***
- Magnetism and induction: ***magnetic sensing, NMR***
- Optics: ***animal vision and microscopy***
- Waves: ***echolocation***



Crouch and Heller (2014)

IPLS course design at Swarthmore: Develop relevant content

IPLS Mechanics

- Kinematics and Dynamics: ***random vs. coherent motion***, *biomechanical stability*
- Energy: *chemical energy*
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- Thermo: ***heat conduction and free energy***

IPLS E&M

- Electricity/circuits: ***cell membrane, nerve signaling***
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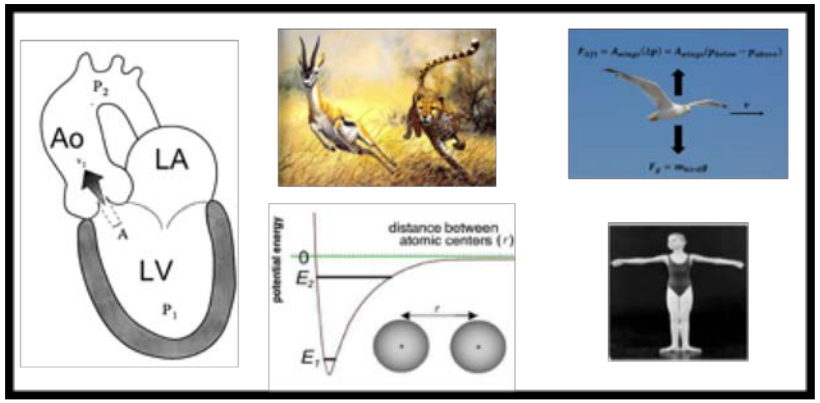
- Optics: *animal vision and microscopy*
- Waves: *echolocation*

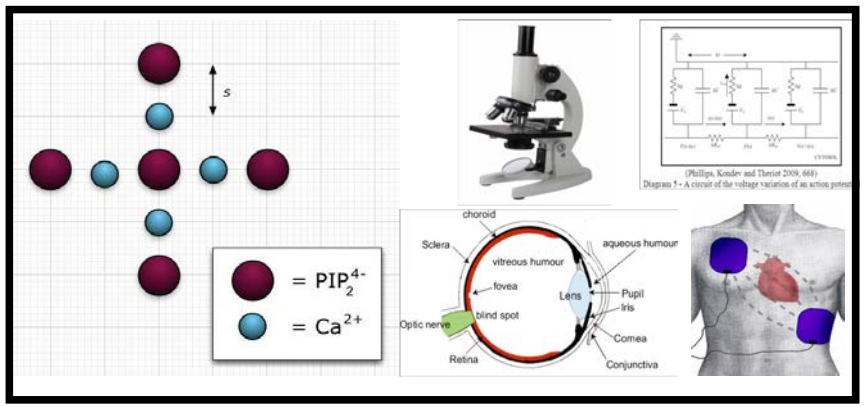
Cell Biology

Animal Physiology

Neurobiology

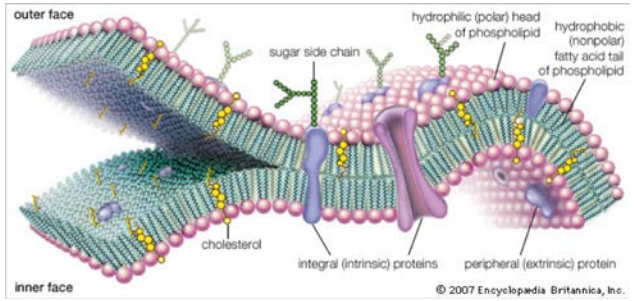
(Bio)chemistry

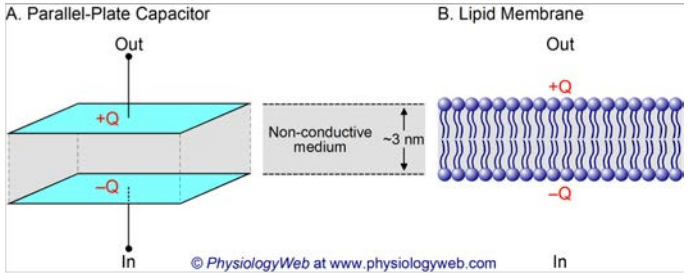


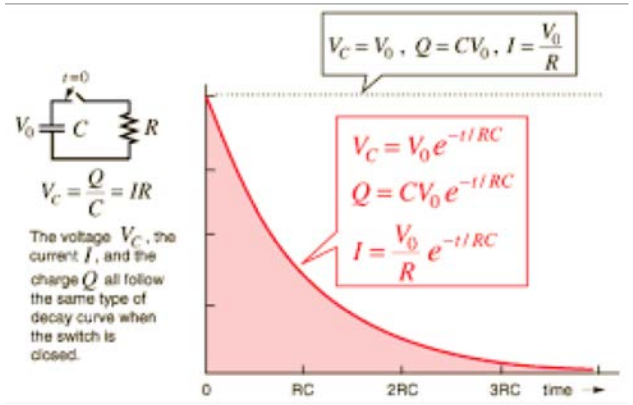


Crouch and Heller (2014)

IPLS course design at Swarthmore: Develop relevant skills







BIOLOGICAL SYSTEM
(Cell Membrane)

↕

SIMPLE PHYSICAL MODEL
(Electric Capacitor)

↕

GRAPHS & EQUATIONS
(associated with charging/discharging a capacitor)

IPLS task design and delivery at Swarthmore:

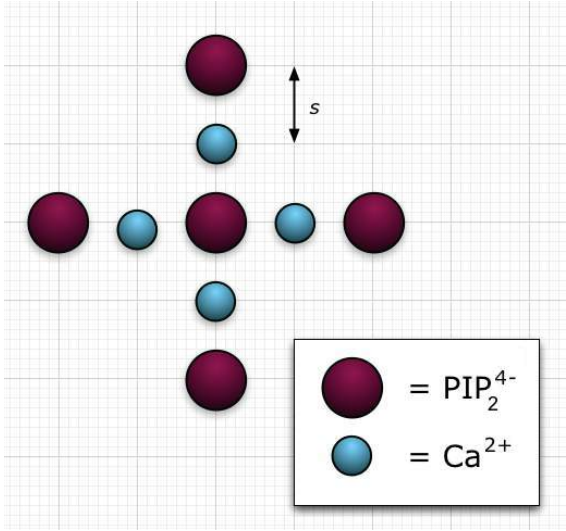
"Authenticity" and "Expansive Framing"

Watkins et al. (2011)

Engle et al. (2011)

EXAMPLE:

Rare, highly negatively charged lipids form clusters on the cell membrane surface for certain cellular processes. These clusters include small positive ions. For the simple model of a cluster shown, show that with doubly charged Ca^{2+} ions, electric forces hold the cluster together — but not with singly charged Na+ ions.



Nearly all of the work examining the impacts of IPLS curricula on student learning has been done ***within the IPLS courses themselves***.

Little is known about the impact of IPLS on knowledge and attitudes in ***subsequent learning environments***.

Longitudinal research questions

RQ1 (SKILLS): Do IPLS students demonstrate a greater ability to **leverage physics competencies** in their later biology coursework, compared to their peers with no college physics or traditional introductory physics? If so, in what ways?

RQ2 (ATTITUDES): Do IPLS students **view physics as more relevant and connected** to their biology and chemistry coursework, compared to their peers with no college physics or traditional introductory physics? If so, in what ways?

Why Swarthmore?

- Small institution where **faculty can collaborate closely** on curricula, and have some sense of what others are teaching.

- Small student body with limited course options makes it **possible to identify typical student trajectories***

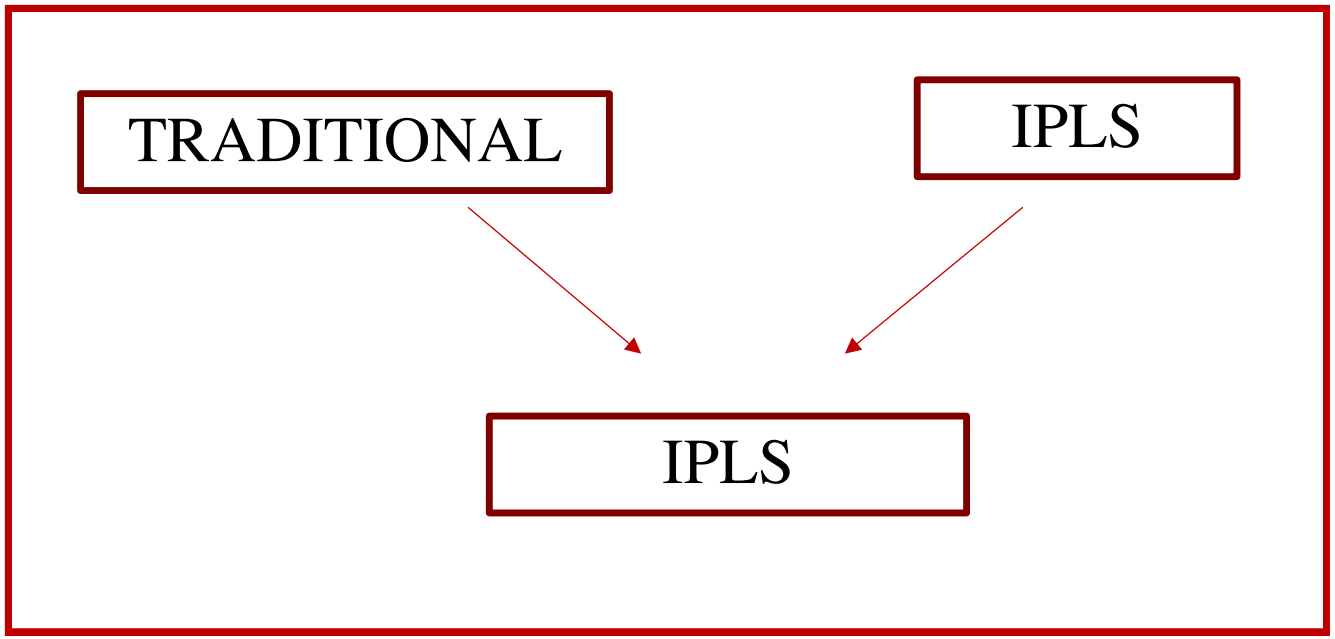
- **Loyal students** who can be followed over multiple years relatively easily

***Harder than anticipated!**

Also, a (potentially) fortuitous curricular landscape

First Semester:
(Mechanics)

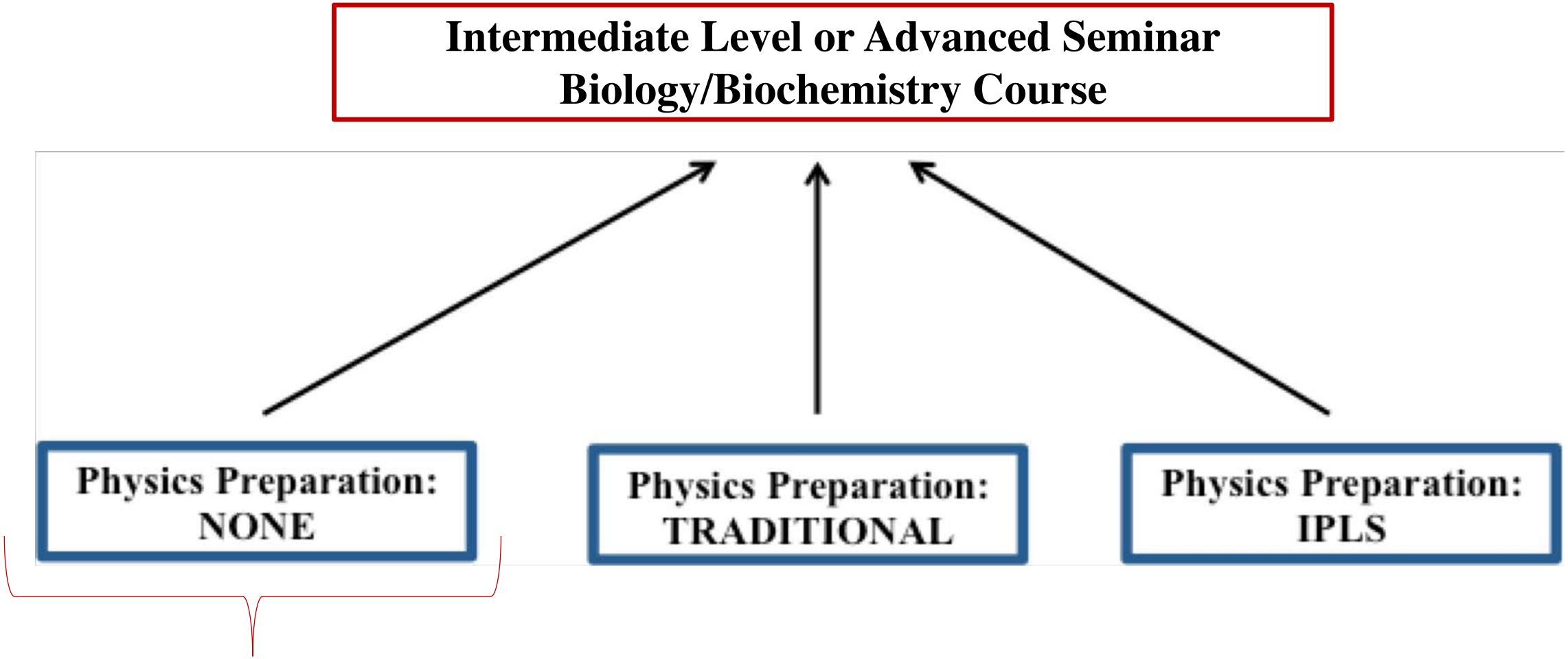
Second Semester:
(E&M)



Students in the IPLS courses:

- Mostly pre-med or life science majors
- Mostly sophomores and juniors
- Most have taken courses in both bio and chem

Physics is not a *requirement* for the biology major at Swarthmore.

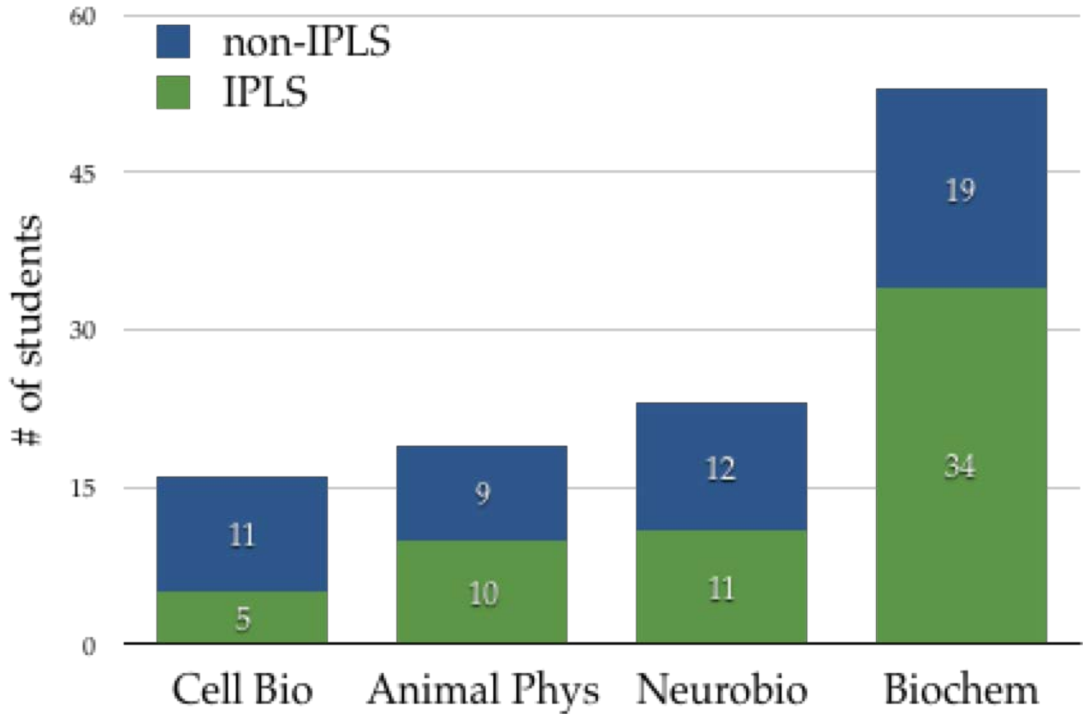


Data sources from years 1 and 2

- Student written work on embedded tasks
- Think-aloud interviews
- Attitudinal surveys
- Journal reflections

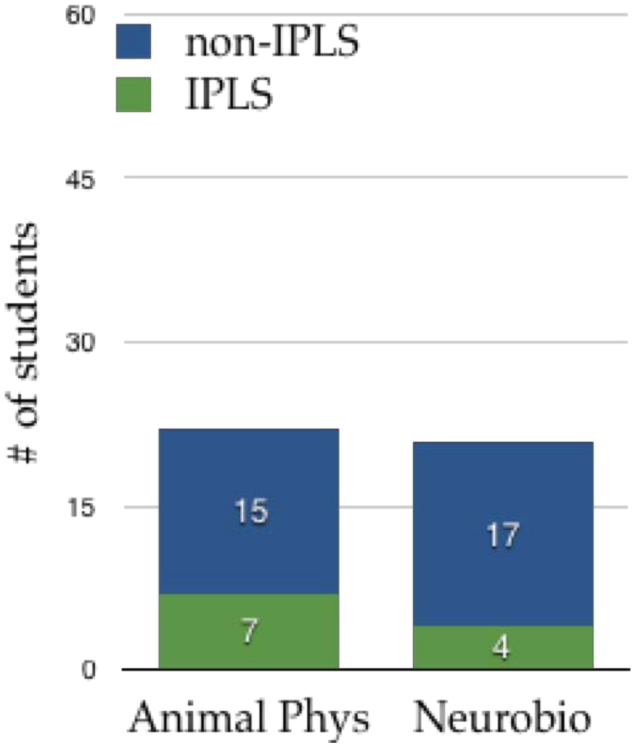
YEAR ONE (17-18)

- Biochem (S18, $N = 53$)
- Animal Phys. (F17, $N = 24$)
- Neuro (S18, $N = 23$)
- Cell Bio (S17, $N = 16$)



YEAR TWO (18-19)

- Animal Phys. (F18, $N = 22$)
- Neuro. (S19, $N = 21$)



Talk Outline

- Motivation for a Pilot Longitudinal Study at Swarthmore

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  - What skills do students exhibit?
    - ❖ Core methodological challenges encountered in assessing skills

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Attitudes toward the **RELEVANCE of PHYS/MATH** to biology

Students responded with level of agreement on a 5-point Likert scale to statements like:

- ***It is beneficial to me, as a biologist, to be proficient in physics***
- ***Ideas I learn in physics are rarely useful in biology***
- ***Physics is largely irrelevant for understanding biological processes***

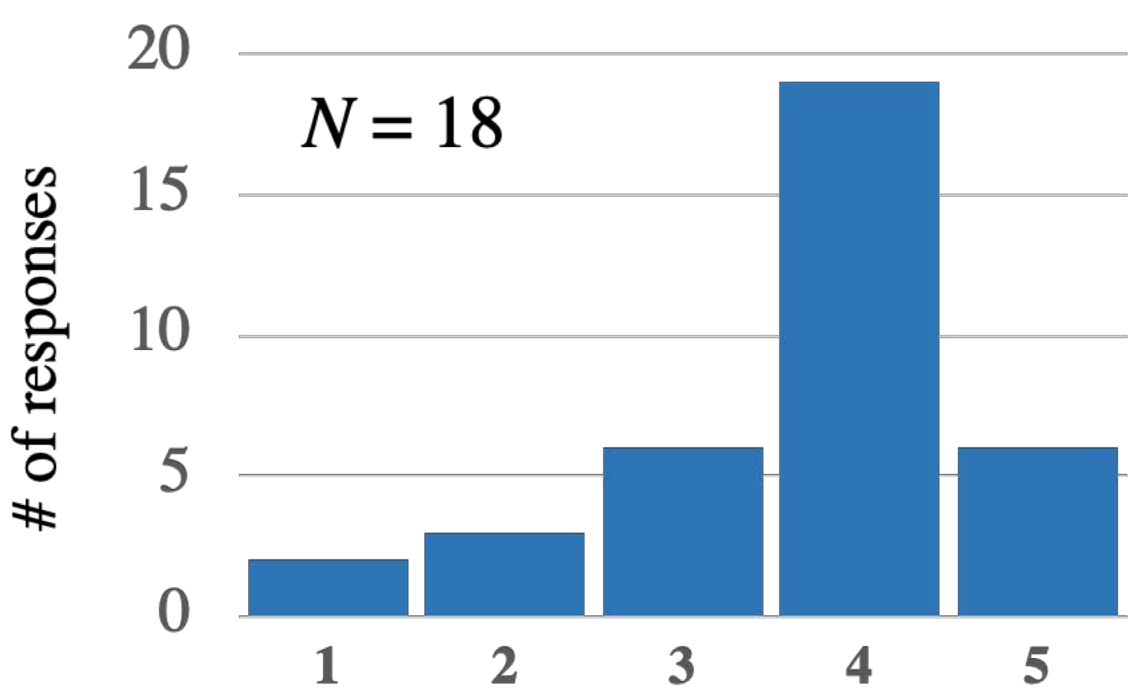
- Scores were flipped as needed so that a 5 always represents positive sentiment.

- Same set of statements given for relevance to biology of (a) math and (b) chemistry.

Questions adapted from MBEX Interdisciplinary Cluster, K. Hall, Ph.D thesis, 2013

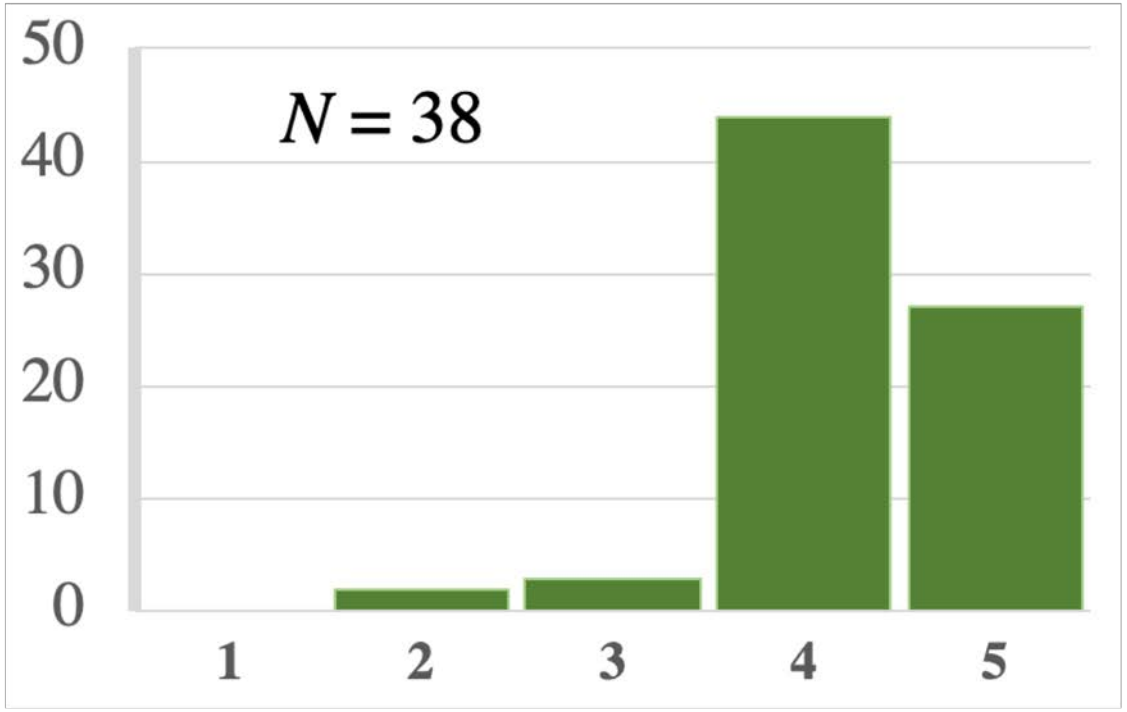
Attitudes toward **RELEVANCE OF PHYSICS** to biology <u>after first semester</u>

No IPLS physics yet



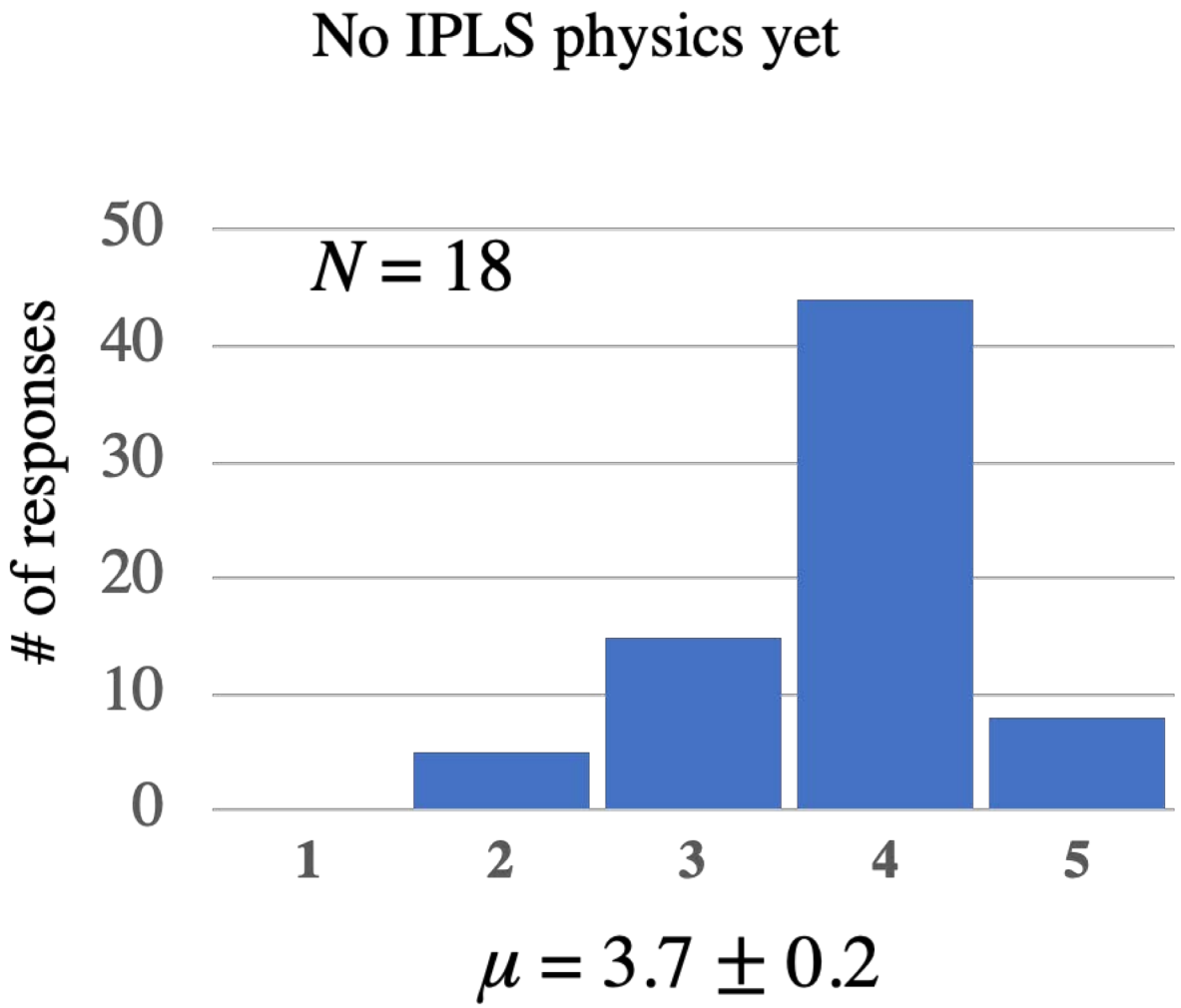
$\mu = 3.7 \pm 0.2$

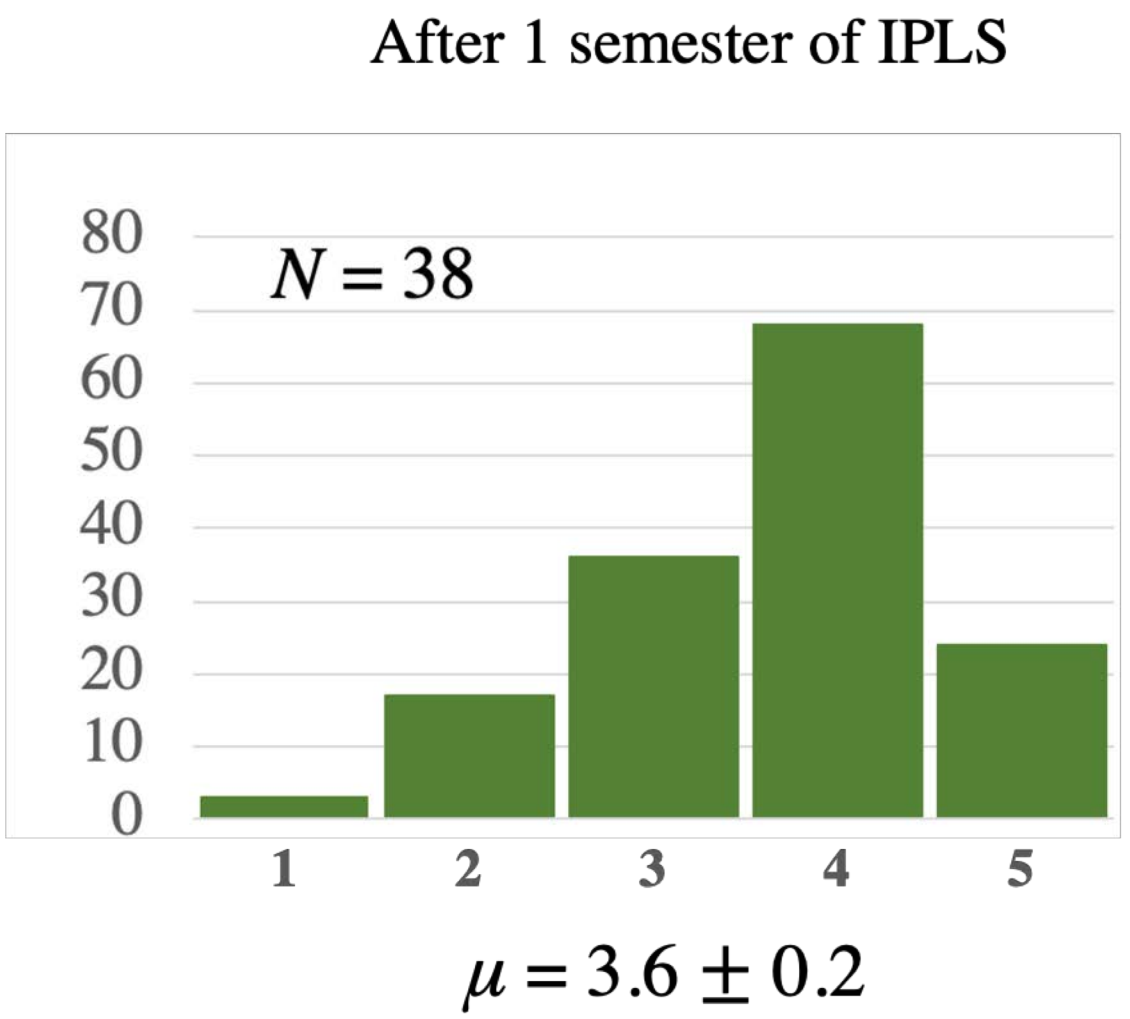
After 1 semester of IPLS



$\mu = 4.3 \pm 0.1$

Attitudes toward **RELEVANCE OF MATH** to biology <u>after first semester</u>

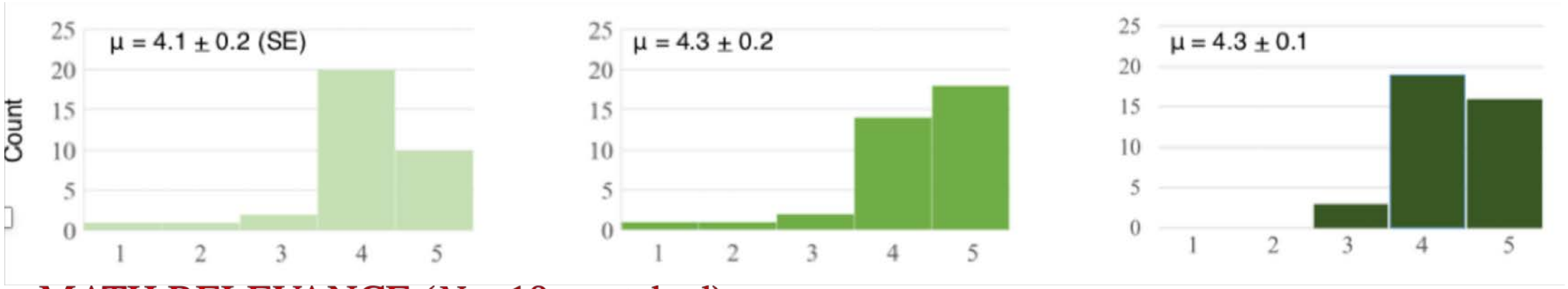




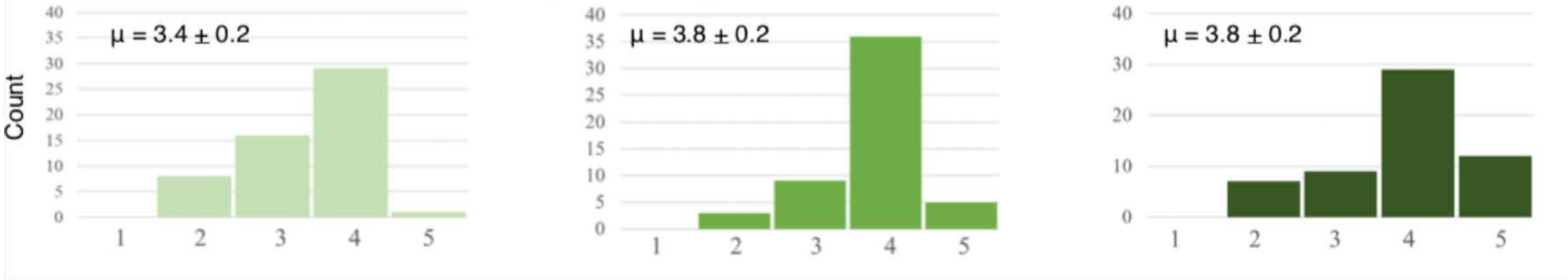
Attitudes toward the **RELEVANCE OF PHYS/MATH** improve from before to after second-semester IPLS, and are maintained a year later.

PRE-2nd SEMESTER IPLS POST-2nd SEMESTER IPLS 1 YEAR LATER

PHYSICS RELEVANCE (N = 19, matched)

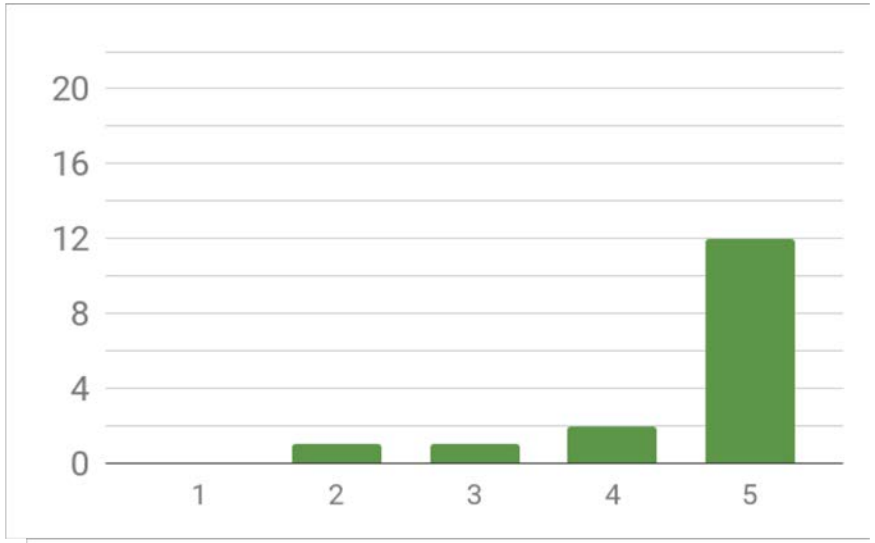


MATH RELEVANCE (N = 19, matched)



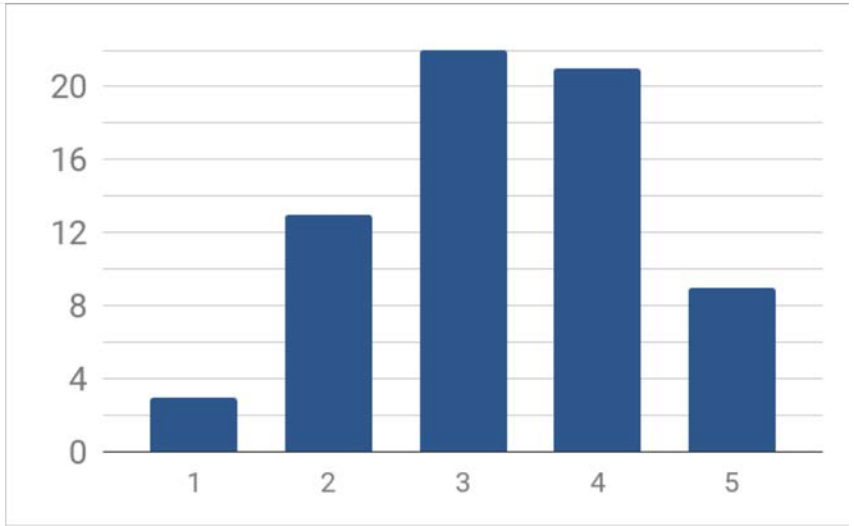
Attitudes toward **RELEVANCE OF PHYSICS** are more positive among IPLS students than non-IPLS students at the start of post-IPLS biology courses.

IPLS ($N = 4$)



$\mu = 4.6 \pm 0.4$

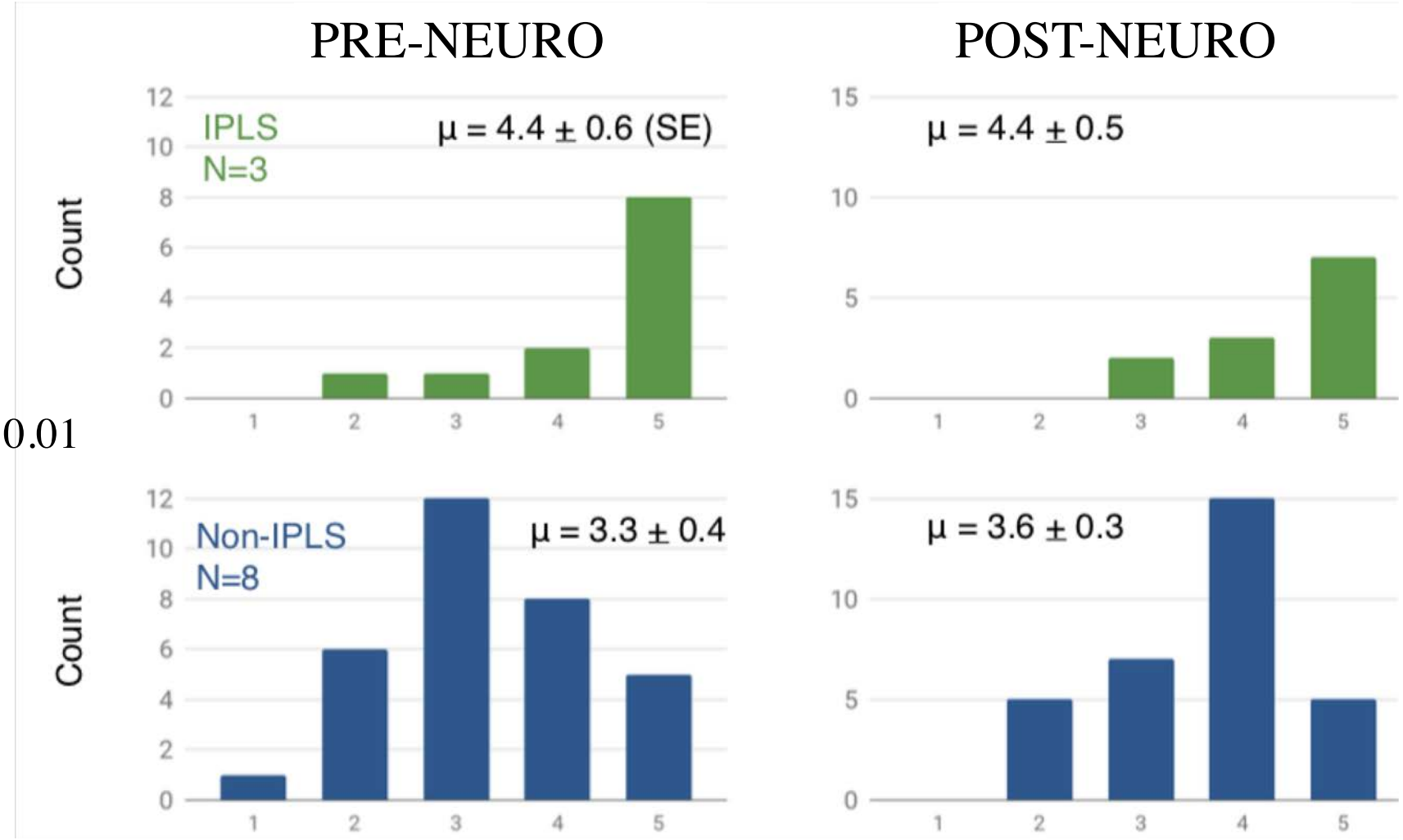
non-IPLS ($N = 17$)



$\mu = 3.3 \pm 0.3$

$p < 0.001$

Attitudes toward the **RELEVANCE OF PHYSICS** improve for non-IPLS students during the biology courses, but not to IPLS levels.



$p < 0.01$

$p = 0.013$

Similar results for pre-post survey responses in Animal Physiology and Cell Biology.

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Core methodological challenge I:

How much input *should the IPLS instructors/research team have in designing the embedded tasks in biology courses?*

LESS INPUT **MORE INPUT**

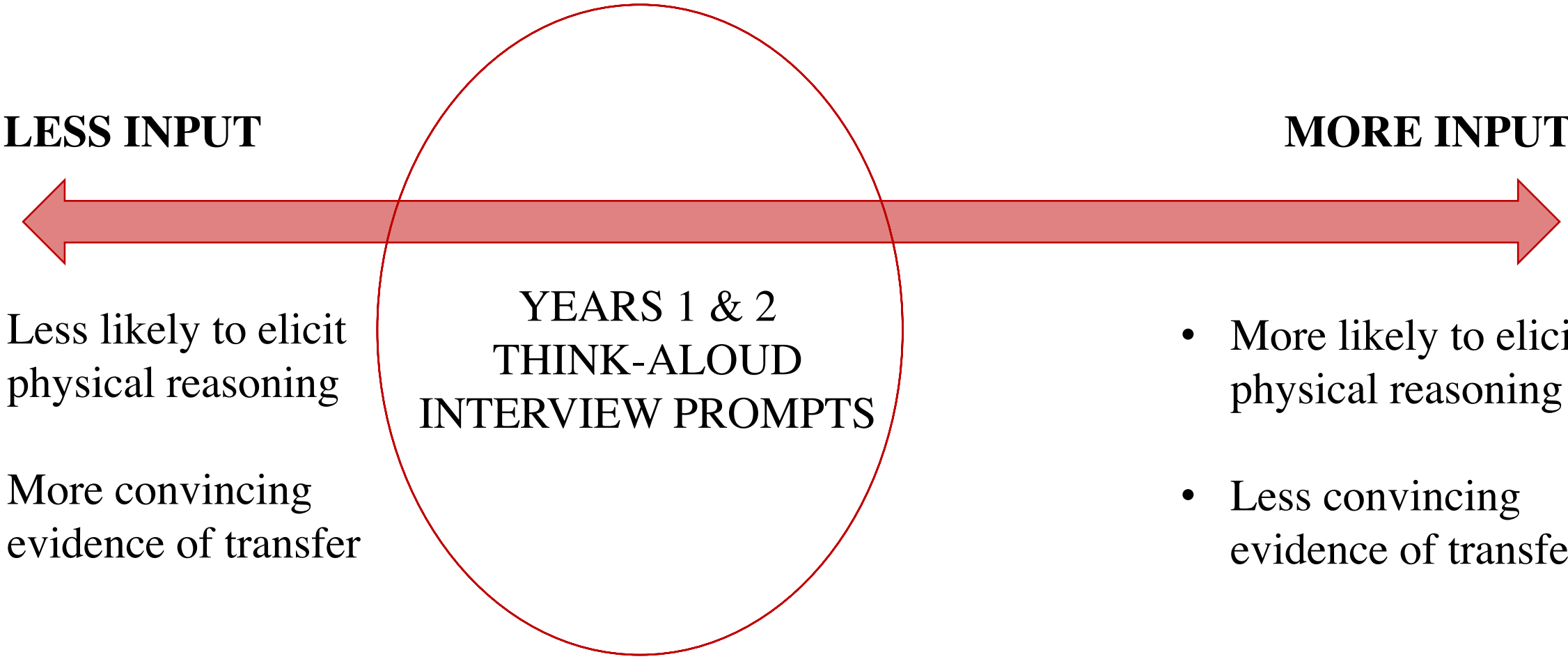
- Less likely to elicit physical reasoning
- More convincing evidence of transfer

YEARS 1 & 2
EMBEDDED TASKS
(Designed by Bio instructors)

- More likely to elicit physical reasoning
- Less convincing evidence of transfer

Core methodological challenge I:

How much input *should the IPLS instructors/research team have in designing the embedded tasks in biology courses?*



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- More likely to elicit physical reasoning
- Less convincing evidence of transfer

Core methodological challenge I:

How much input *should the IPLS instructors/research team have in designing the embedded tasks in biology courses?*

LESS INPUT **MORE INPUT**

- Less likely to elicit physical reasoning
- More convincing evidence of transfer

YEARS 2 & 3
Transfer task within the intro physics course itself

- More likely to elicit physical reasoning
- Less convincing evidence of transfer

Core methodological challenge II:

*How does one look for interdiscip. learning in courses for **which physics is not required**, but in which the topics lend themselves to physical reasoning?*

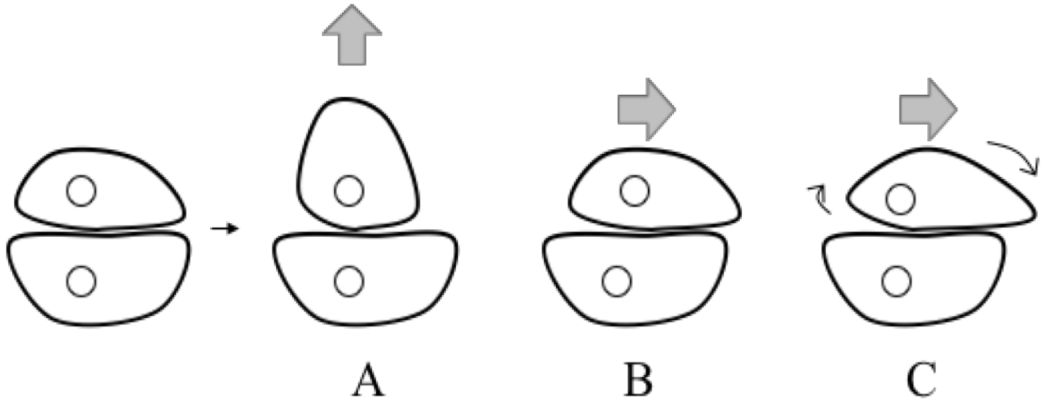
- Analyzed data in a manner that tried to **disentangle value gained from IPLS** from what the course instructor teaches/conveys in the biology course itself.

- Developed **emergent coding schemes** for detecting presence or absence of (usually unprompted) physical reasoning.

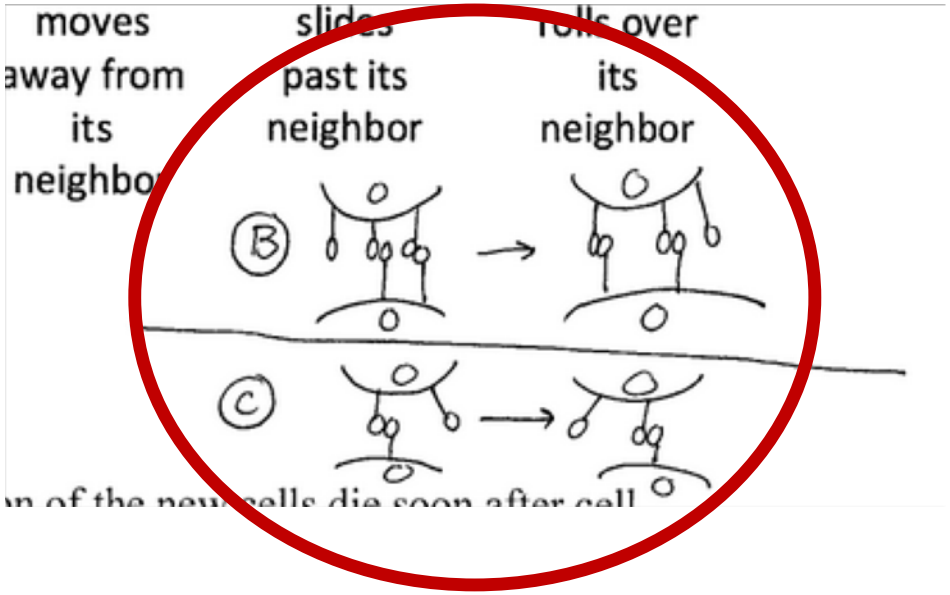
- When possible, sought to develop codes that **do not evaluate correctness**.

[from Cell Adhesion Problem in Cell Biology]

How would you model this mechanical resistance? Rank from greatest to least resistance.



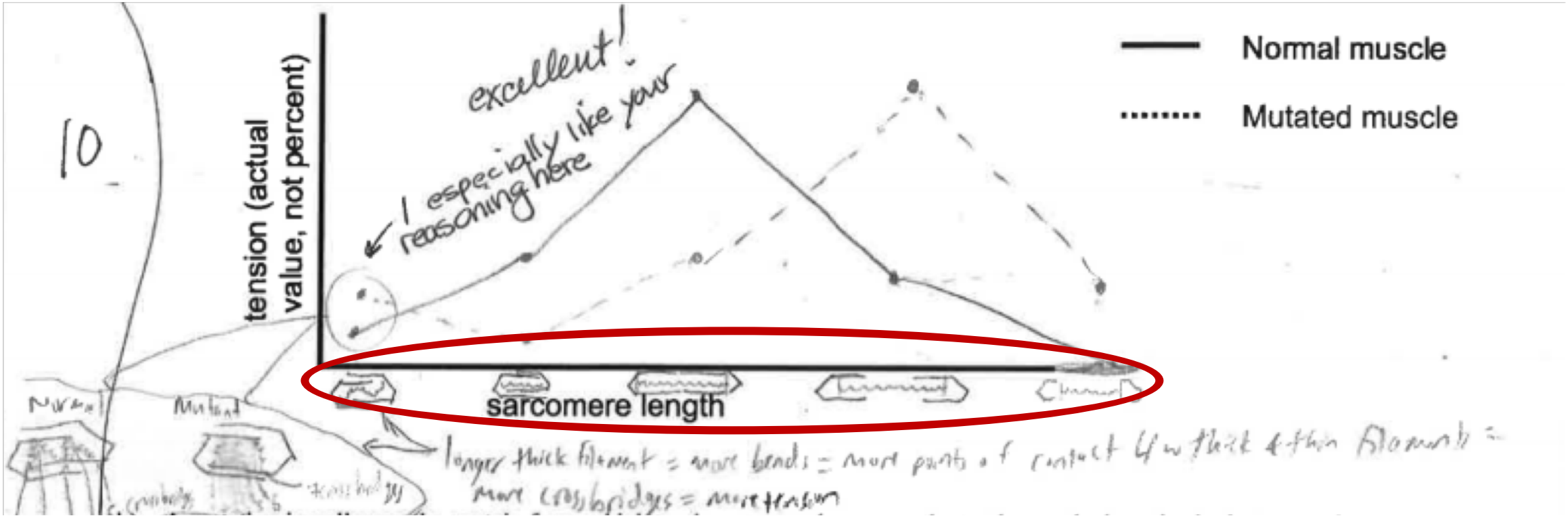
Cell adhesion



This student's work includes multiple detailed diagrams (unprompted) that account for individual cadherin-cadherin interactions.

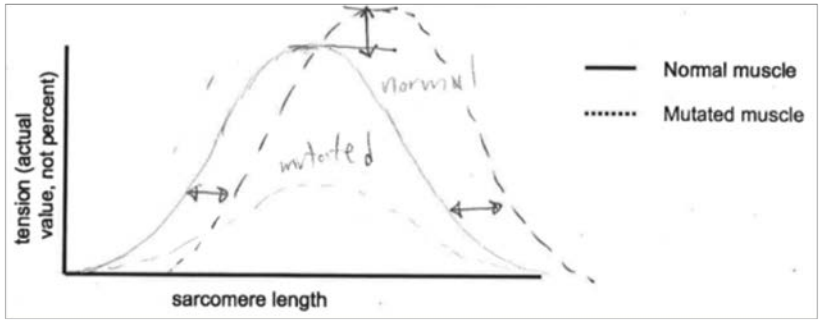
[from Skeletal Muscle Function Problem in Animal Physiology]

What will be the effect of a specific mutation on the length-tension curve for a sarcomere?

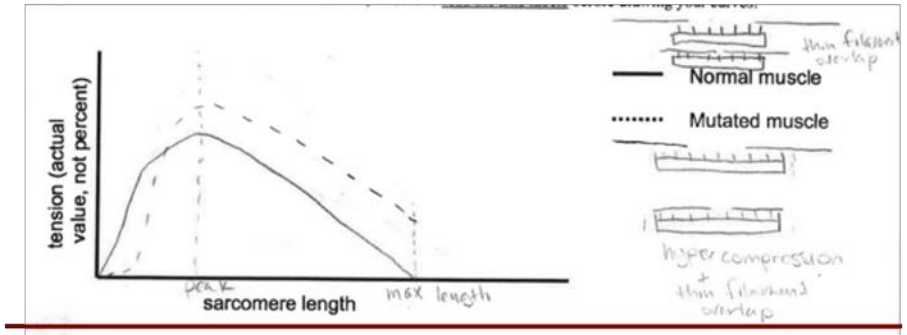


Coding of written work:
Example from Animal Physiology F17

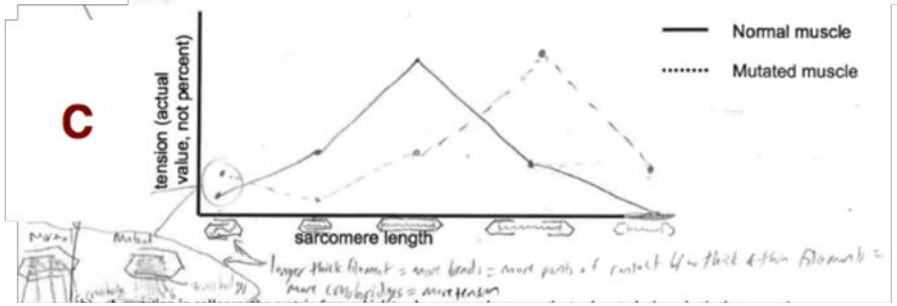
A



B



C



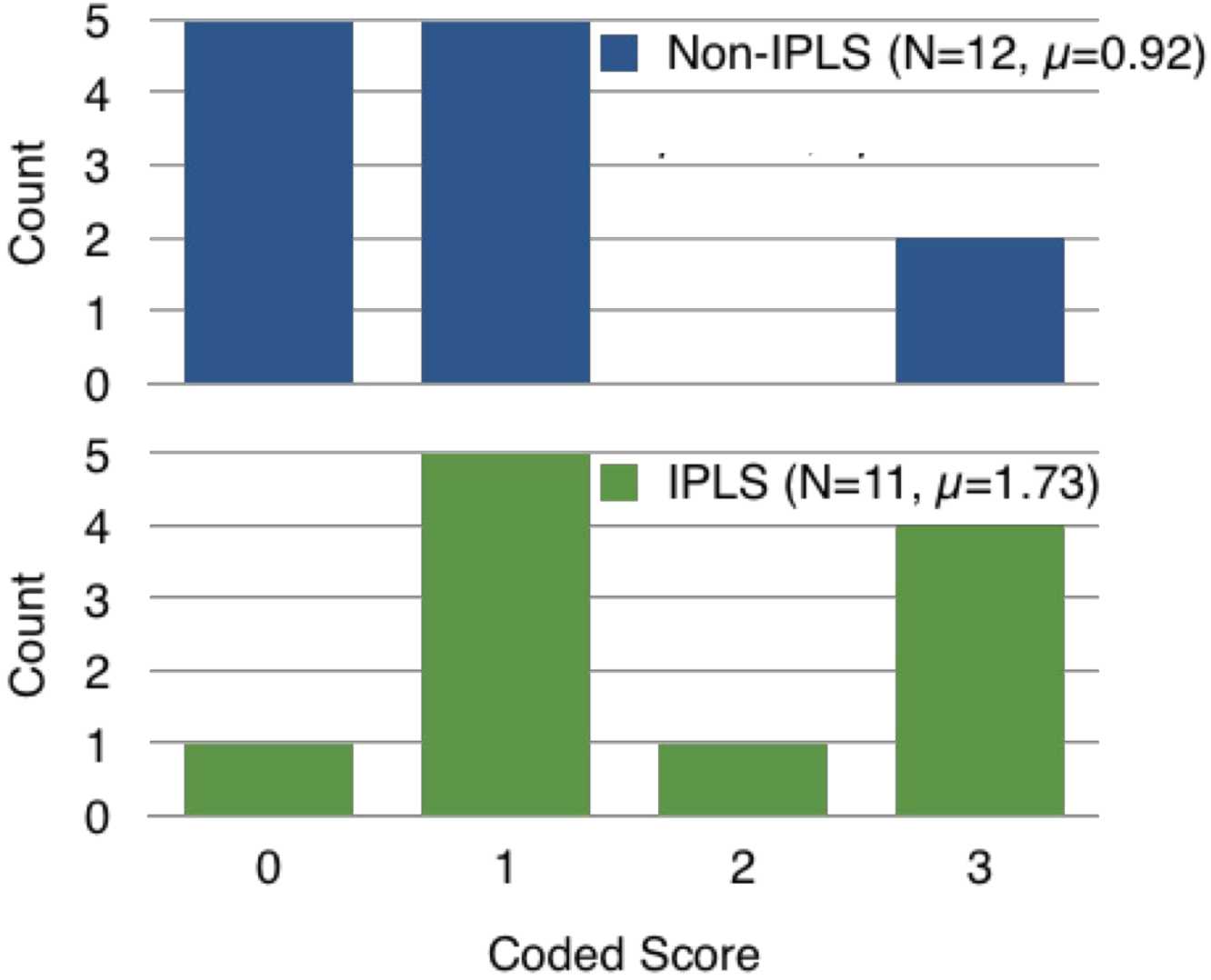
Codes

- Description of changing parameters
- Diagram of muscle in different configurations
- Graph accounts for buckling
- Graph labeled

CODE

STUDENT	Description	Diagram	Buckling	Label
A (None)	✗	✗	✗	✗
B (Trad.)	✗	✓	✓	✓
C (IPLS)	✓	✓	✓	✓

Physical Reasoning:
Single task (from Neurobiology S18)



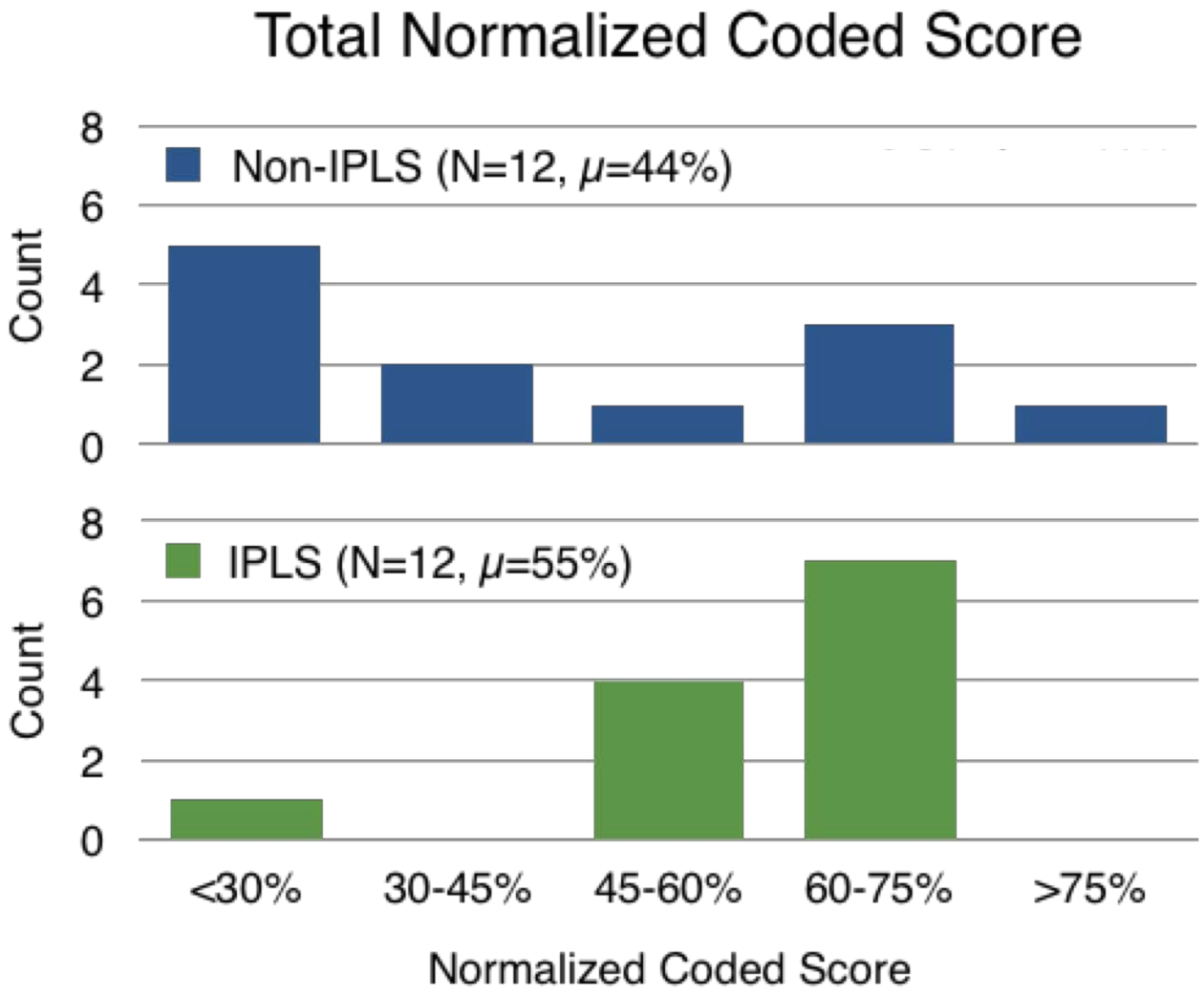
$p = 0.10; \Delta\mu = +0.81$

p-values were determined using a rank-sum test (also called a Mann-Whitney *U* test or Wilcoxon test). This test was chosen because it is suitable for non-parametric data and small sample sizes.

Non-IPLS:

- > 75% no Swarthmore physics
- < 25% traditional physics at Swarthmore

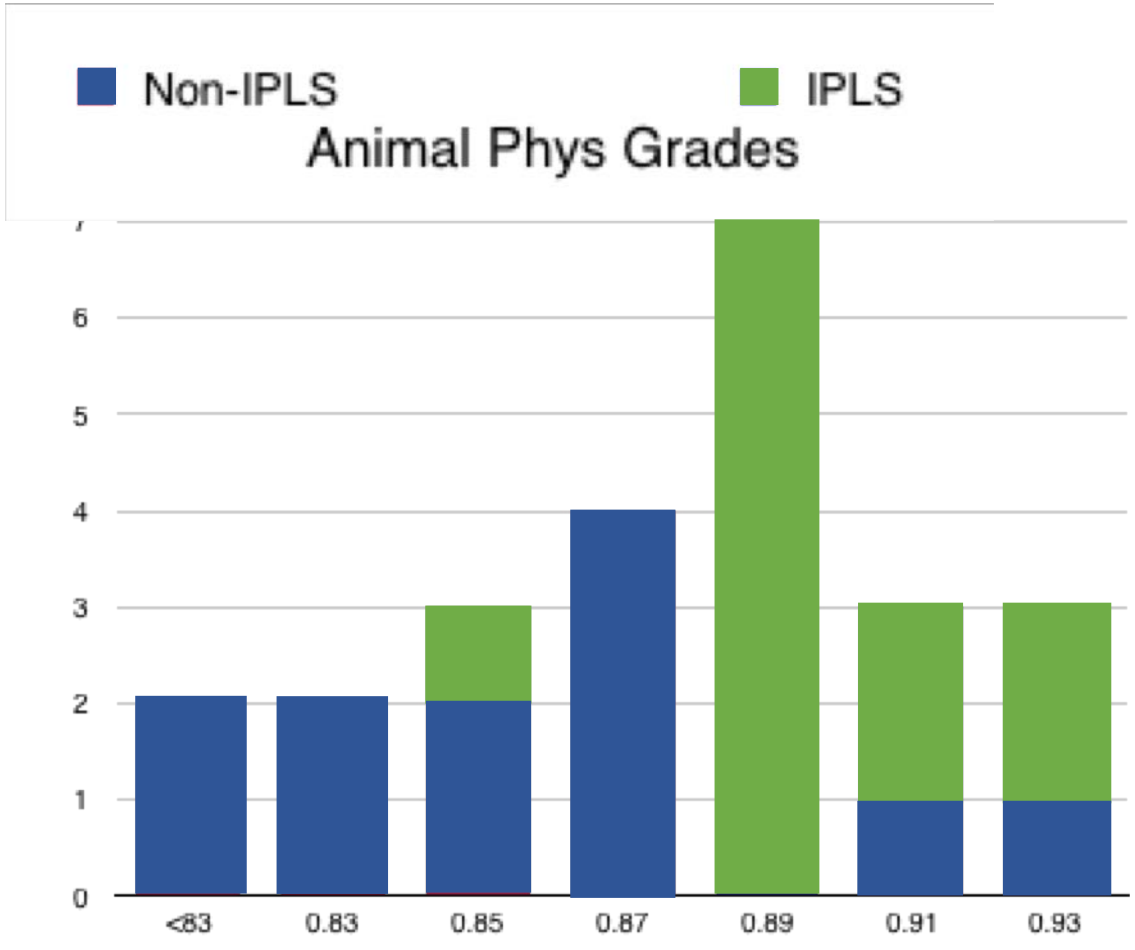
Physical Reasoning:
All tasks (from Animal Physiology F17)



$p = 0.31; \Delta\mu = 11\%$

Similar (small) effects seen for coding of tasks in neurobiology and biochemistry courses.

Grades: The IPLS student group earned higher Animal Physiology grades (F17) than did Non-IPLS student group



$p = 0.04; \Delta\mu = 4\%$

- The IPLS student grade distribution in our sample matches that of all IPLS students.
- The IPLS students also do not seem to be "better biology students," as measured by intro Bio grades.
  - No correlation exists between IPLS *grades* and Animal Physiology grades.
    - No such correlation exists with Neurobiology grades

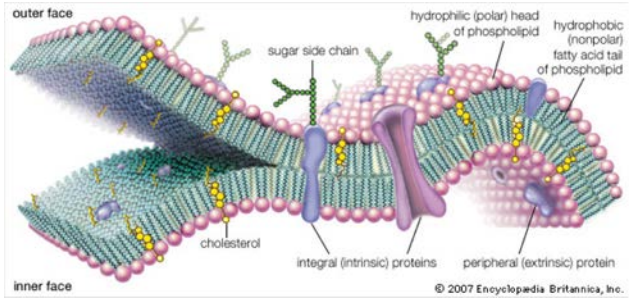
Embedded task results summary

- For all embedded tasks analyzed, the mean coding score for IPLS students was equal to or higher than that of non-IPLS students
- Trends strongly suggest correlation between IPLS and physical reasoning
- Larger sample size needed for statistical significance in many cases

Core methodological challenge III:

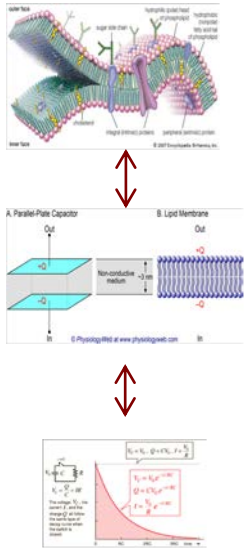
How does one assess interdisciplinary learning in courses which ***present content differently*** *than IPLS, and include* ***different messaging****?*

➢ Content and terminology



ΔV (IPLS) -vs- V_m (Neurobiology)

➢ Messaging



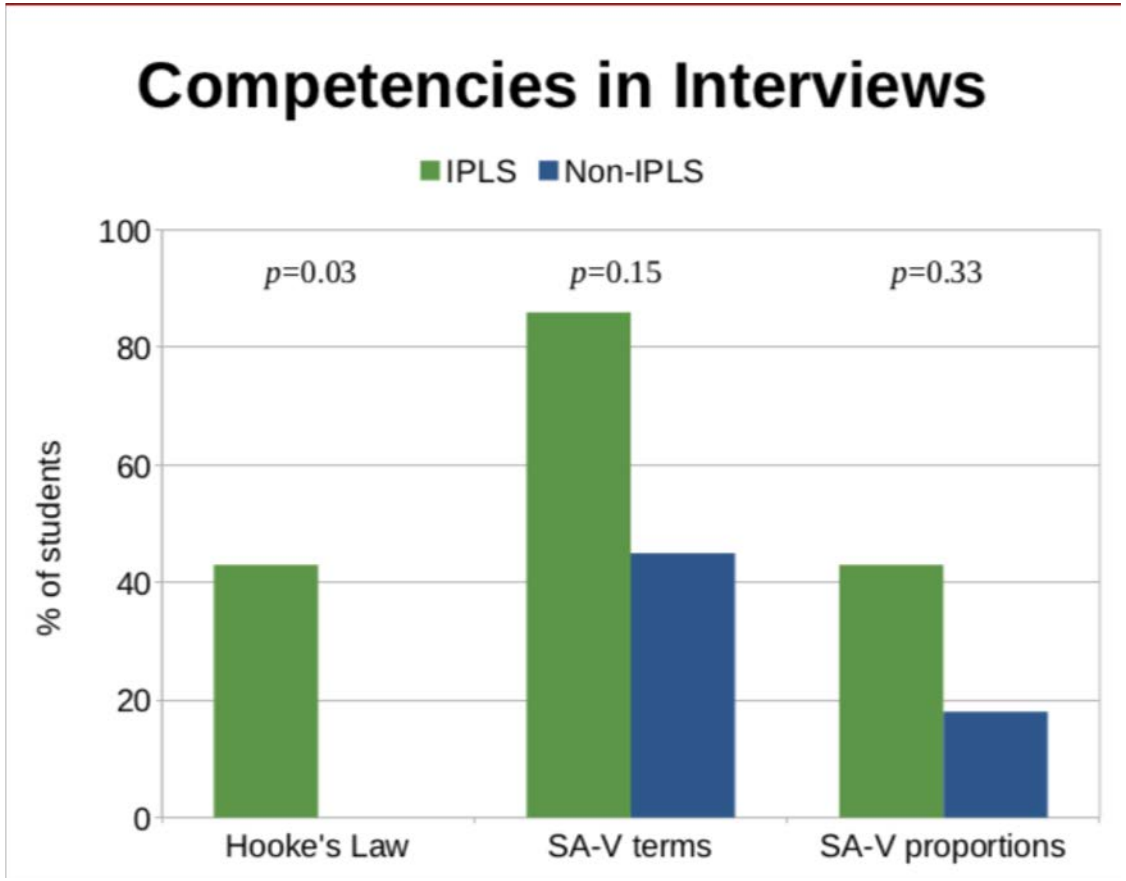
Repeatedly and explicitly emphasized (IPLS)

-vs-

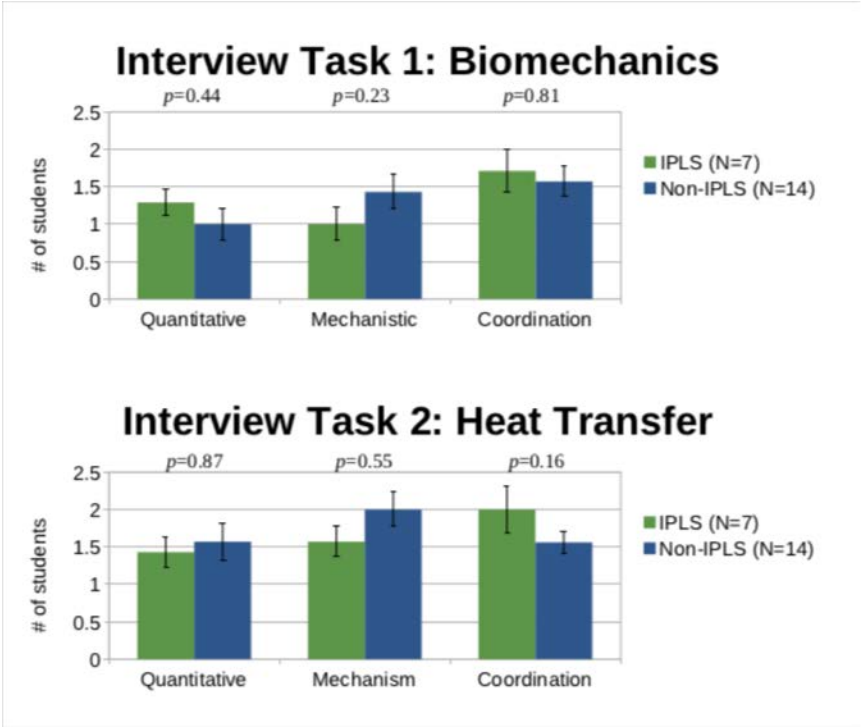
Modeled by example, but not discussed explicitly; qualitative reasoning given primacy (Neurobiology)

Both written embedded tasks and think-aloud interviews made this challenge evident…

In think-aloud interviews, Animal Physiology (F18) students who had taken IPLS showed signs of greater competency with some particular aspects of physics…



… but it is a complicated story.



Key methodological lesson learned:

Iterative communication, not just at the curriculum design stage, but also at the assessment stage.

- *Must be prepared for the types of responses that students are likely to give.*
- *What seems to us like a prompt that calls for simple physical models may seem to a student like a prompt that calls for a detailed biological explanation.*

Talk Outline

- Motivation for a Pilot Longitudinal Study at Swarthmore

- Preliminary Results from Years One and Two of the Study
  - What attitudes do students express?
  - What skills do students exhibit?
    - ❖ Core methodological challenges encountered in assessing skills

- **Preliminary Conclusions and Unanswered Questions**

Preliminary Conclusions

- Strong evidence that **attitudes toward the relevance of physics and math improve during the IPLS course, and are maintained after leaving the course**. Some but not all of these attitudinal gains can be achieved in the biology courses themselves.

- There are **indications that IPLS students exhibit more competency** with physical modeling and coordination between representations than do their non-IPLS peers, but we need a larger *N* to confirm this.

- Even for an IPLS course that was inspired by the content of IPLS students' biology courses, it is **essential that distinctions between learning environments be taken in to account when planning assessments** of interdisciplinary learning.

Unanswered Questions: The role of context

- How do the **prompts** in embedded tasks and think-aloud interviews, and the **perspectives that students bring to those prompts**, influence our ability to see a signal of interdisciplinary reasoning?

- Do traditional and IPLS intro physics students perform differently on transfer tasks given **at the end of the intro physics course**?

This was the first half of a pilot study…

We are very open to thoughts and suggestions for improvement!

Thank you!


Jonathan Solomon ’20


Nathaniel Peters ’18


Haley Gerardi ’17


Aqil MacMood ’20

- **Nathaniel, Aqil, and Haley are all giving talks this afternoon in Session CB.**
- **We will also have posters at PERC on Wednesday!**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