Beyond Assessing Knowledge: Card Sorting, Superheroes, and Moving Towards Measuring Biological Expertise

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San Francisco State University

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SEPAL

The Science Education
Partnership & Assessment Lab
San Francisco State University

Meet a New Colleague!

Share with a person near you that you do NOT already know…

1. **Your name**

2. **Your institution and department**
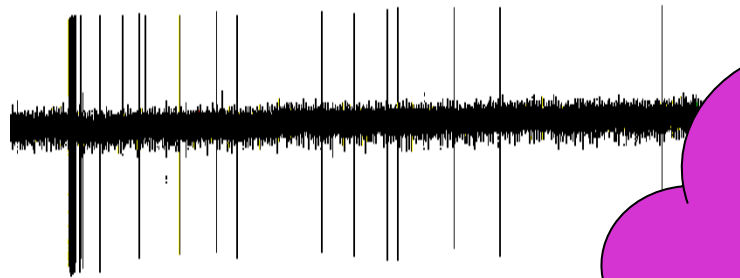
3. **What the term "assessment" means to you…**

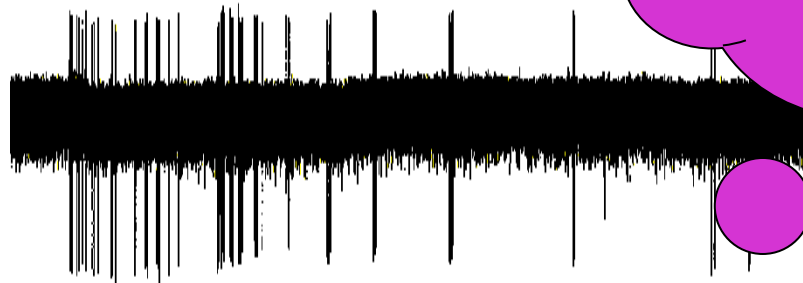# From Neurobiology Research to Biology Education Research…

Neurophysiology:
Single Unit Recording in Peripheral Nerve

Anatomy:
Electron Microscopy

Control condition

Neuropathic condition

And who are you?!?!

Journal of Neuroscience, 1998
Neuroscience, 2002

Journal of Comparative Neurology, 1998
Journal of Comparative Neurology, 2000

SEPAL: The Science Education Partnership and Assessment Laboratory

SEPAL

The Science Education
Partnership & Assessment Lab
San Francisco State University

(≈ The Tanner Lab)

Founded in 2004…

- **Programs**
- **Coursework**
- **Research**

Ideas that Drive SEPAL Research

- Twice as many undergraduates leave the sciences as the humanities

- Women and scientists of color continue to be underrepresented in the sciences

- Few scientists have formal training in teaching

- Research in biology education lags behind other science disciplines

TALKING ABOUT LEAVING

Why Undergraduates Leave the Sciences

ELAINE SEYMOUR and NANCY M. HEWITT

- **There is a dearth of research on how students' ideas are changing (or not) about biology during their undergraduate education?**
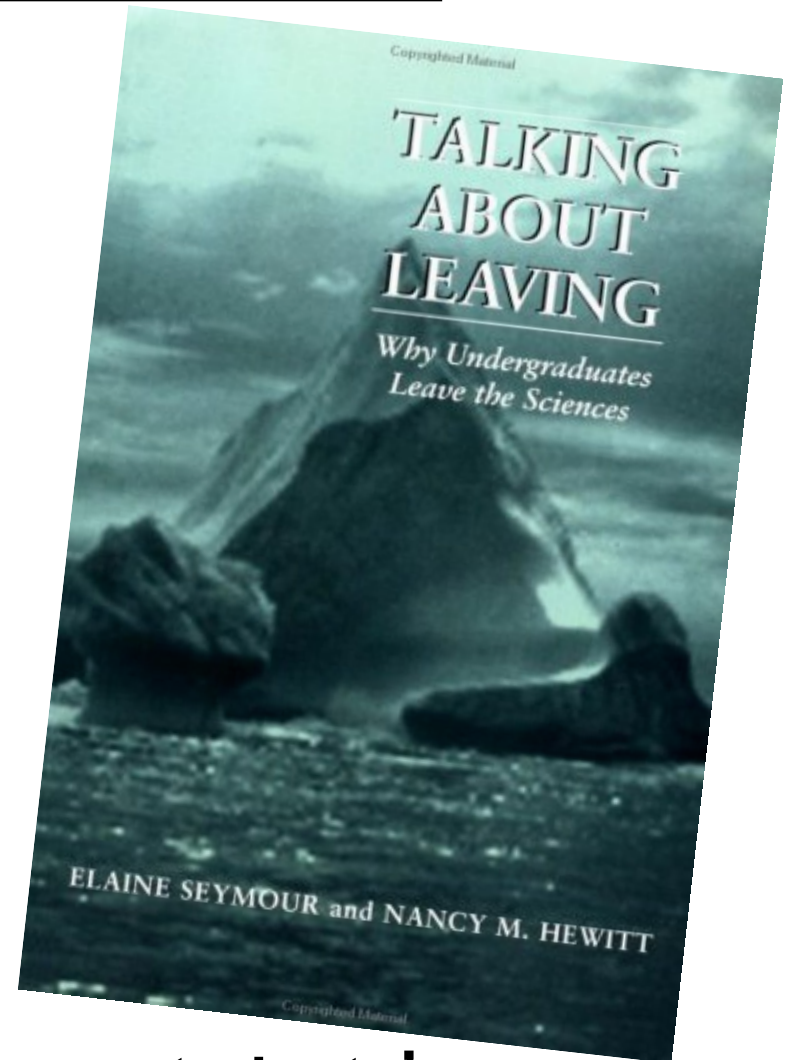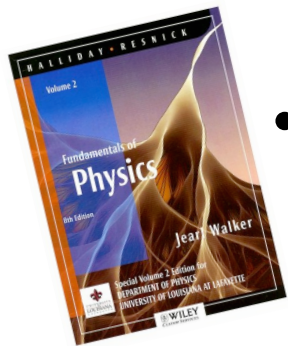
- **About the problem of measuring how students develop expertise in a discipline**
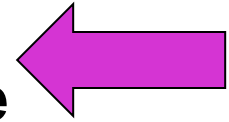
- **A common experience using card sorting to probe expertise**

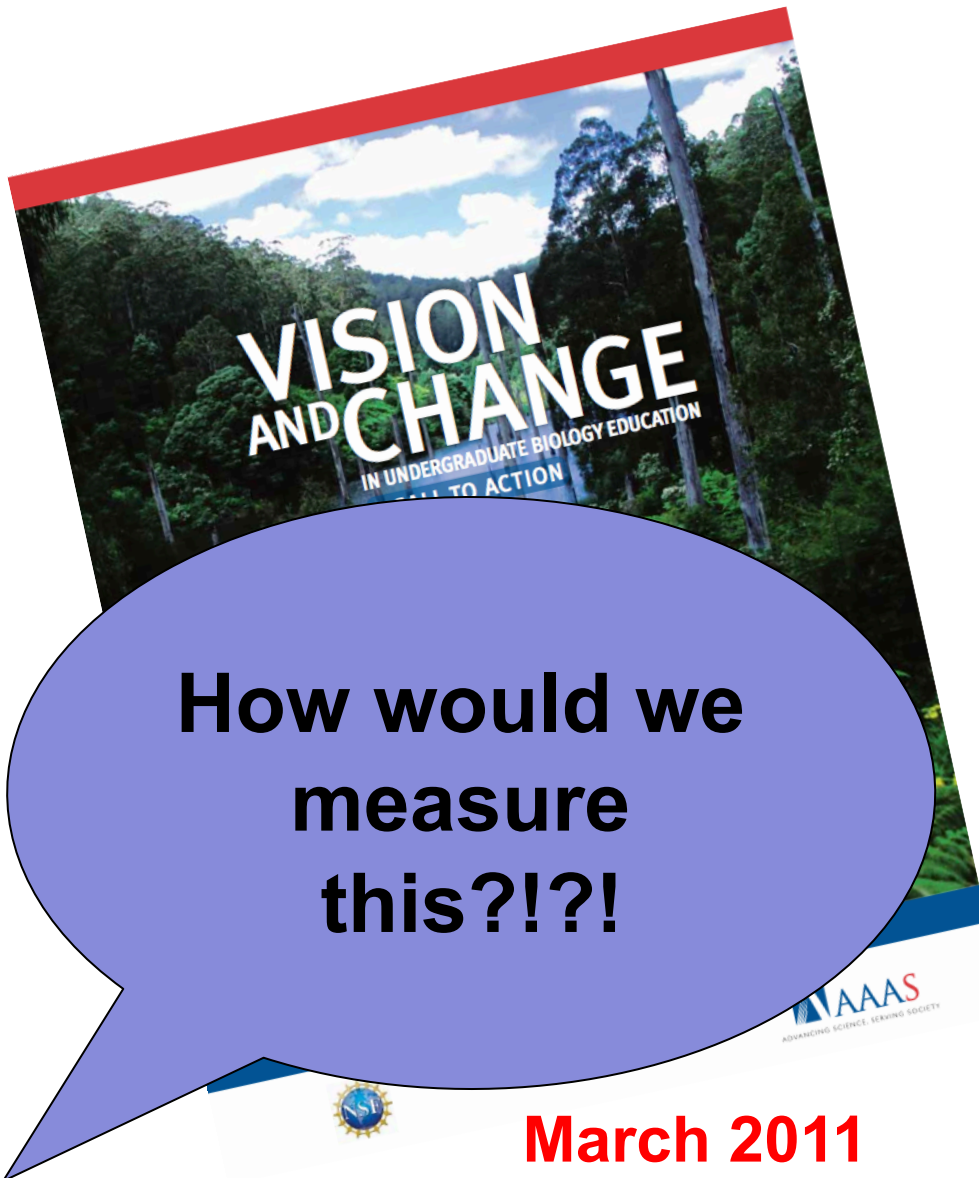- **A piece of card sorting history from cognitive psychology**

- **The development of a novel card sorting task to measure biology expertise**

- **Questions, comments, and continuing conversations…**

What do we expect undergraduates to be able to do as a result of their undergraduate biology education?

How would we measure this?!?!

March 2011

"Biology in the 21st century requires that undergraduates learn how to integrate concepts across levels of organization and complexity and to synthesize and analyze information that connects conceptual domains."
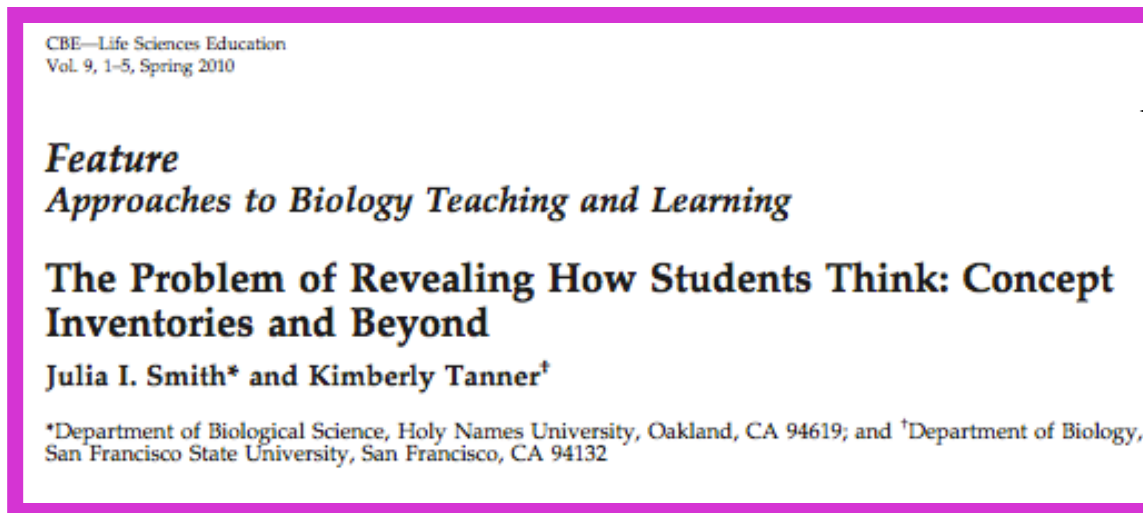
Thinking Like a Biologist…

To what extent do current measurement approaches yield insight into the development of *Thinking Like a Biologist*?

Exams and Quizzes…

Concept Inventories...

CBE—Life Sciences Education
Vol. 9, 1–5, Spring 2010

Feature
Approaches to Biology Teaching and Learning

The Problem of Revealing How Students Think: Concept Inventories and Beyond

Julia I. Smith* and Kimberly Tanner[†]

*Department of Biological Science, Holy Names University, Oakland, CA 94619; and [†]Department of Biology, San Francisco State University, San Francisco, CA 94132

Unclear if these tools measure *Thinking Like a Biologist…*

- *Open-ended written assessm...*
- *Videotaped interviews*

All appear to be limited to measuring SLICES or PIECES of knowledge…

And then an insight came from analyzing interview data…

Student Interviews: "The greenhouse effect can be made smaller by planting trees."
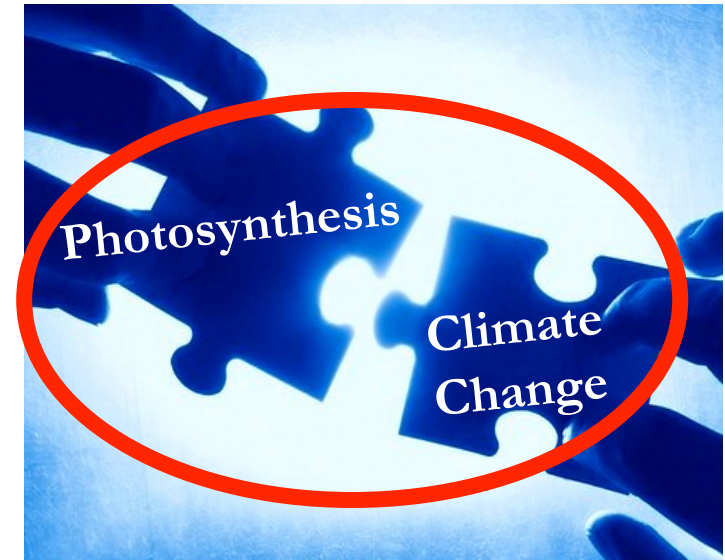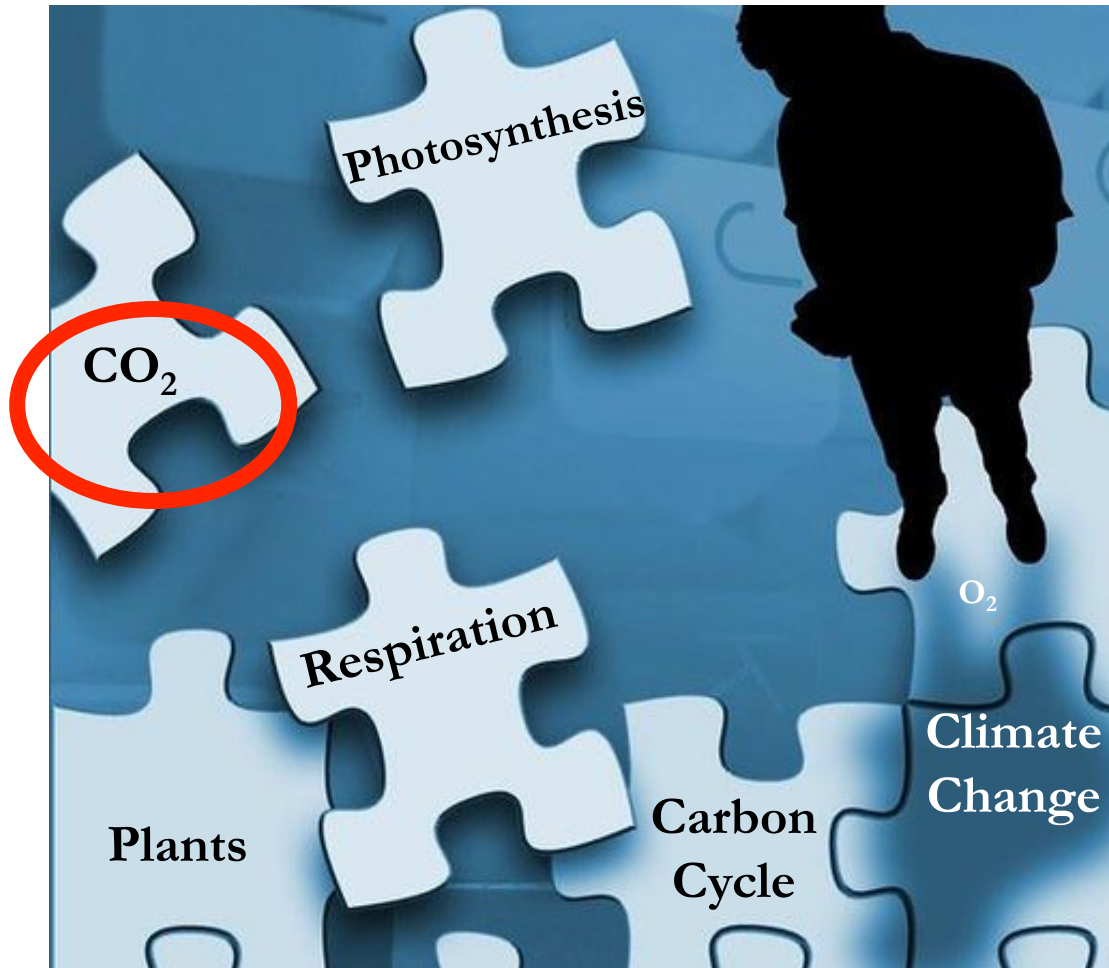
...not happening

Perhaps we should be measuring the *STRUCTURE of knowledge… the CONNECTIONS between the pieces!*

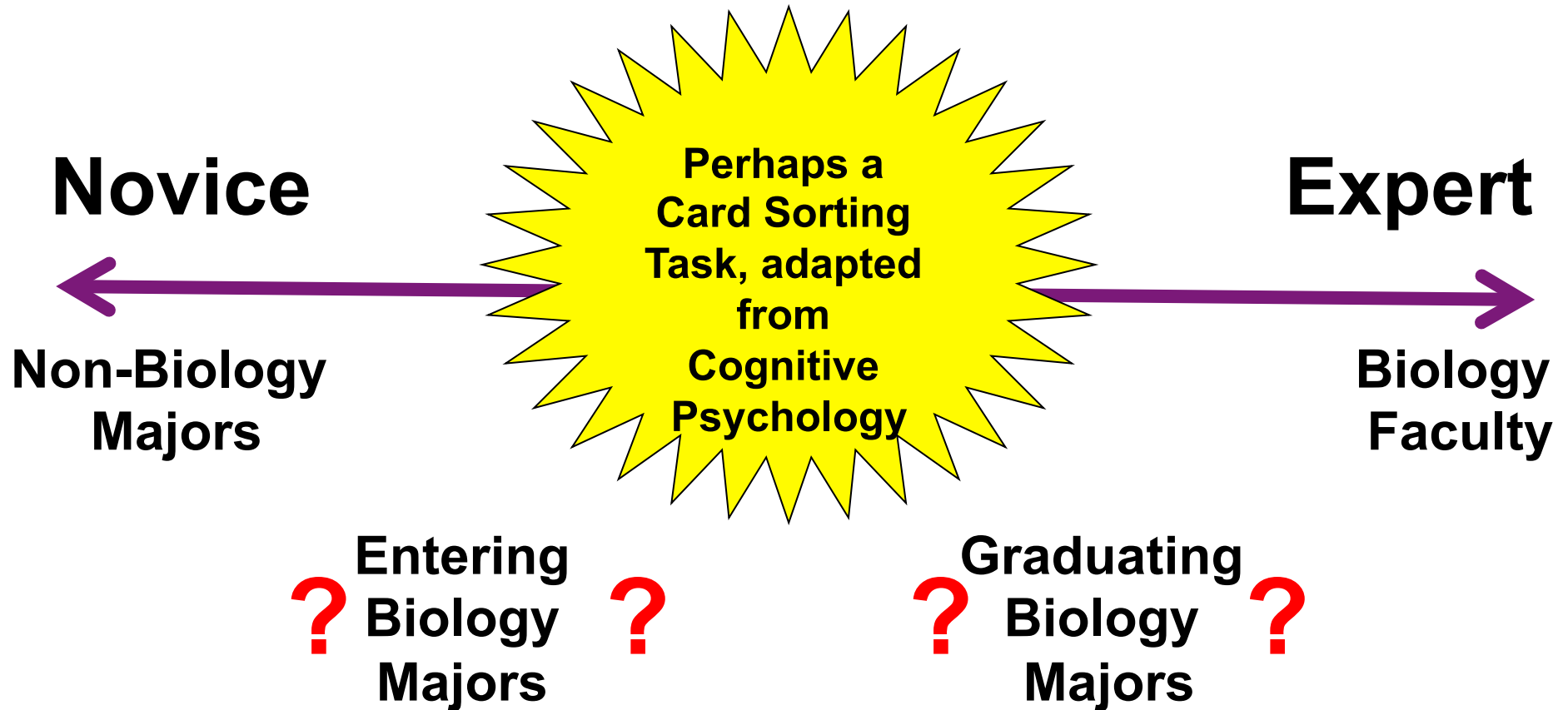In cognitive psychology, EXPERTISE is about the STRUCTURE of experts' knowledge.

# So, how might we probe expertise – the structure of biology knowledge, the connections between the pieces – among biology majors?

Novice

Non-Biology Majors

Perhaps a Card Sorting Task, adapted from Cognitive Psychology

Expert

Biology Faculty
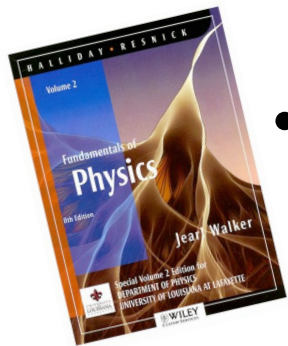
? Entering Biology Majors ? Graduating Biology Majors ?

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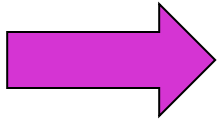
- A common experience using card sorting to probe expertise

- A piece of card sorting history from cognitive psychology

- The development of a novel card sorting task to measure biology expertise

- Questions, comments, and continuing conversations…

A Common Experience with Card Sorting…

Card Sorting Task

- With your partner, remove the cards from your envelope.

- Together, sort these 9 cards into groups based on…

  a fundamental organization of superheroes

- The only guidelines are that…
    - each card must belong to only one group
    - your team must have at least 2 & less than 9 groups

- Once you have formed your groups, decide on a name that for each group that reflects why you put them together.

- Happy card sorting!

What Were Some of Your Approaches to Sorting Superheroes?

How Do Superhero Novices Sort?

Robot Type

Flying Type

Animal Type

Iron Man

Novices sort based on PHYSICAL APPEARANCE…

Hypothesized "SURFACE FEATURES"

This is just one of likely many novice approaches…

How Do Superhero Novices Sort?

Robot Type

Flying Type

Animal Type

Iron Man

How does it feel to…
– *be a novice?*

– *be labeled a novice?*

– *organize your ideas differently than the "instructor?"*

This is just one of likely many novice approaches…

How Do Superhero Experts Sort?

The Avengers   **Justice League**   **X-Men**

Iron Man

Experts sort based on
SUPERHERO TEAMS…

Hypothesized "DEEP FEATURES"

How Do Superhero Experts Sort?

Marvel Comics   **DC Comics**   **Marvel Comics**

Iron Man

Or sometimes based on **PUBLISHING COMPANY…** an ****UNHYPOTHESIZED**** *"DEEP FEATURE"*

How Do Superhero Novices Sort?

Robot Type

Flying Type

Animal Type

Iron Man

To what extent do we make our expert frameworks in biology explicit to students in our classrooms?

How do we do this?

This is just one of likely many novice approaches…

How Do Superhero Experts Sort?

Marvel Comics   DC   Marvel Comics

STRUCTURE
of an individual's
CARD SORT
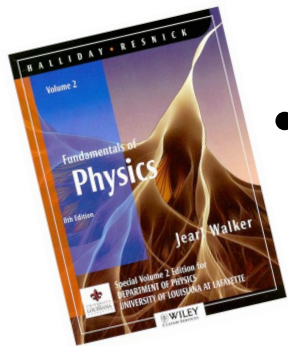may reflect
something about…

STRUCTURE of their
KNOWLEDGE…
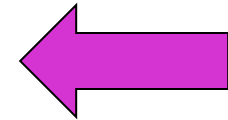
and the development of
EXPERTISE…

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- Questions, comments, and continuing conversations…

Cognitive Psychologists Use Card Sorts to Study the Expertise in a Variety of Fields

Categorization and Representation of
Physics Problems by Experts
and Novices*

MICHELENE T. H. CHI

PAUL J. FELTOVICH

ROBERT GLASER

University of Pittsburgh

Cited thousands of times since published in 1981

Dr. Michelene Chi
Arizona State University

Chi and Colleagues Developed a Card-Sorting Task to Characterize Physics Expertise

Card Sorting Task

- Selected 24 problems from Halliday & Resnick's (1974) *Fundamentals of Physics*
- Copied problems on to cards
- Subjects asked to sort into groups based on similarity of solution
- Conducted as a think-aloud interview
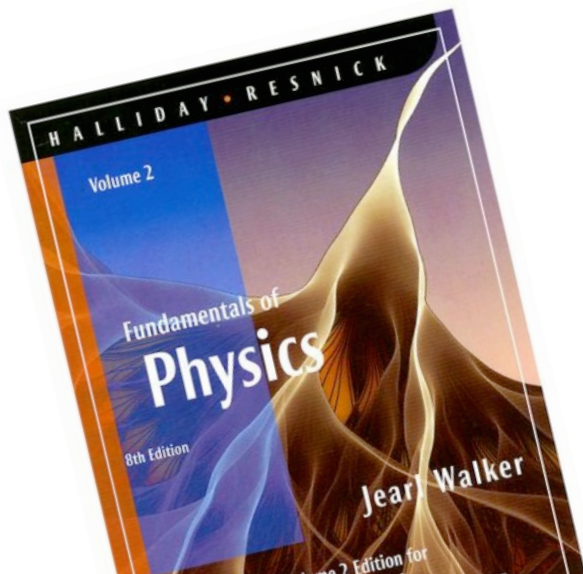
Subjects

- 8 Novices (undergraduates who completed Mechanics)
- 8 Experts (advanced physics PhD students)

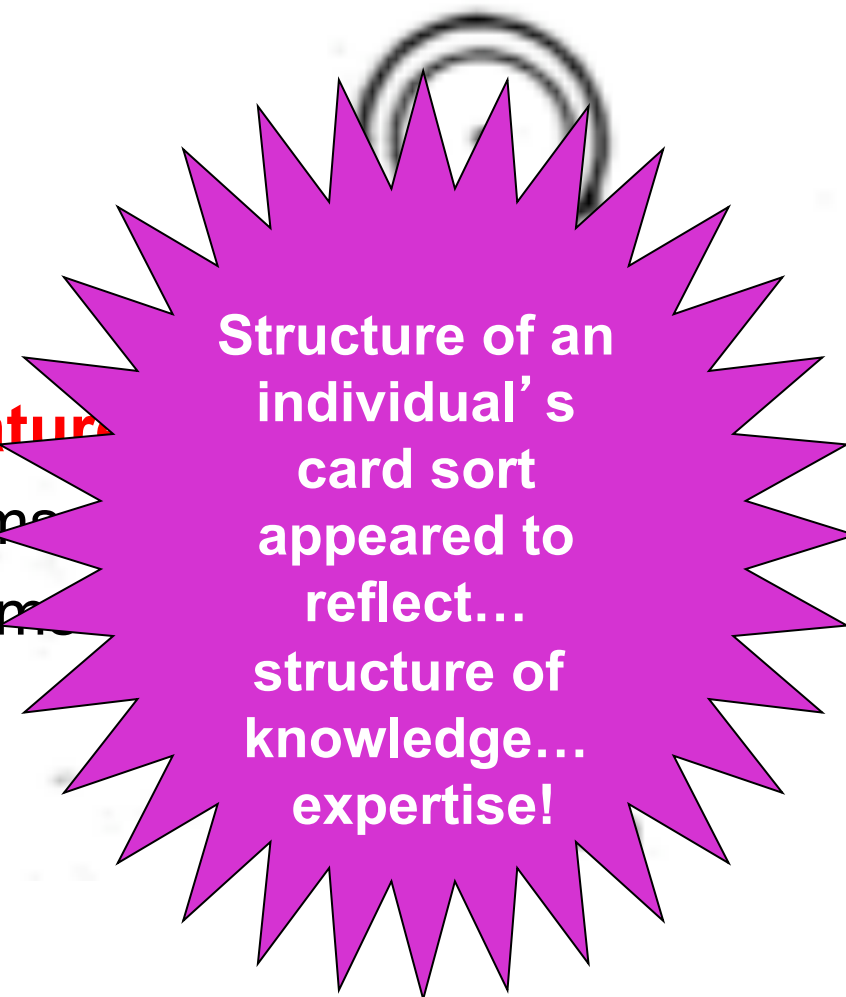# Physics Novices and Physics Experts Sorted Physics Problems Differently

Novices Sorted on "Surface" Features

- Pulley problems
- Incline plane problems
- Friction problems

Experts Sorted on "Deep" Features

- Newton's Second Law Problems
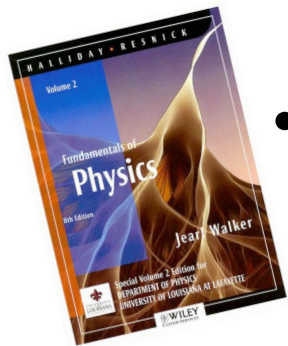- Conservation of Energy Problems
- Work-Energy Problems

Structure of an individual's card sort appeared to reflect… structure of knowledge… expertise!
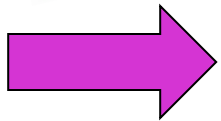
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Could we use a card-sorting task to probe the structure of biology knowledge? expertise?

Hypothesized Novice "Surface" Features in Biology

- Organism type: e.g. insects, humans, plants, etc.

Hypothesized Expert "Deep" Features in

- **Fundamental Biological Principles**

    - Evolution and natural selection

    - Pathways and transformation of energy and

    - Relationships between structure and function

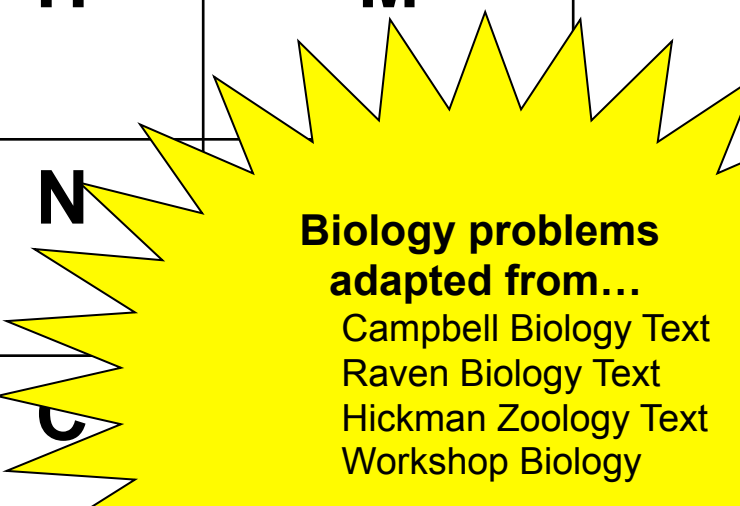   - Storage and passage of information in living systems

Deep features aligned with big ideas for…

- New AP Biology
- Vision & Change

Constructed Card Stimulus Set Representing both Surface and Deep Features in Biology

	Pathways and transformation of energy and matter	Storage and passage of Information about how to build and operate living	Evolution and natural selection	Relationships between structure and function
	HYPOTHESIZED DEEP FEATURES			
Plant	D	J	K	I
Insect	F	B	H	M
Human	L	O	N	
Micro-organism	A	E	C	

HYPOTHESIZED SURFACE FEATURES

Biology problems adapted from…
Campbell Biology Text
Raven Biology Text
Hickman Zoology Text
Workshop Biology

Sample Card…

A

A glucose-fed yeast cell is moved from an aerobic environment to an anaerobic one. For the cell to continue generating ATP at the same rate, how would the rate of glucose consumption in this micro-organism need to change?

Hypothesized **Surface** Feature: **Micro-organism**

Hypothesized **Deep** Feature: **Pathways and transformation of energy and matter**

Research Design and Methods

Unframed Sort
(like Chi study)

Framed Sort

16 cards

⬇

2-15 groups, named by the individual

⬇

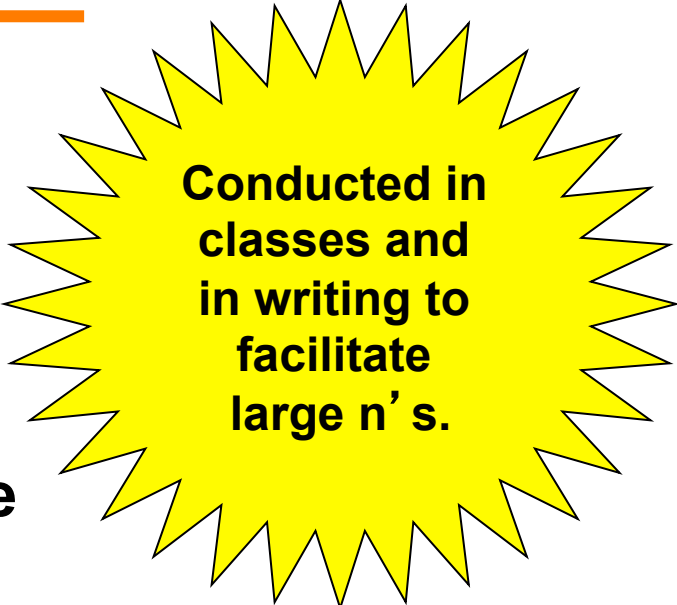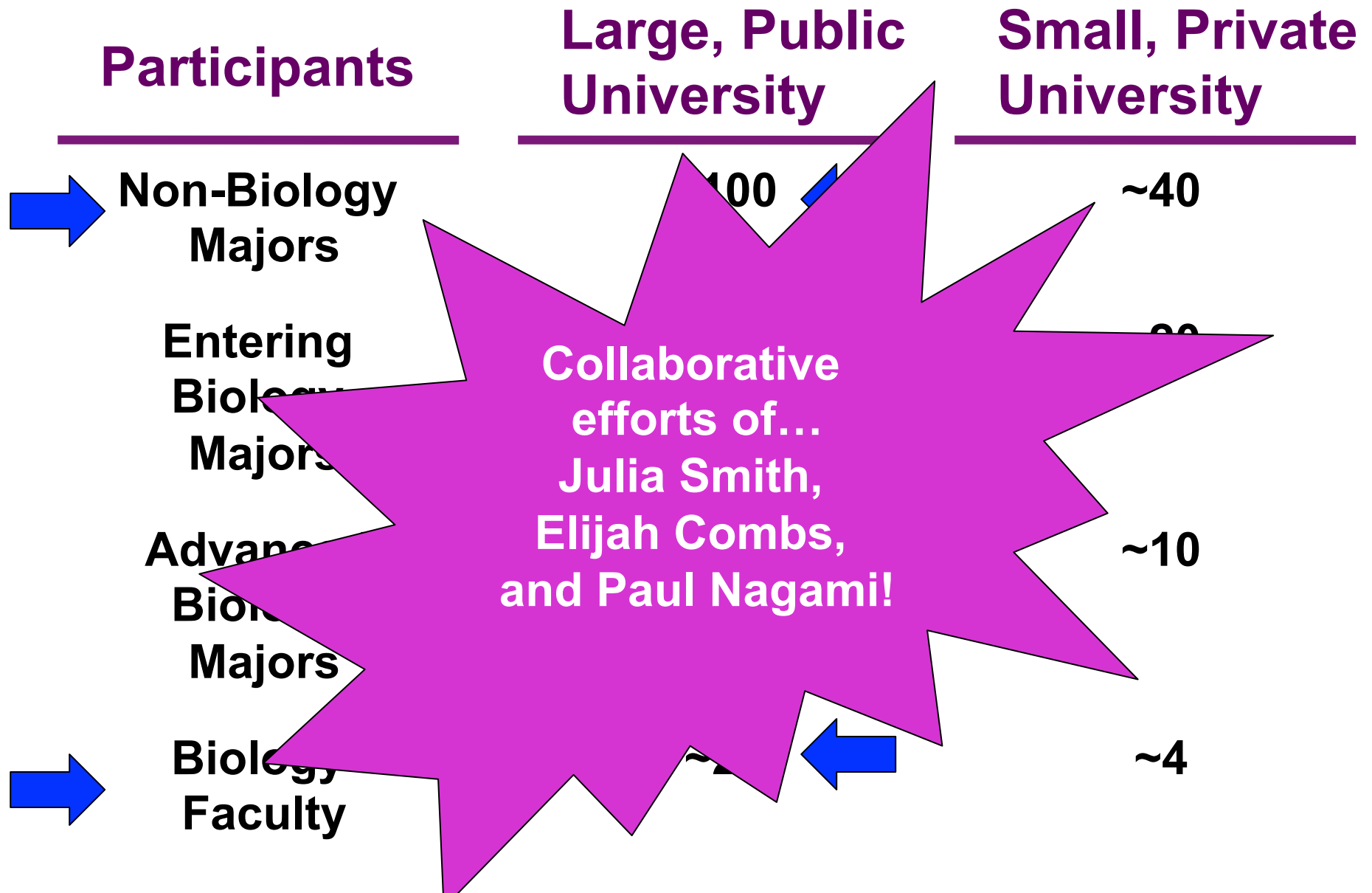Two reflection questions

16 cards

⬇

4 groups, named by the researchers

⬇

Two reflection questions

Conducted in classes and in writing to facilitate large n's.

Research Design and Methods

Participants	Large, Public University	Small, Private University
Non-Biology Majors	~100	~40
Entering Biology Majors		
Advanced Biology Majors		~10
Biology Faculty		~4

Collaborative efforts of…
Julia Smith,
Elijah Combs,
and Paul Nagami!

# What does the Unframed Sort data look like?

Biology Faculty

In the space provided below, please name the groups that you created and indicate the letters of each of the problems belonging to each group.

Metabolic Energy Flow

A, D, L, F

Artifical/Na...

Cell & Organismal Reproduction

B, E, J, O

Morphological Properties

P, M, G, I

Quantitative analysis of % of card pairs that are hypothesized deep vs. surface feature pairings.

Non-Biology Major Student

Start Time ___9:24___   Stop Ti...

In the space provided below, please name the... letters of each of the problem...

microorganism: A C E G

insects : B H M F

plant : D K J I

humans : P O N L

Finding #1: Biology Faculty Construct Significantly More Deep Feature Card Pairs and Fewer Surface Feature Card Pairs than Non-Biology Majors

Unframed condition

A
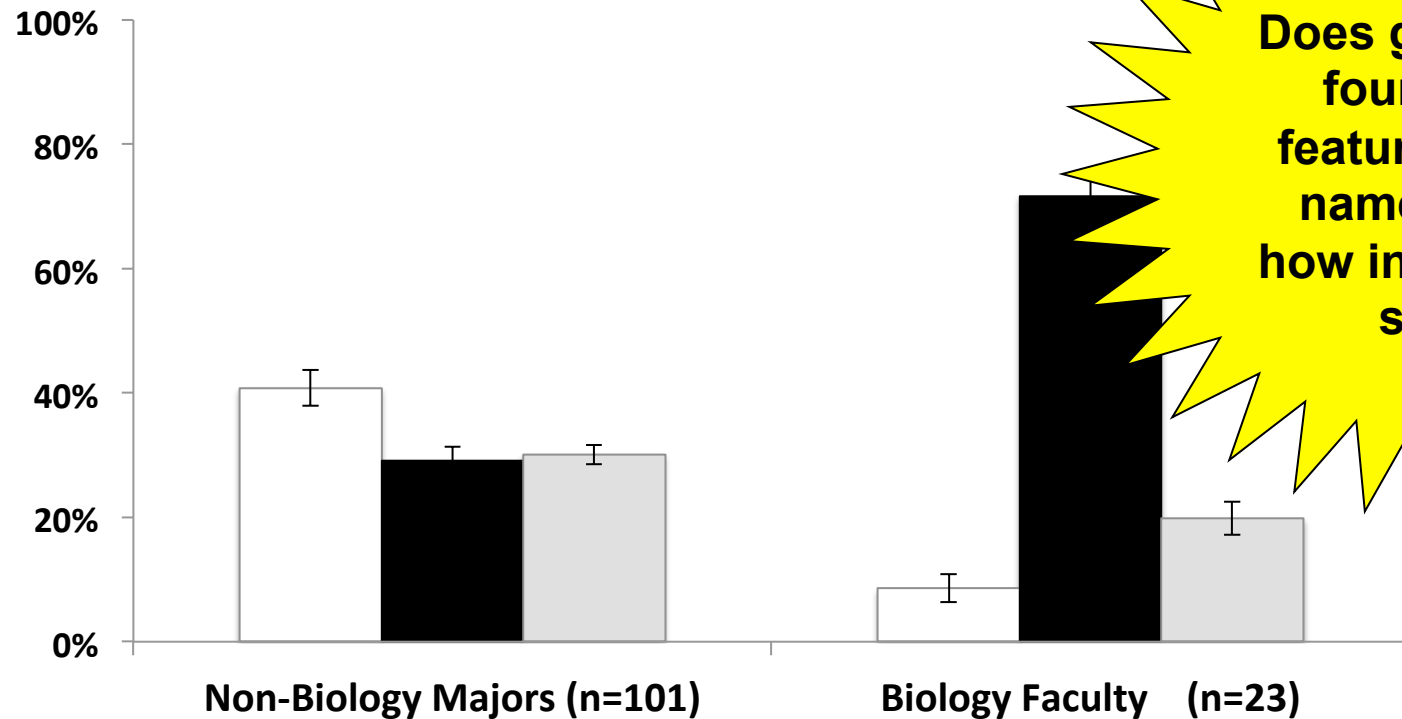
Does giving the four deep feature group names shift how individuals sort?

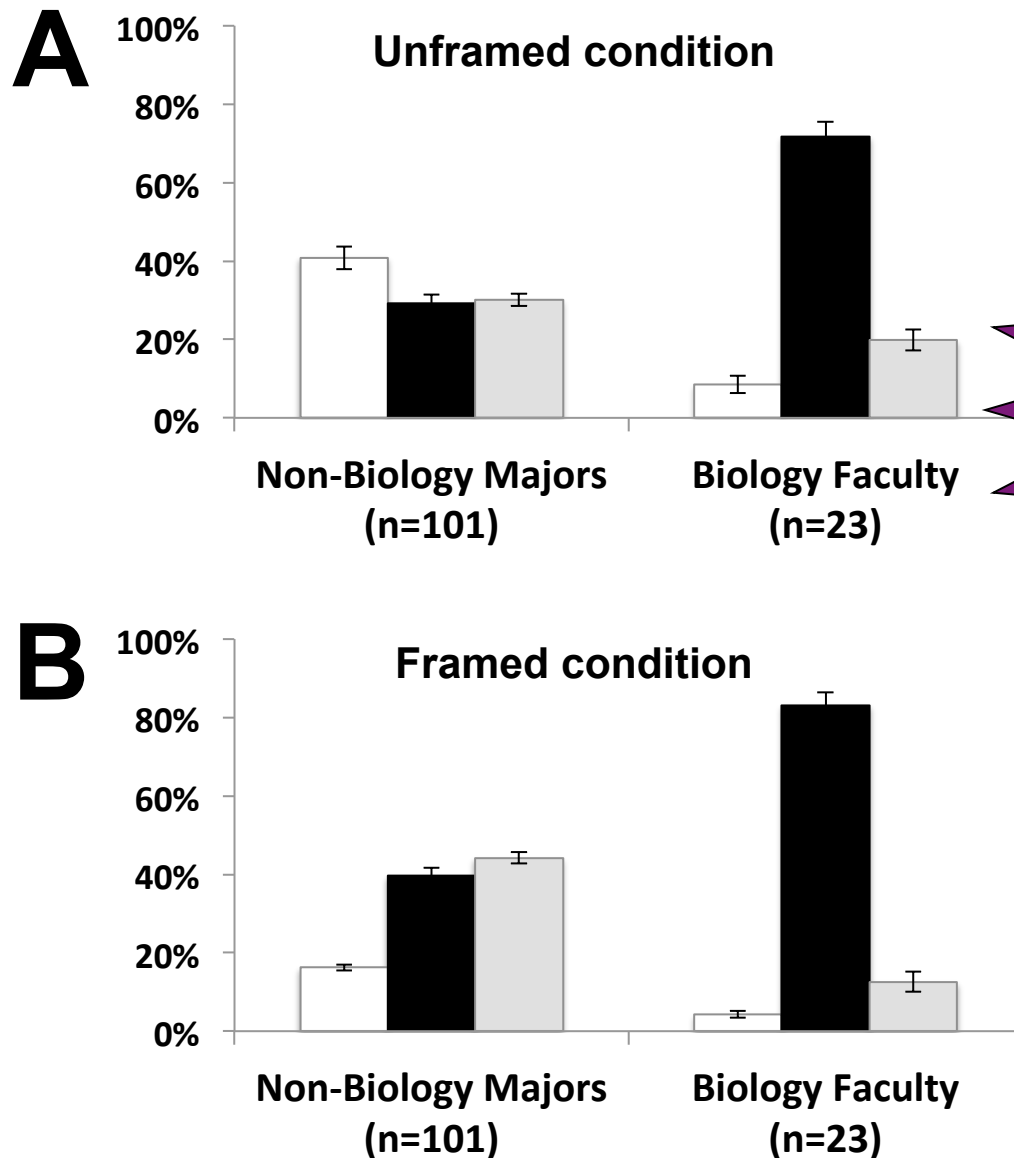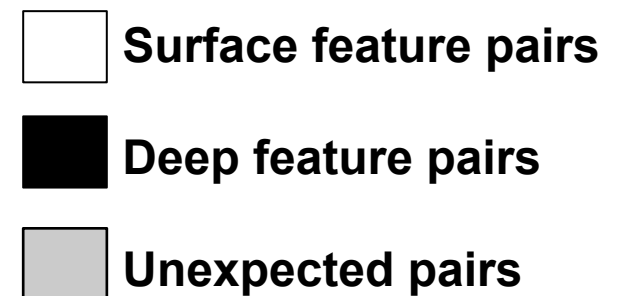Non-Biology Majors (n=101)   Biology Faculty   (n=23)

Surface feature pairs   Deep feature pairs   Unexpected pairs

Finding #2: Framing (Giving the Deep Features) Does NOT Appear to Shift Non-Majors Toward Deep Feature Sorting, but They Do Shift Away from Surface Features

To Read More…
CBE: Life Sciences Education, Winter 2013
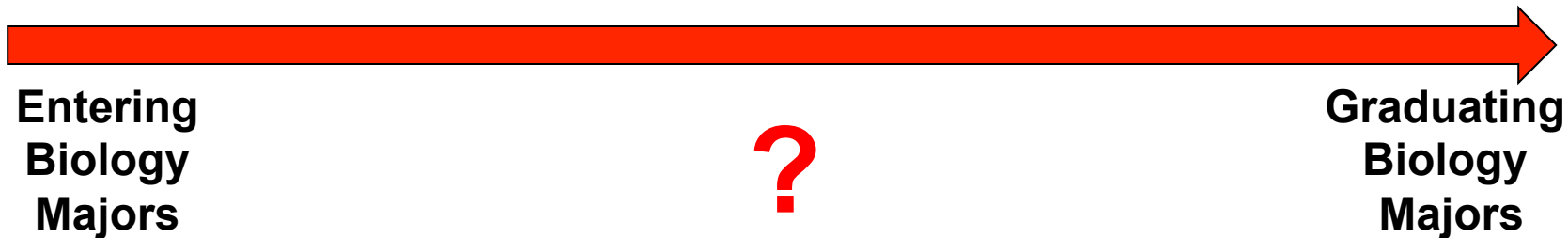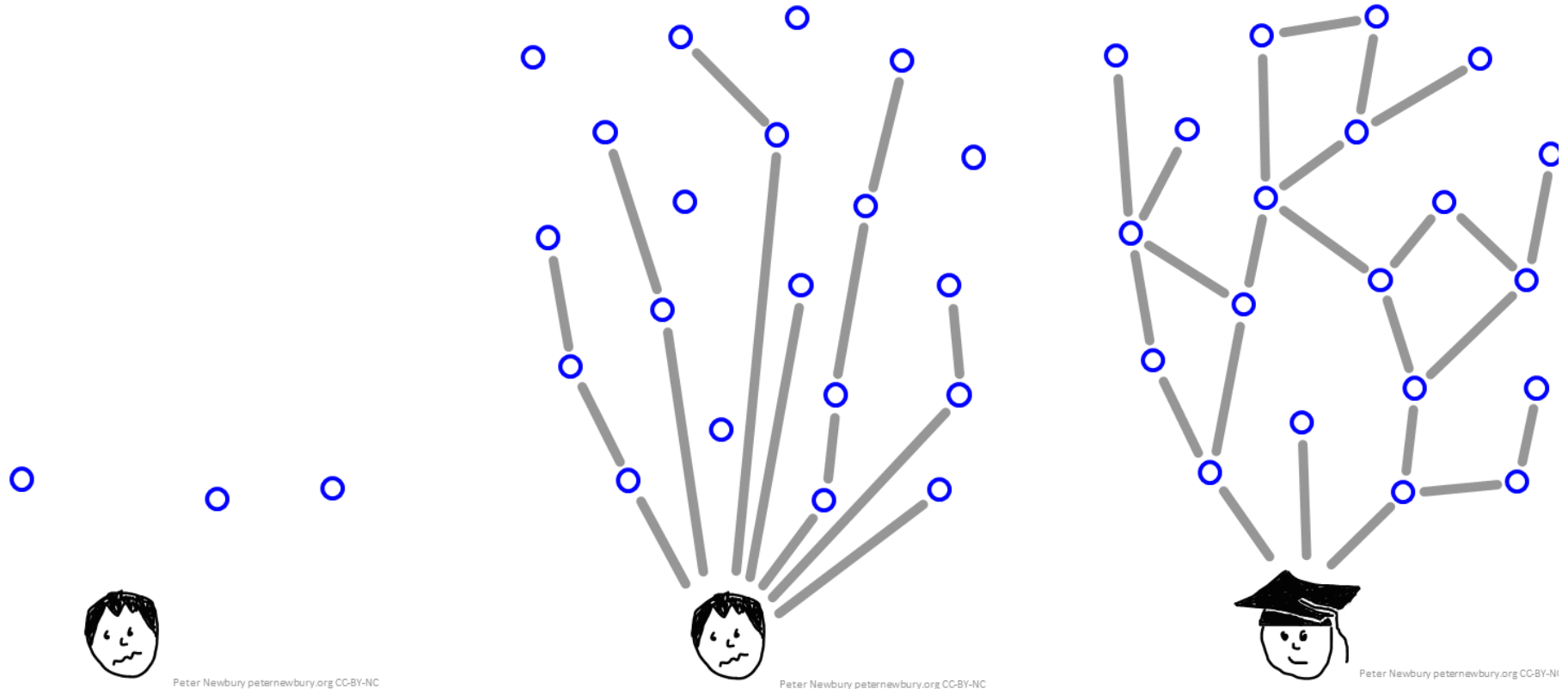

Improved Card Sorting – using hypothesis-driven stimuli and quantitative analysis metrics – is an adaptable assessment tool…

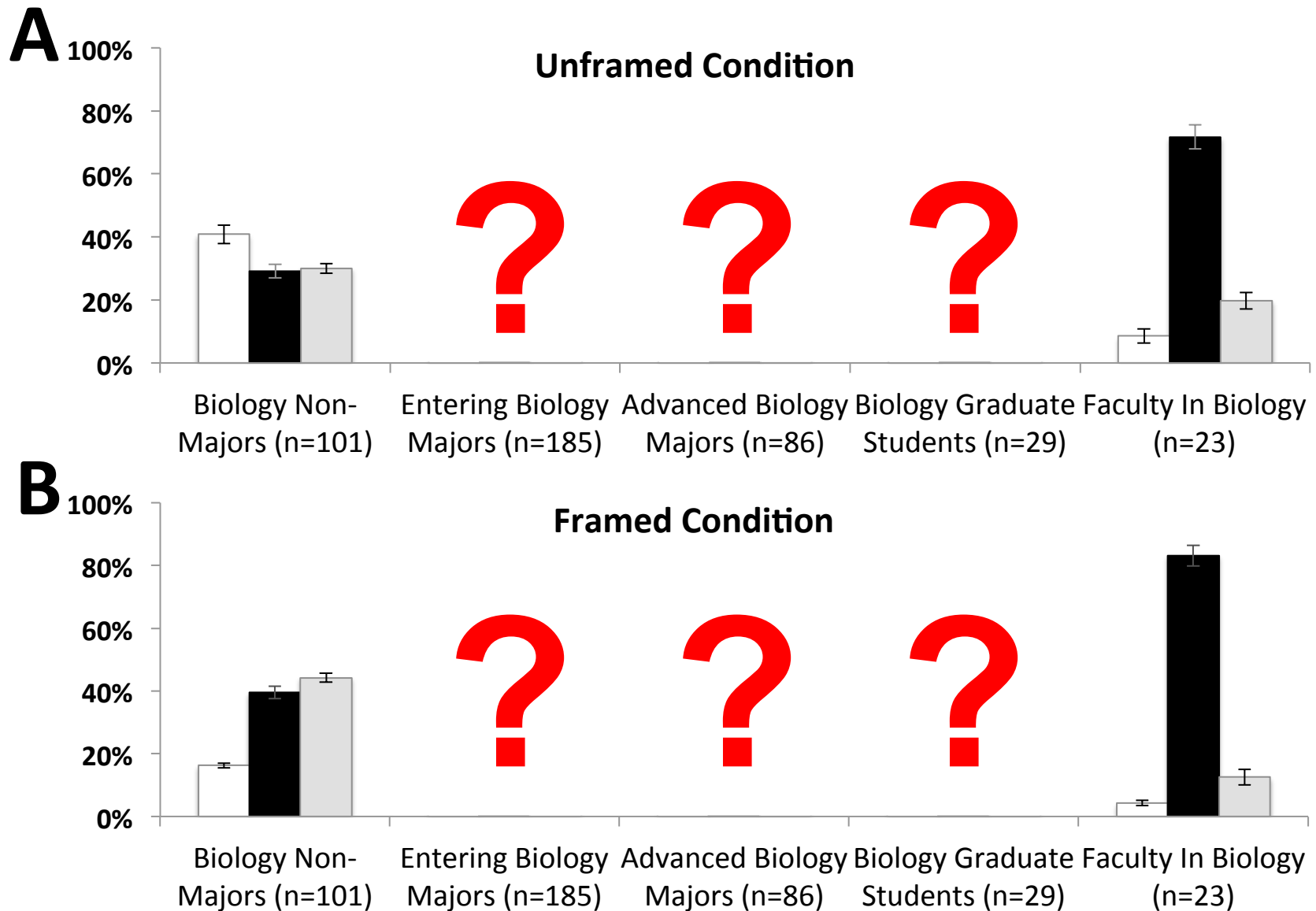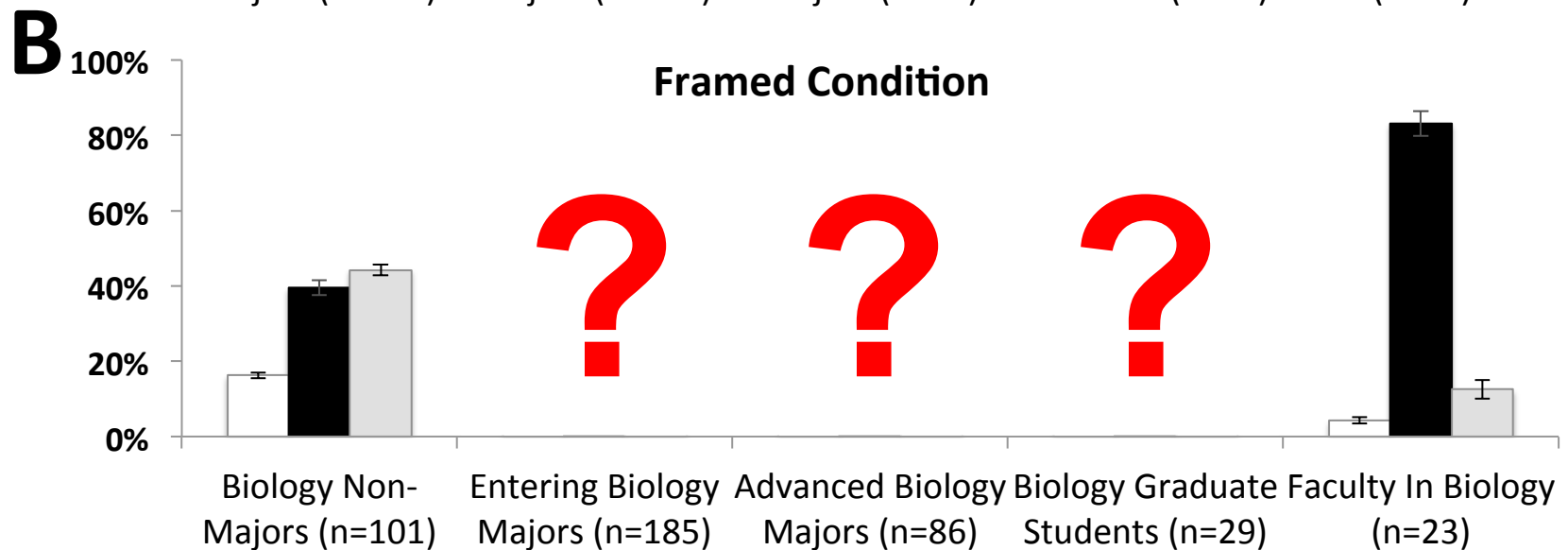# To what extent do biology majors organize their biology knowledge more like experts by the time they graduate?



Entering Biology Majors

?

Graduating Biology Majors

Peter Newbury peternewbury.org CC-BY-NC

Peter Newbury peternewbury.org CC-BY-NC

Peter Newbury peternewbury.org CC-BY-N(

Visuals from Peter Newbury at UC San Diego!

To what extent do biology majors organize their biology knowledge more like experts by the time they graduate?
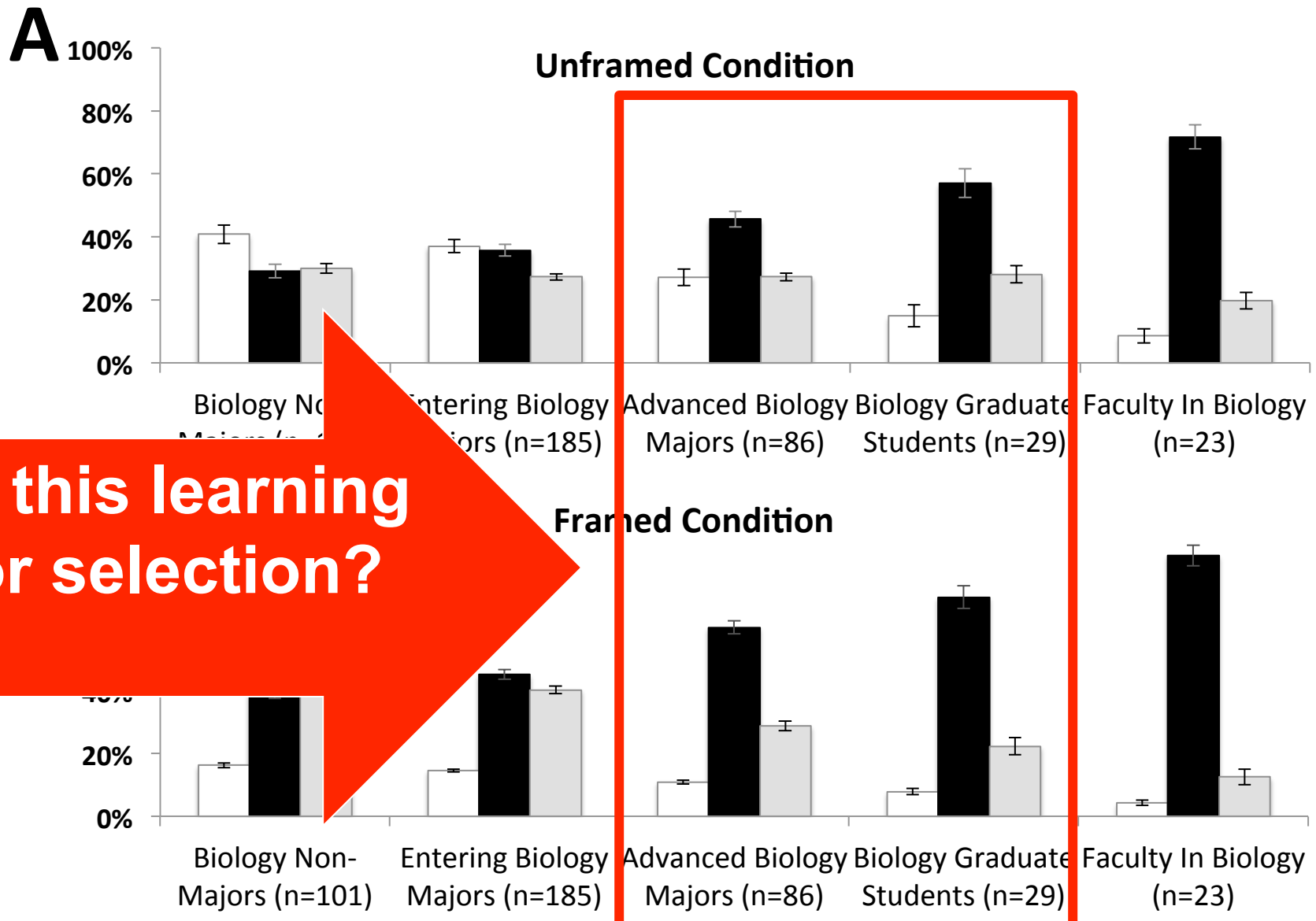
A — Unframed Condition

B — Framed Condition

To what extent do biology majors organize their biology knowledge more like experts by the time they graduate?

A — Unframed Condition

B — Framed Condition
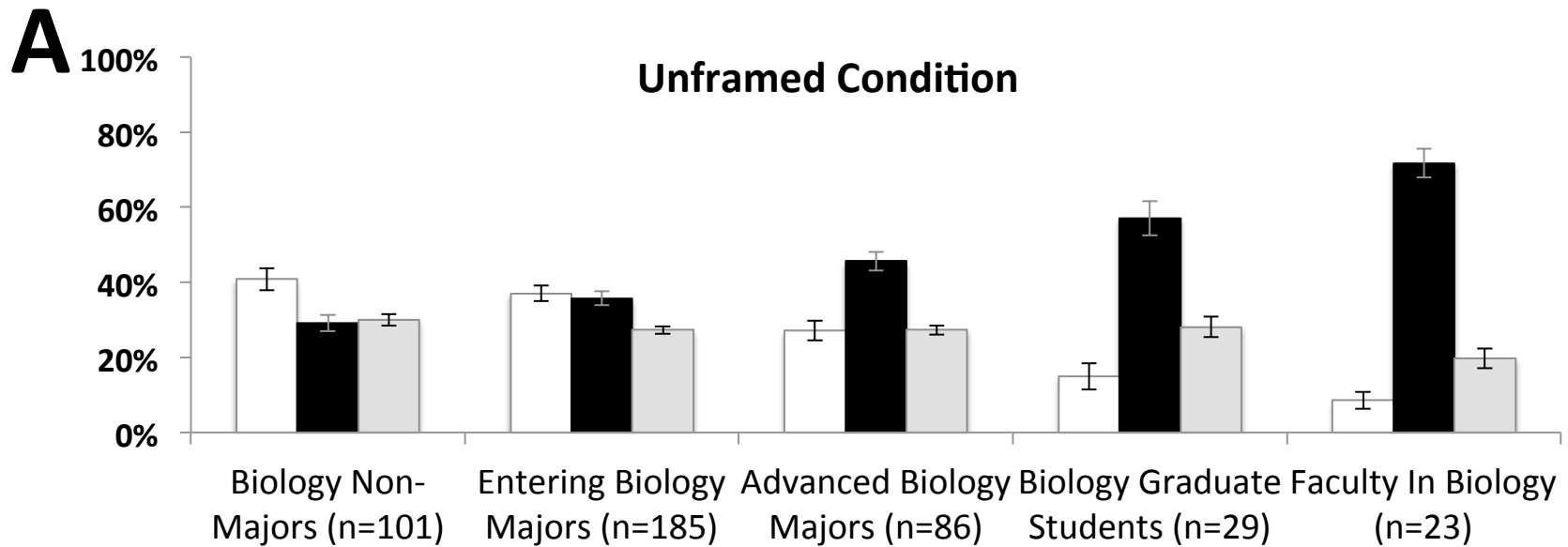
To what extent do biology majors organize their biology knowledge more like experts by the time they graduate?

Building The Discipline Of Biology Education Research

Forty years ago in Neuroscience…

- No *Society for Neuroscience*

- No *Journal of Neuroscience*

- No Ph.D.s in neuroscience

- No annual neuroscience conferences

What might the discipline of Biology Education Research look like in 2055?

Acknowledgments

- *All the students and faculty who participated in the research.*

- **Julia Smith, Professor of Biology, Holy Names University, SEPAL Visiting Scholar**
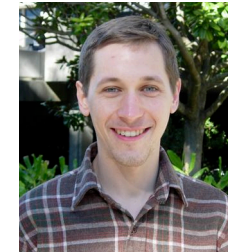

- **Elijah Combs, SEPAL Graduate Student**
- **Paul Nagami, SEPAL Graduate Student**

- **The SEPAL Staff:**
    Trisha DeVera
    Shannon Seidel
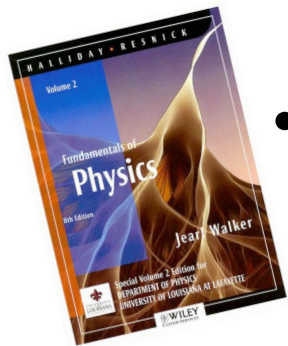

- **The entire SEPAL Lab and Community**

- About the problem of measuring how students develop expertise in a discipline

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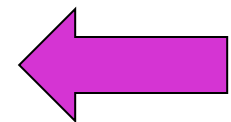

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