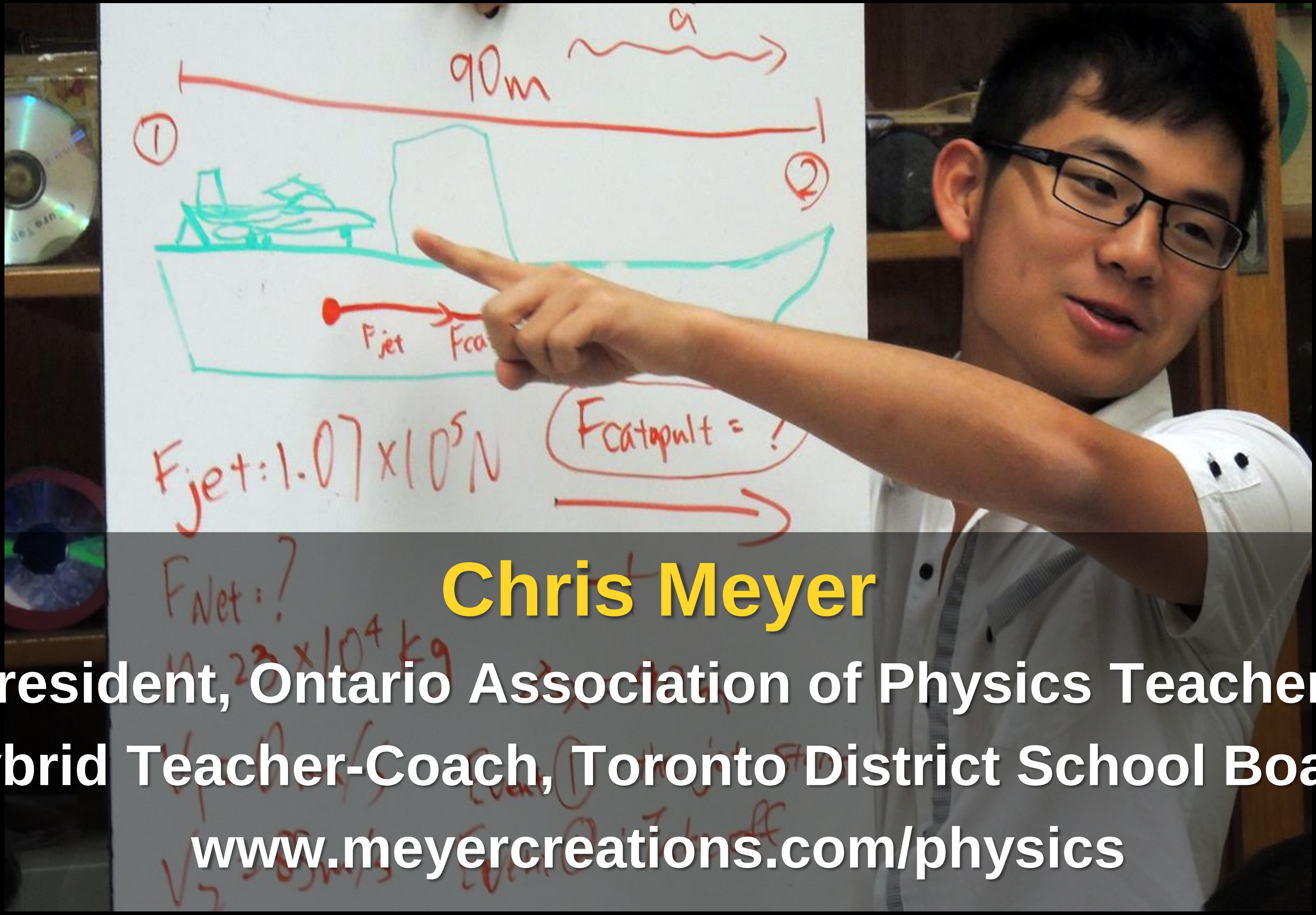
# The Future of Physics Education




## Chris Meyer

**President, Ontario Association of Physics Teachers**
**Hybrid Teacher-Coach, Toronto District School Board**
**www.meyercreations.com/physics**

I

A

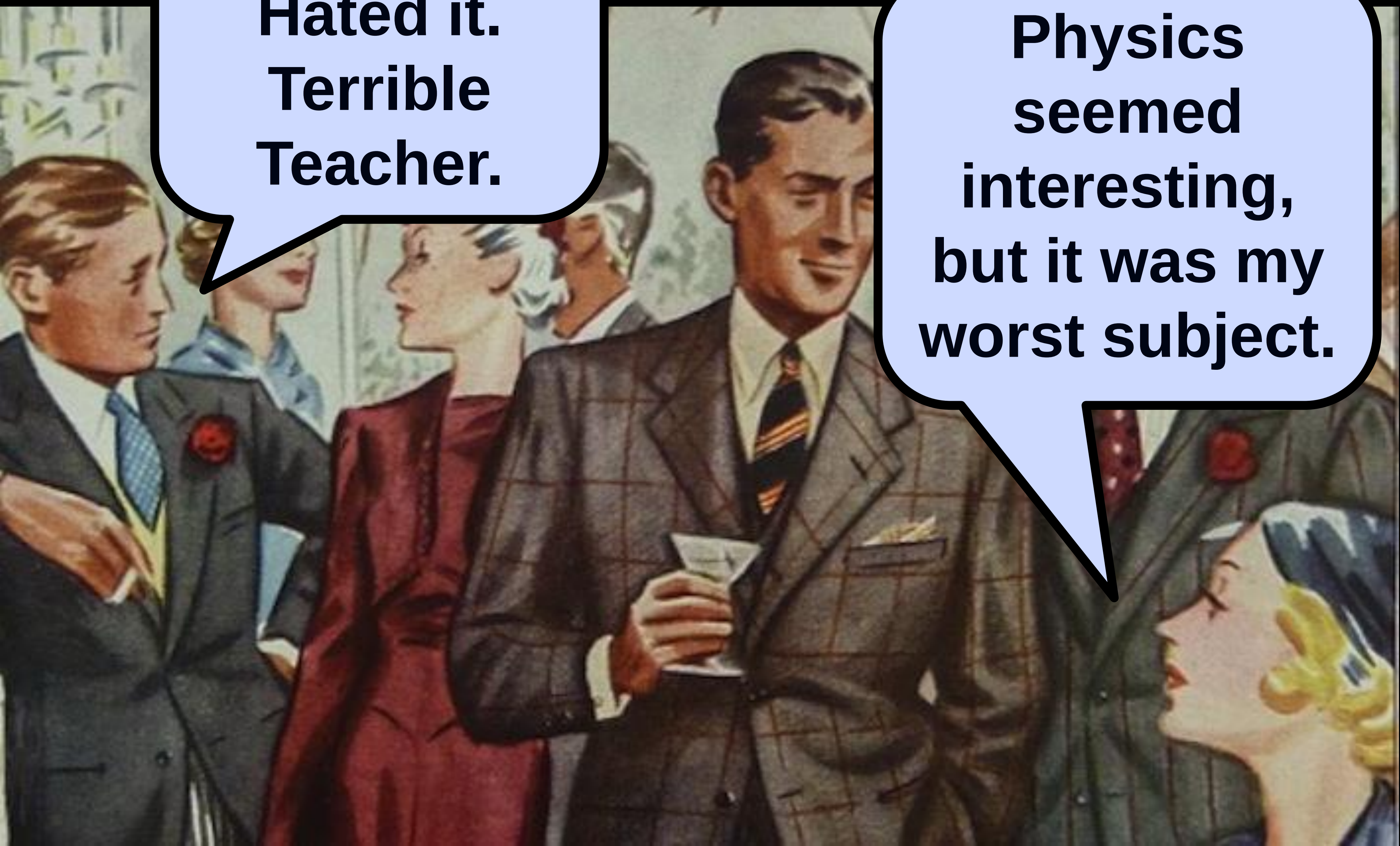
# PHYSICIST

**(and a high school teacher!)**

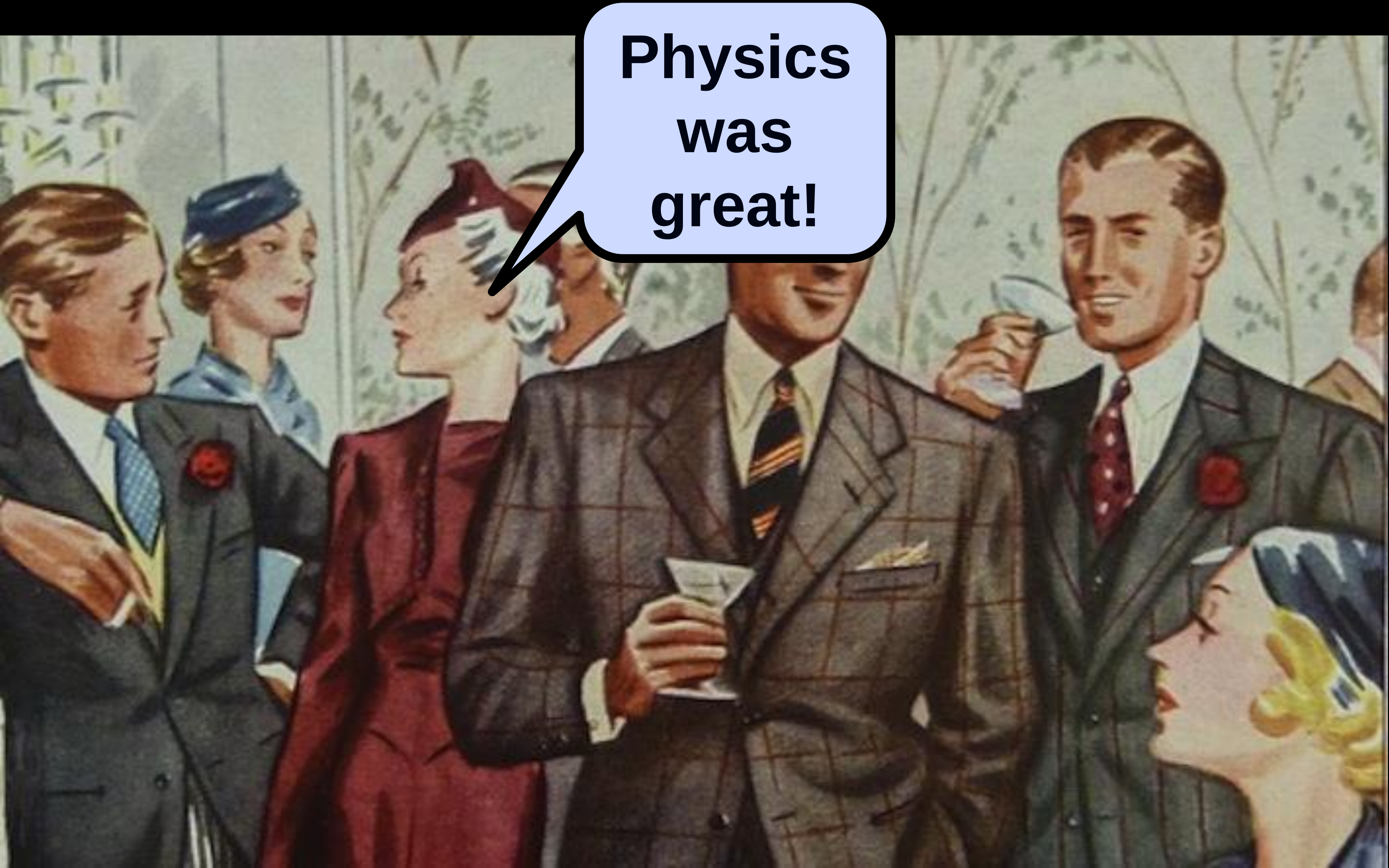
# U of T Physics


ERTW
WE NEED MORE STUDENT SPACE
We did it!
Students win more space

# cktail Party



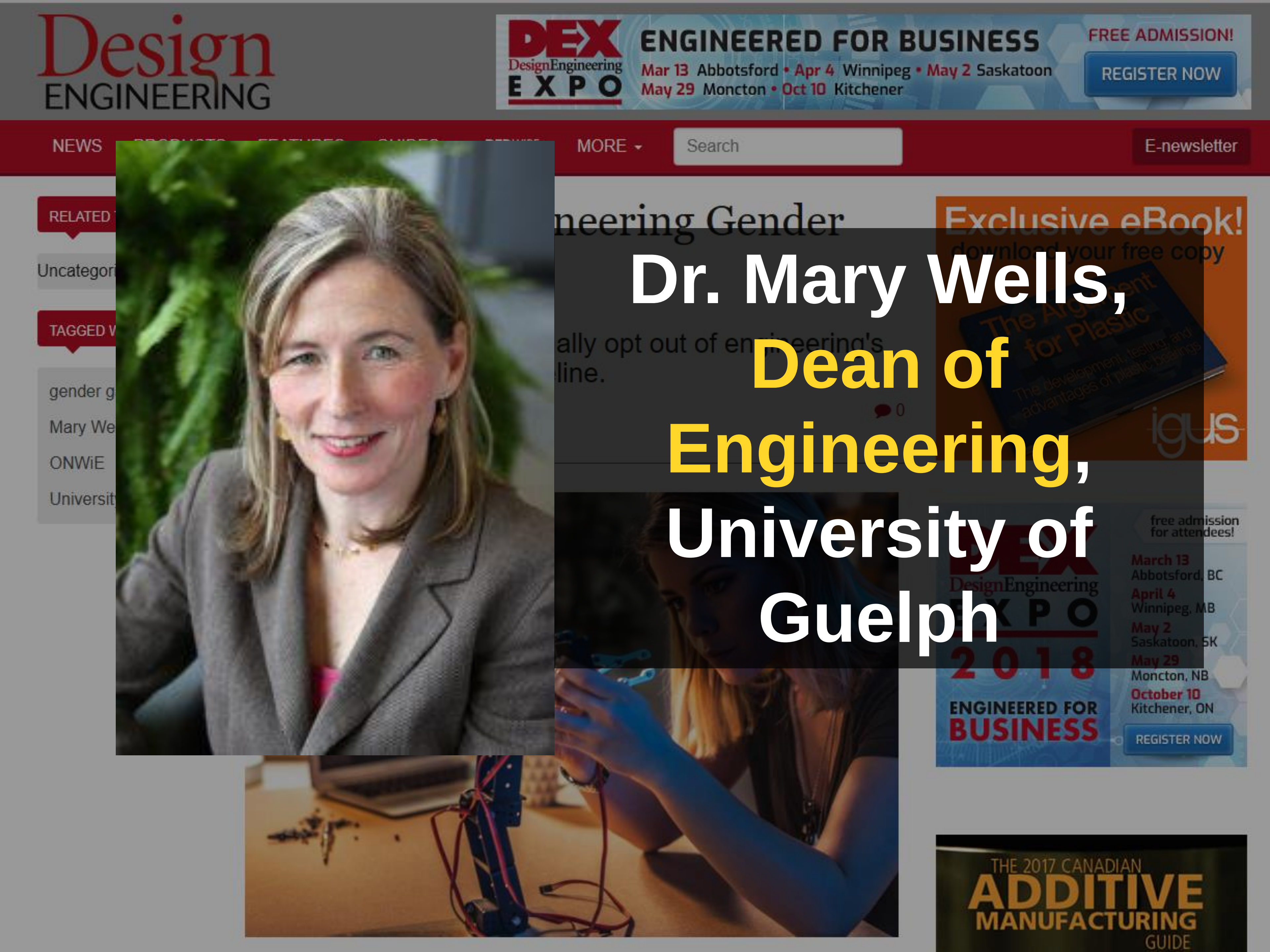
# The Cocktail Party



# Closing the Engineering Gender Gap

Why women disproportionally opt out of engineering's education and career pipeline.

April 3, 2018 0
by By Dr. Mary A. Wells, PhD, FEC, P.Eng.


Dr. Mary Wells,
Dean of Engineering,
University of Guelph
Design ENGINEERING
DEX DesignEngineering EXPO
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Mar 13 Abbotsford • Apr 4 Winnipeg • May 2 Saskatoon
May 29 Moncton • Oct 10 Kitchener
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October 10 Kitchener, ON
2018
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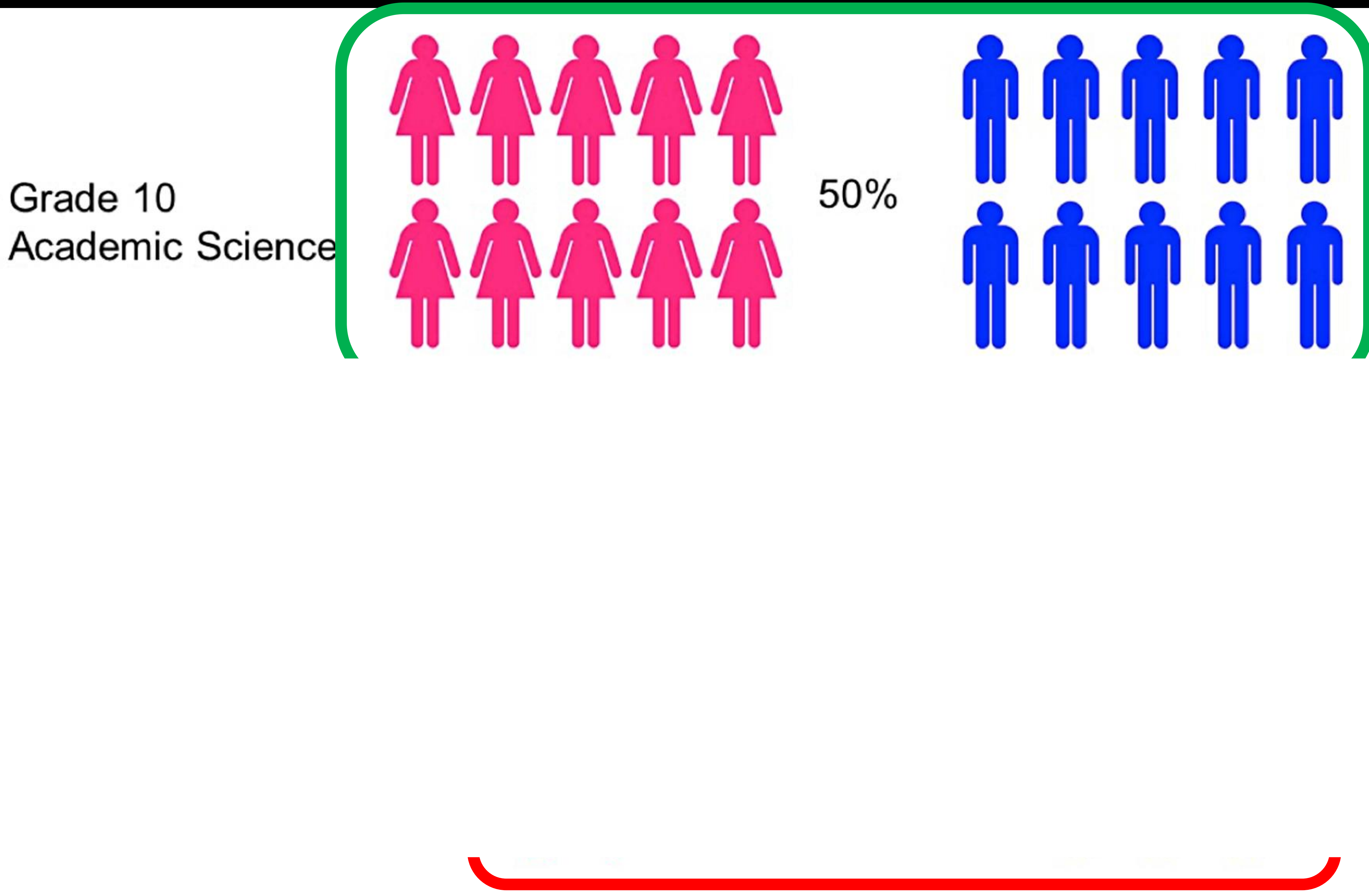
**“Surprisingly, it is not the advanced math courses that cause this divide but rather Grade 11 and 12 physics!”**

**“out of all the natural science courses offered in high school, physics is the least popular”**

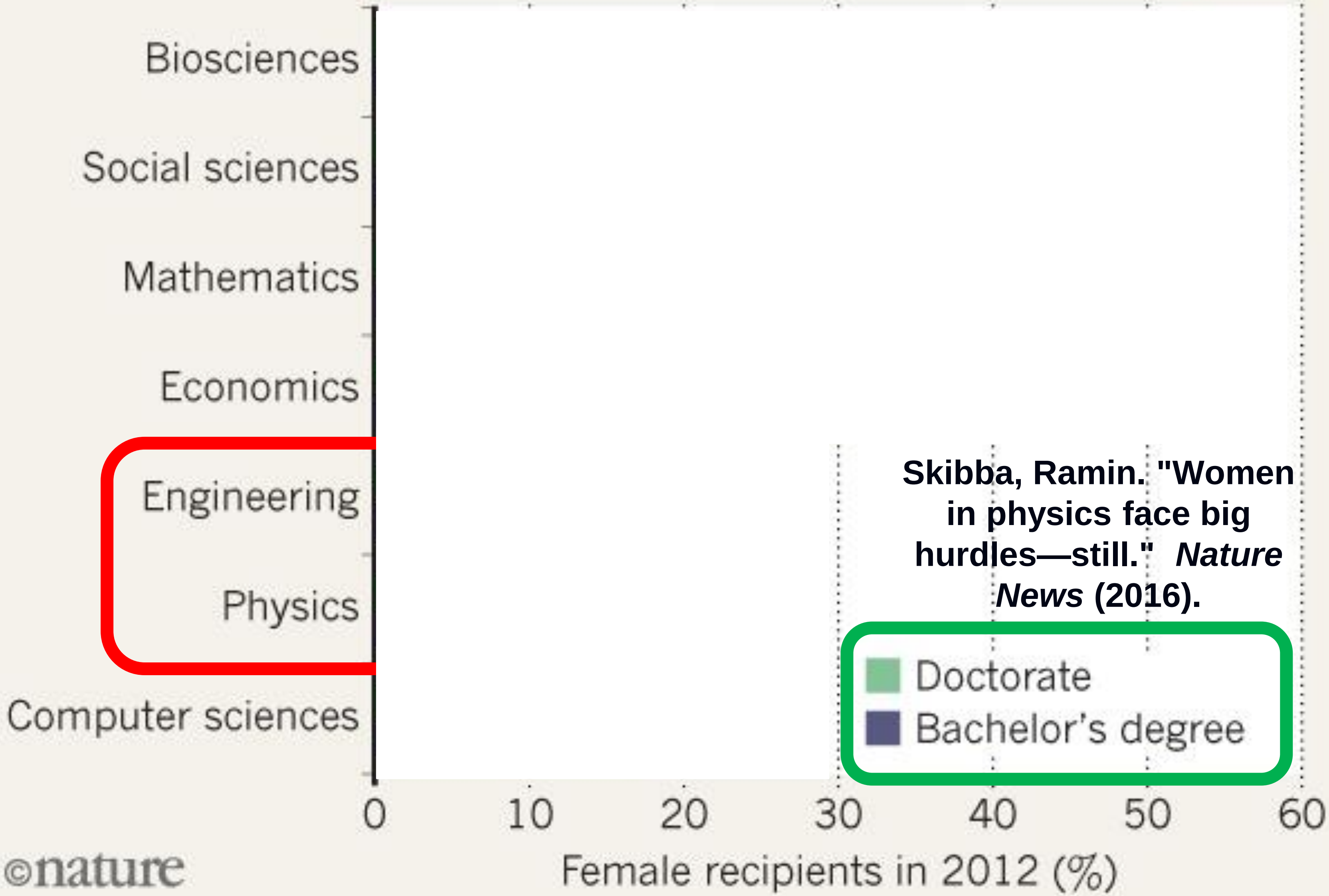
**"Considering physics 12 is a requirement to apply to engineering programs in Canada, this has serious implications for the Canadian engineering talent pipeline."**

# How Serious?



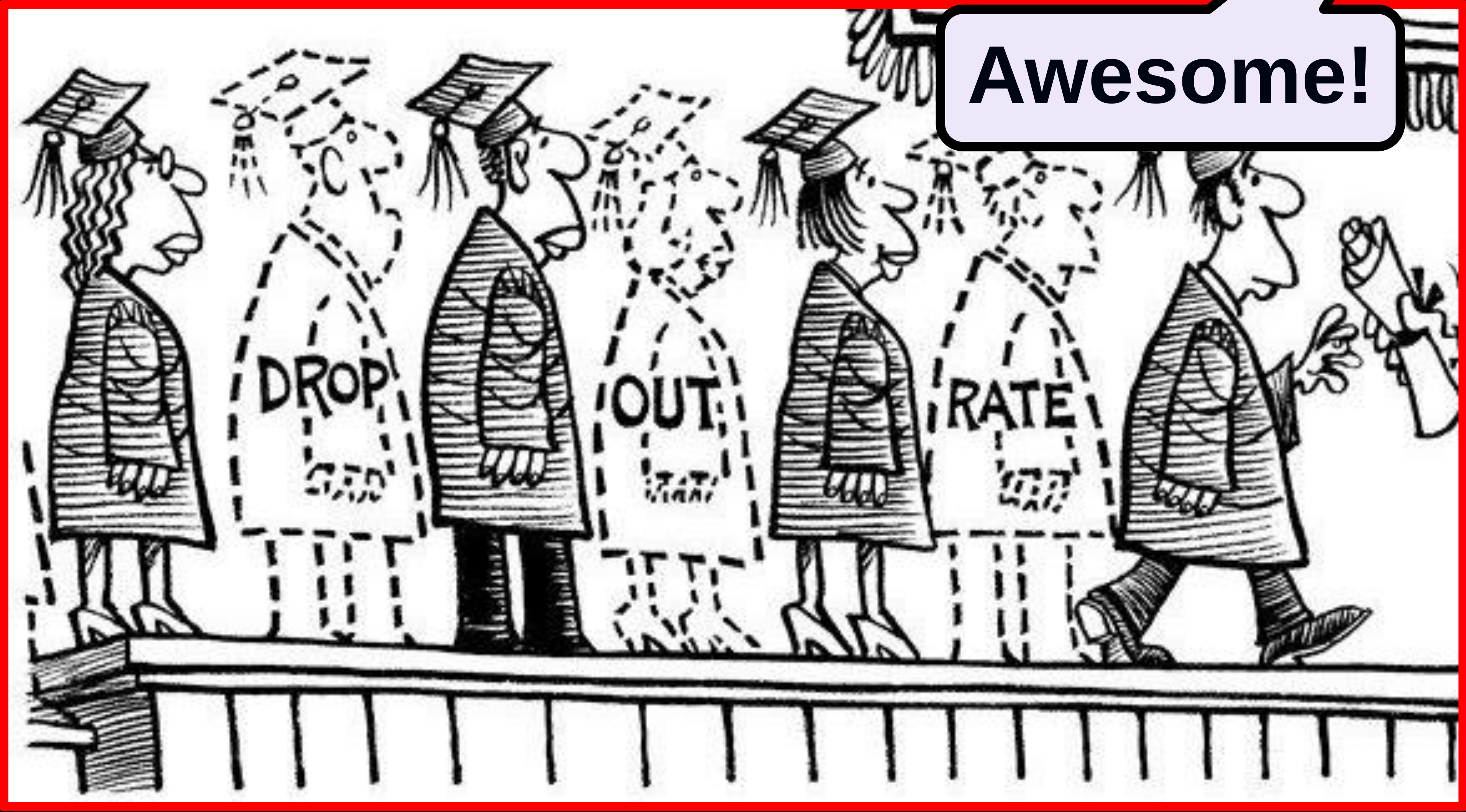
# WOMEN IN SCIENCE

Physics hovers near the bottom of the pack with regard to the percentage of female graduate and undergraduate degree recipients.




**Skibba, Ramin. "Women in physics face big hurdles—still."** ***Nature News*** **(2016).**

# Attrition




Awesome!

# Gender Imbalance


Force Concept Inventory

# Force Concept Inventory

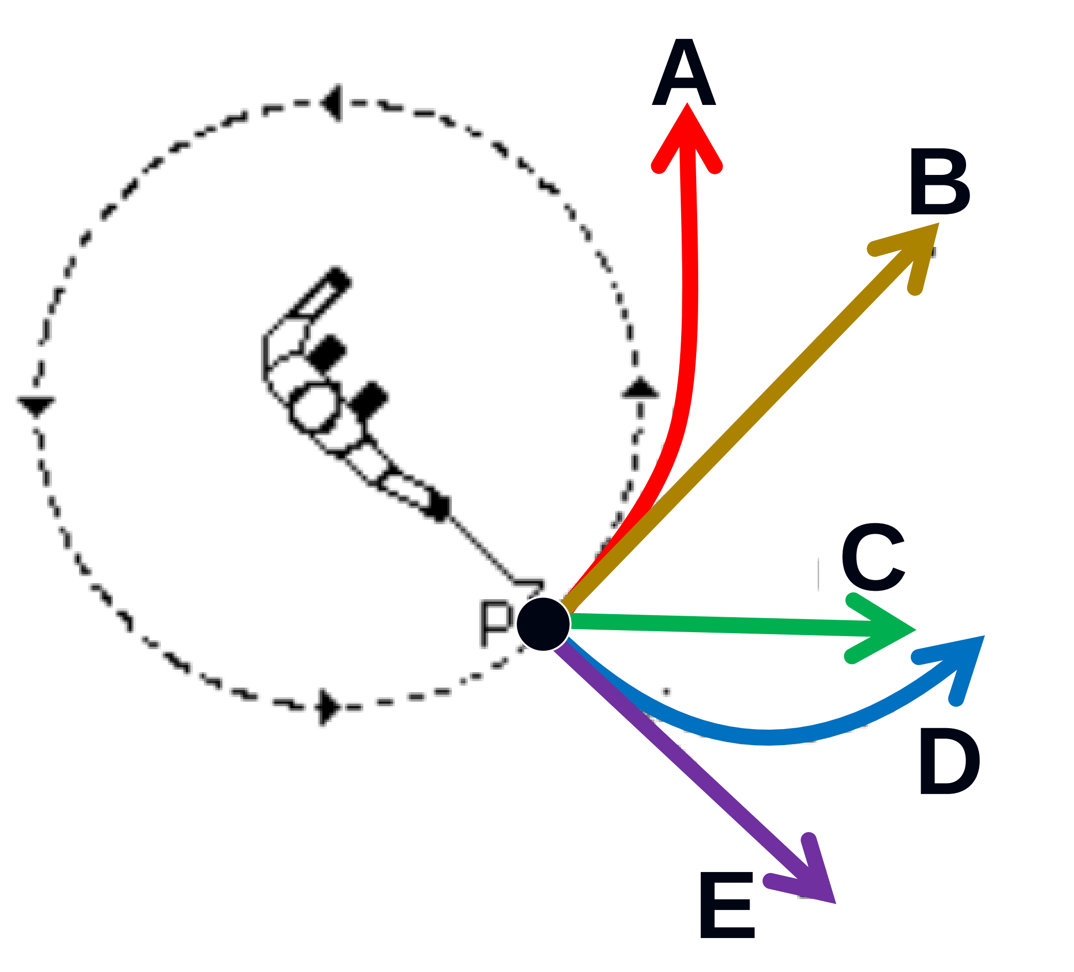
0:30

Stop

A ball on a string is swung in a horizontal circle.

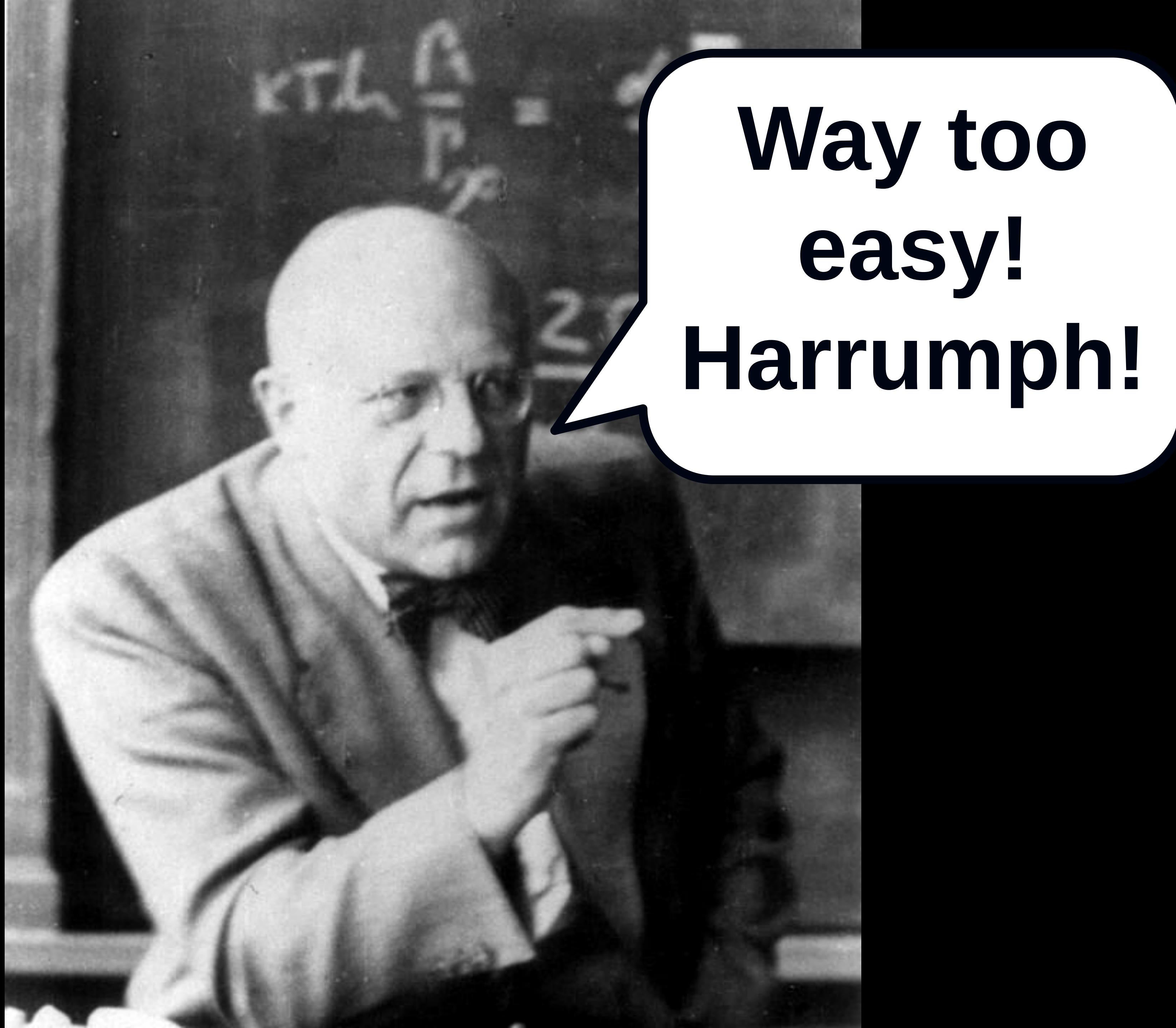
At point P, the string breaks.

**Which path** would the ball most closely follow, observed from above?

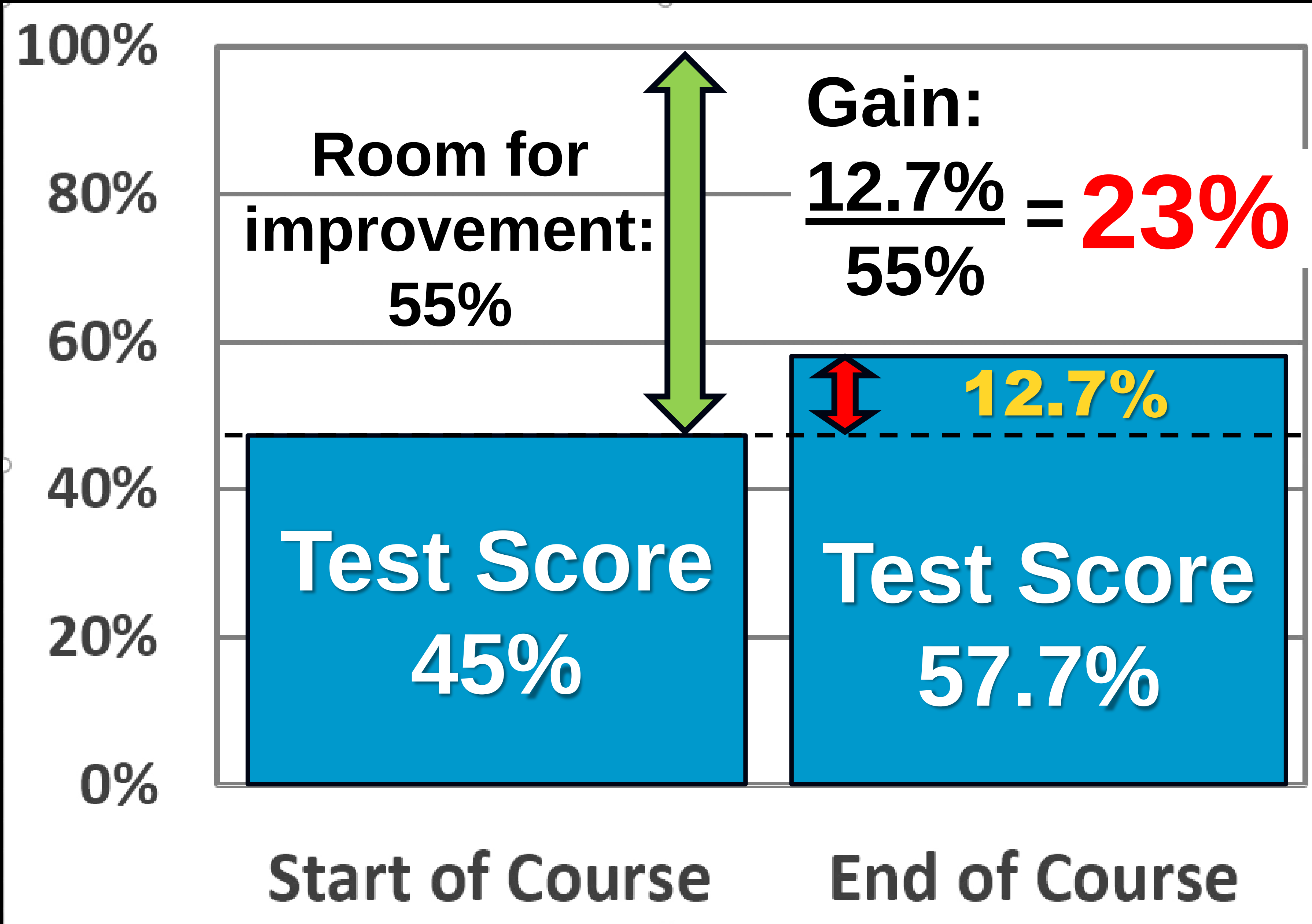




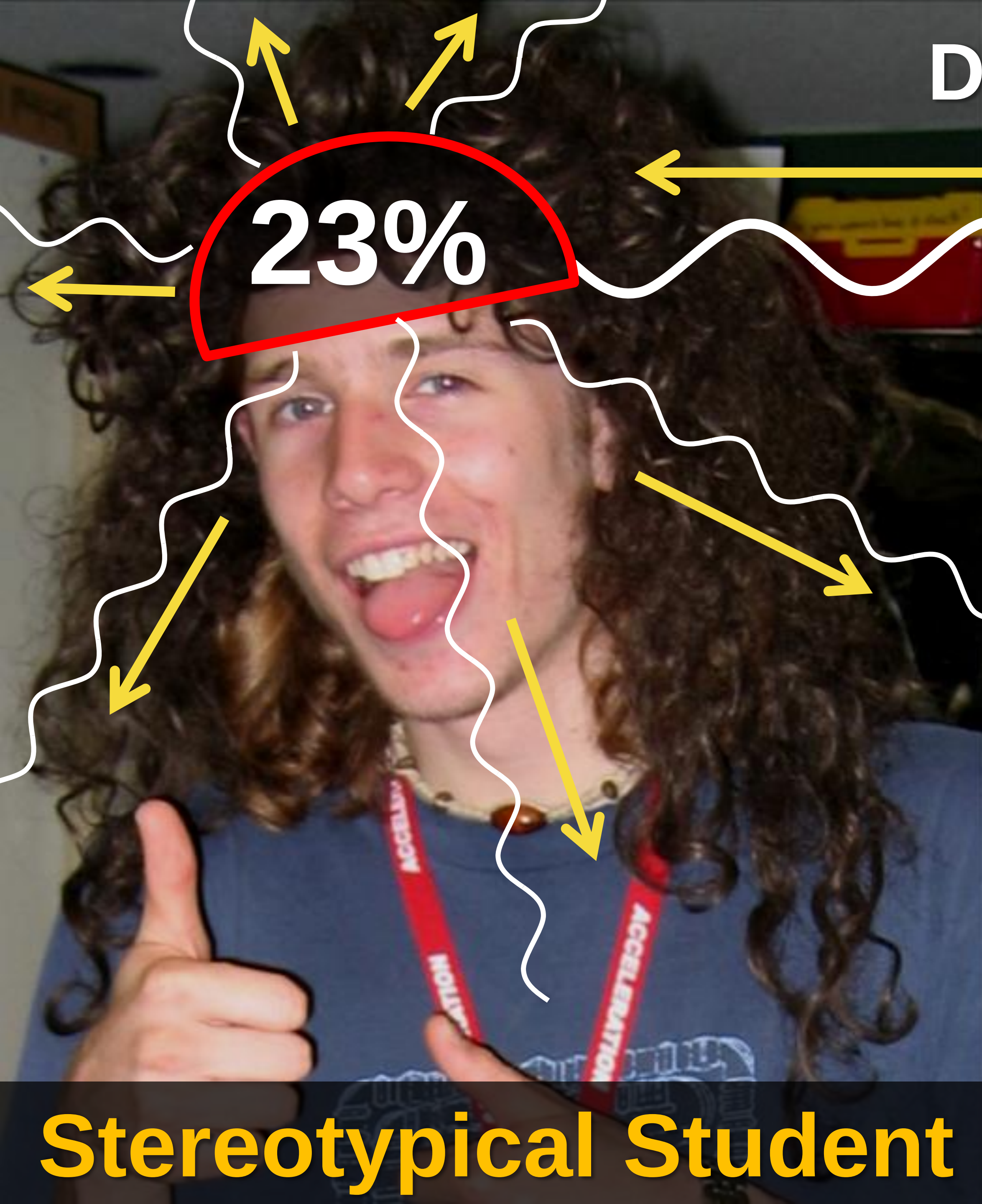
Hestenes, D., Wells, M., & Swackhamer, G. (1992). Force concept inventory. *The physics teacher*, *30*(3), 141-158.


Way too easy! Harrumph!

# Force Concept Inventory Scores

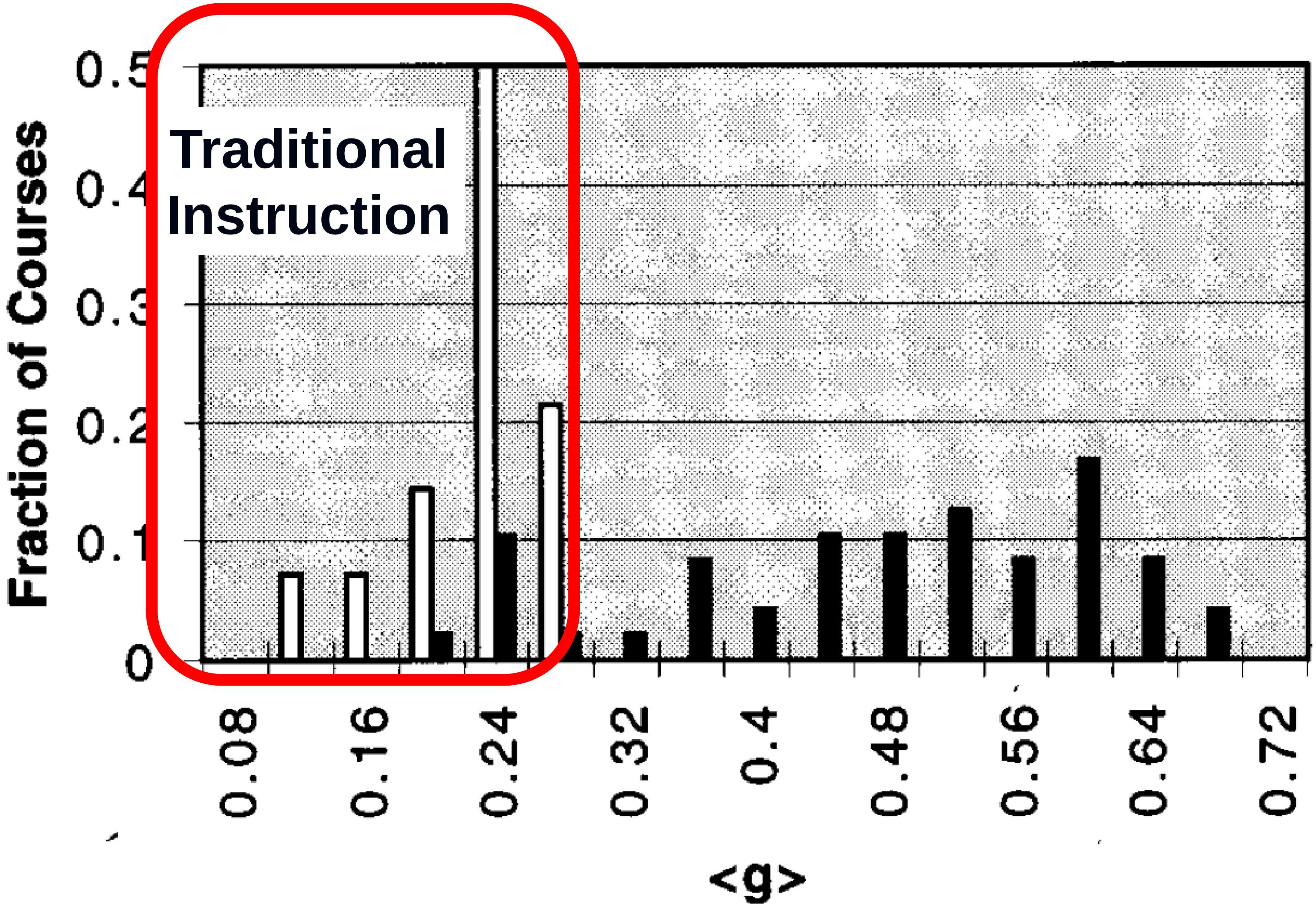


# Distilled Physics Wisdom




77% Scattered

Hake, Richard R. "Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses." *American journal of Physics* 66.1 (1998): 64-74.

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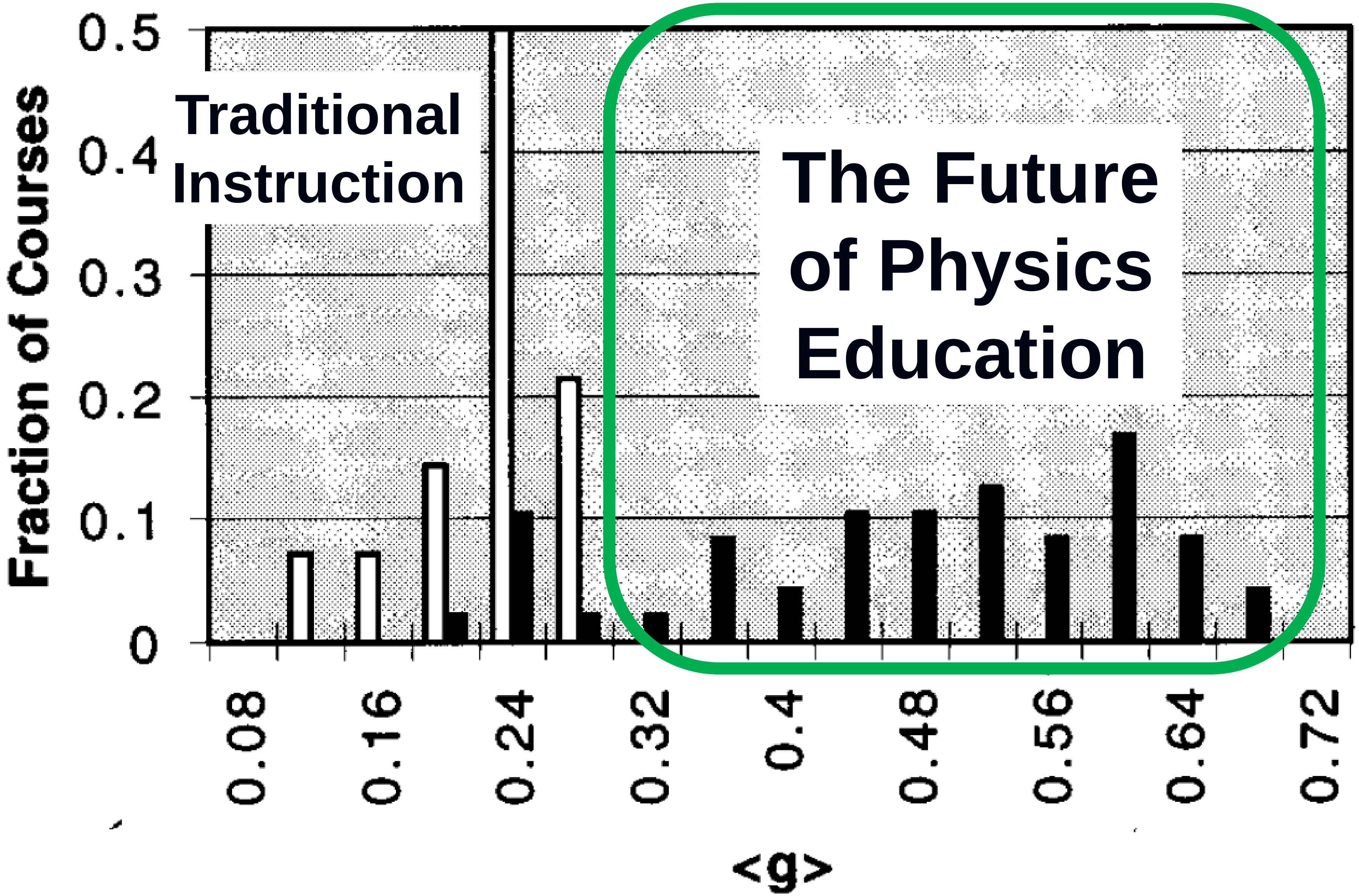
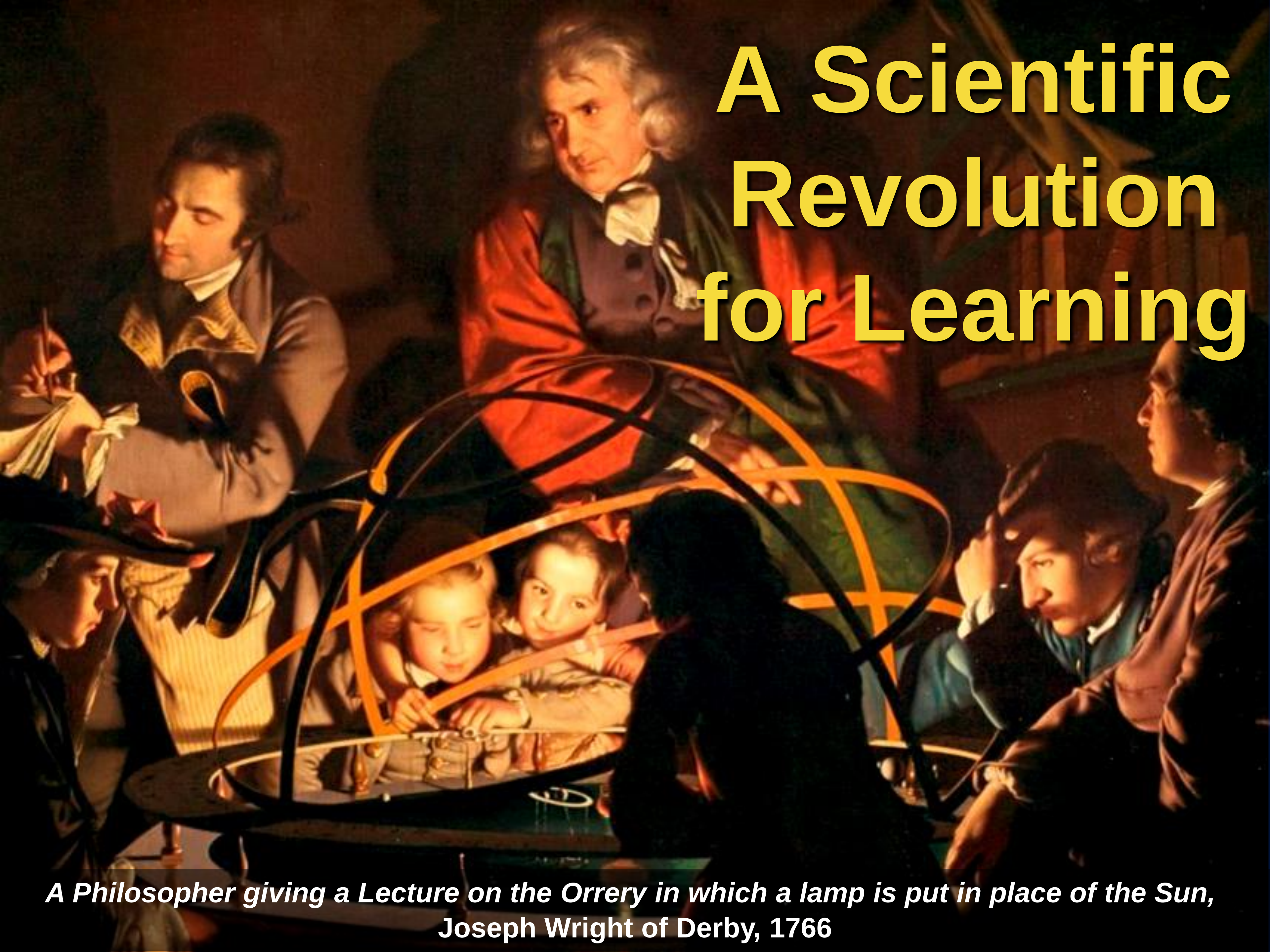


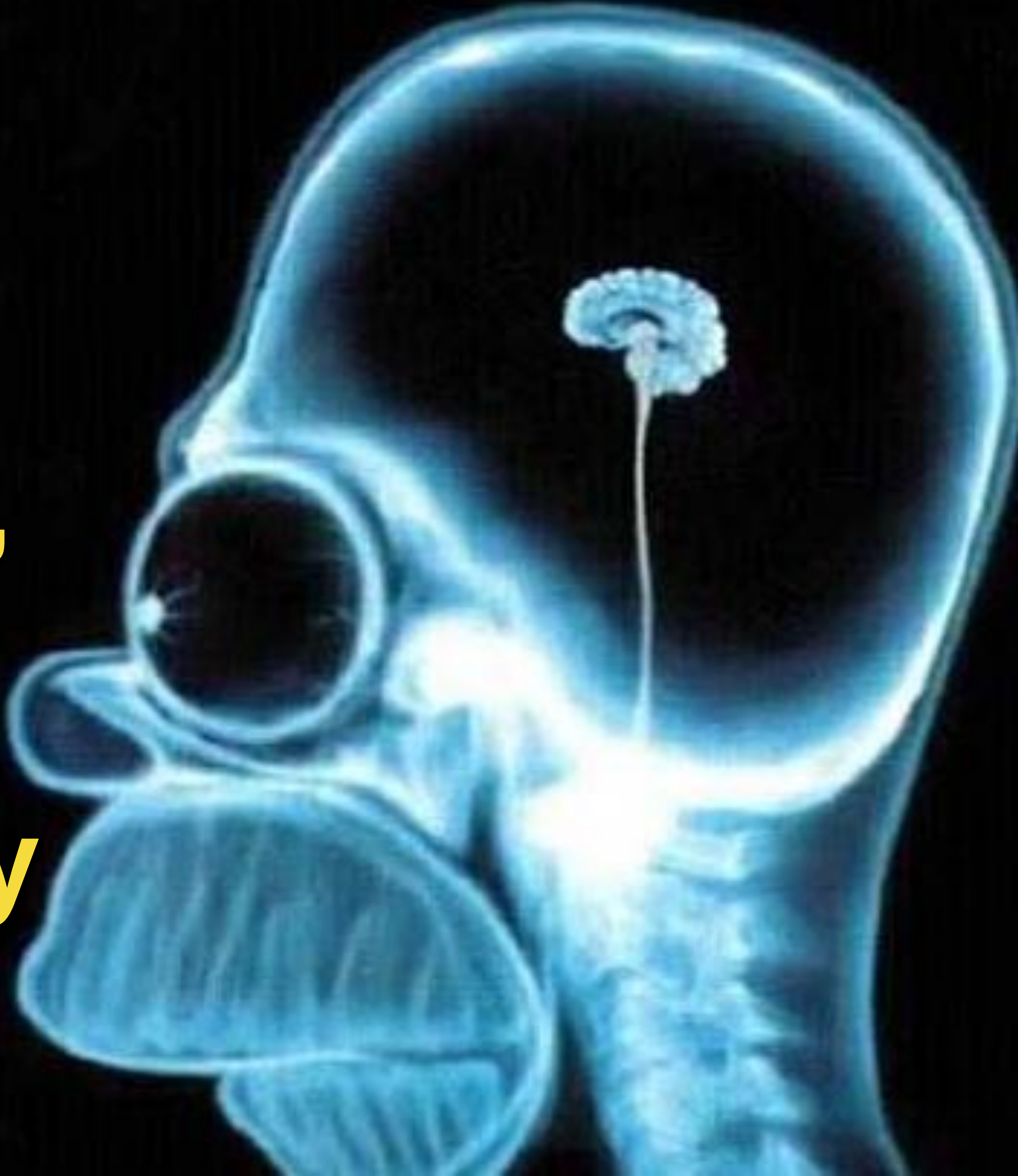

Hake, Richard R. "Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses." *American journal of Physics* 66.1 (1998): 64-74.

# A Scientific Revolution for Learning



*A Philosopher giving a Lecture on the Orrery in which a lamp is put in place of the Sun,* **Joseph Wright of Derby, 1766**

# What happens in students' brains when they learn?



Neuroscience

+

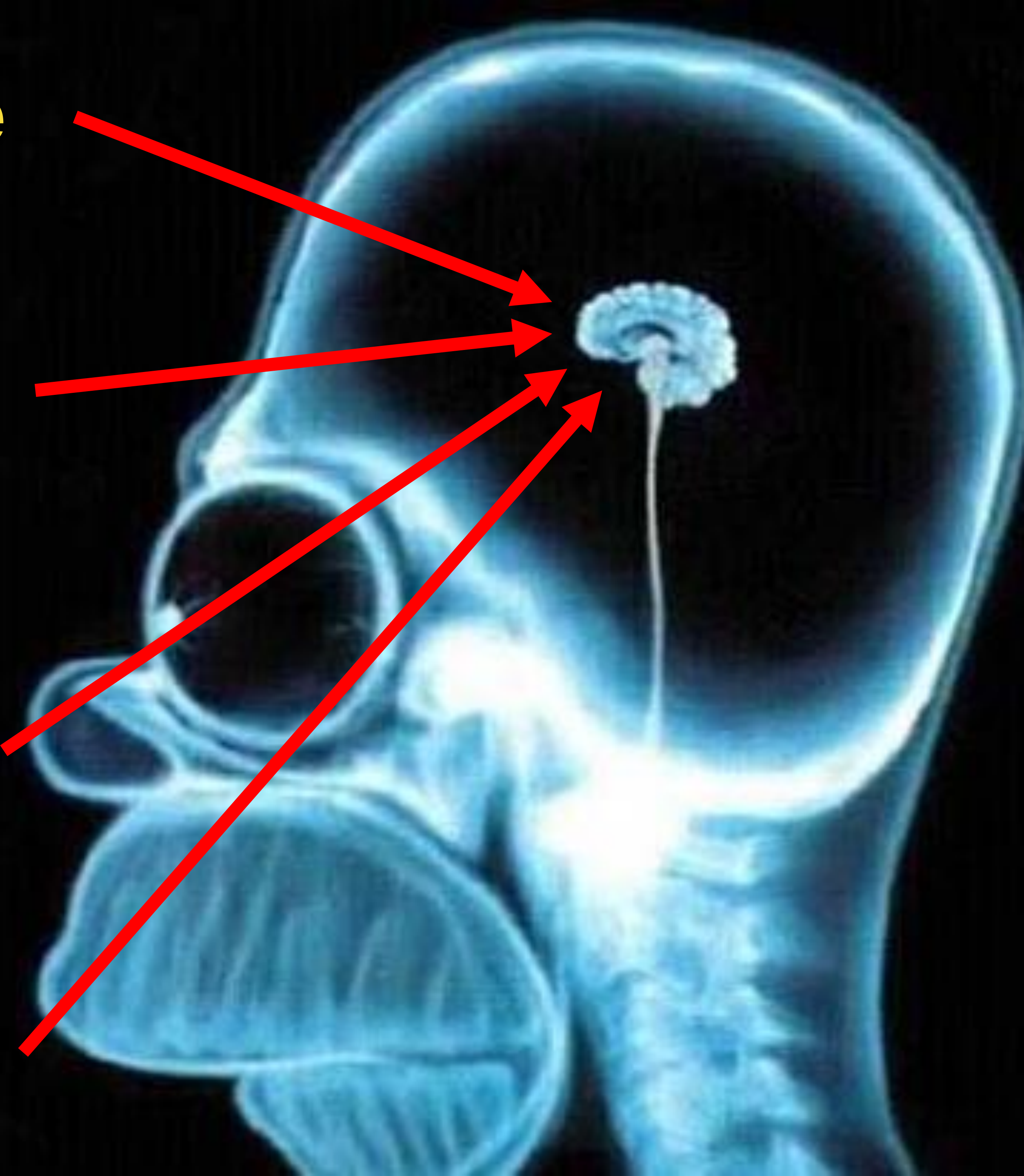
Cognitive Psychology

+

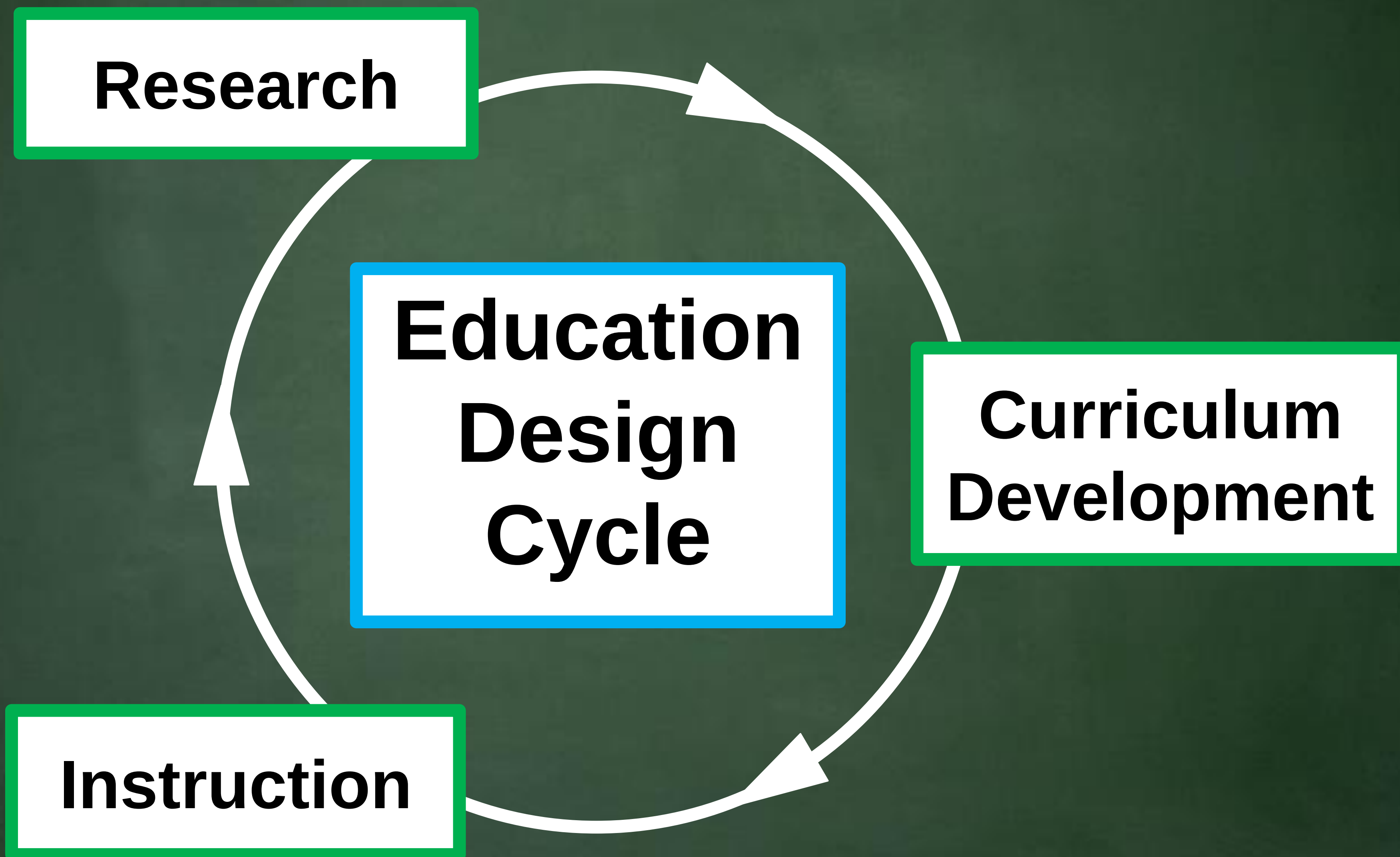
Physics Education Research

+

Classroom Practice



# Applied Science of Learning



# The Goal of STEM Education

**"to maximize the extent to which the learners develop expertise in the relevant subject, where expertise is defined by what scientists and engineers do."**

***Carl Wieman, Physics Nobel laureate***

Wieman, Carl. "Applying New Research to Improve Science Education." Issues in Science and Technology 29, no. 1 (Fall 2012)

# STEM Education Goal


# Observe the Novices

# STEM Education Goal:

## Experts talk to one another

# Work and Learn in Groups

# Social Learning

**“For most individuals, learning is most effectively carried out via social interactions.”**

**Redish, Edward F. "Millikan lecture 1998: Building a science of teaching physics."** ***American Journal of Physics*** **67.7 (1999): 562-573.**

# SPH4U: Newton's Third Law

Recorder: ______
Manager: ______
Speaker: ______
0 1 2 3 4 5

## A: Forces as Interactions

Throughout our unit on forces, we have been making use of the term *interaction*. When two objects affect one another, we say that they *interact*. We have also noticed that these interactions come in the form of a push or a pull on the objects which we call *forces*. This brings us to a very important idea.

Whenever two objects interact, they each exert a force on the other. These two forces are really just two parts of a **single interaction**. We will call the two forces a *3rd law force pair*. The forces in a 3rd law force pair share some important characteristics:

- they have the same magnitude
- they are the same type (gravitational, normal, etc.)
- they involve the same pair of objects
- they point in opposite directions
- they arise and act simultaneously

This understanding of interactions is known as *Newton's 3rd Law*. Please never use the words *action* or *reaction* when describing forces. To do so is simply wrong.

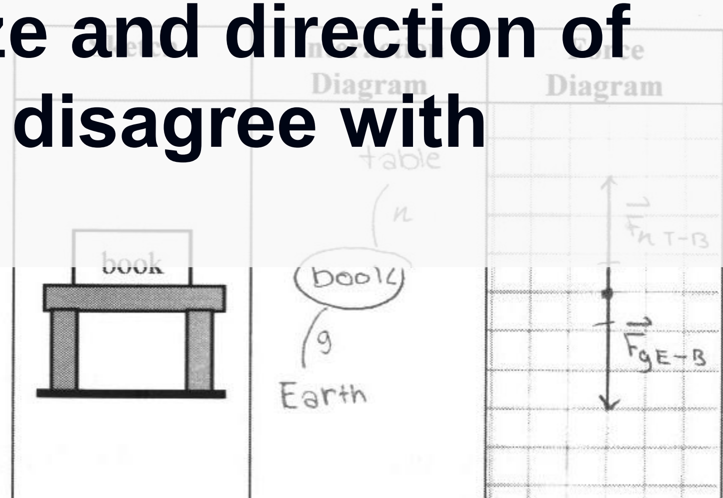
**3. Reason. Isaac says, "I think gravity and the normal force make up a third-law pair in this situation. Just look at the size and direction of the forces." Do you agree or disagree with Isaac? Explain.**

## B: BookLearnin'

One of the ... becomes much more nuanced and subtle. Let's think about your physics book at rest upon a table.

1. Represent. Draw an ID and FD for the system of the book.

To show better the details of an interaction, we can use a more specific force notation which we will call *3rd law notation*. For example the earth interacts ... and we can symbolize this as: $\vec{F}_{g\,E-B}$, which reads: "the force of gravity of the **earth** acting on the **book**". Using this notation we can write Newton's 3rd Law as: $\vec{F}_{A-B} = -\vec{F}_{B-A}$ with the understanding of the characteristics of a force-pair.



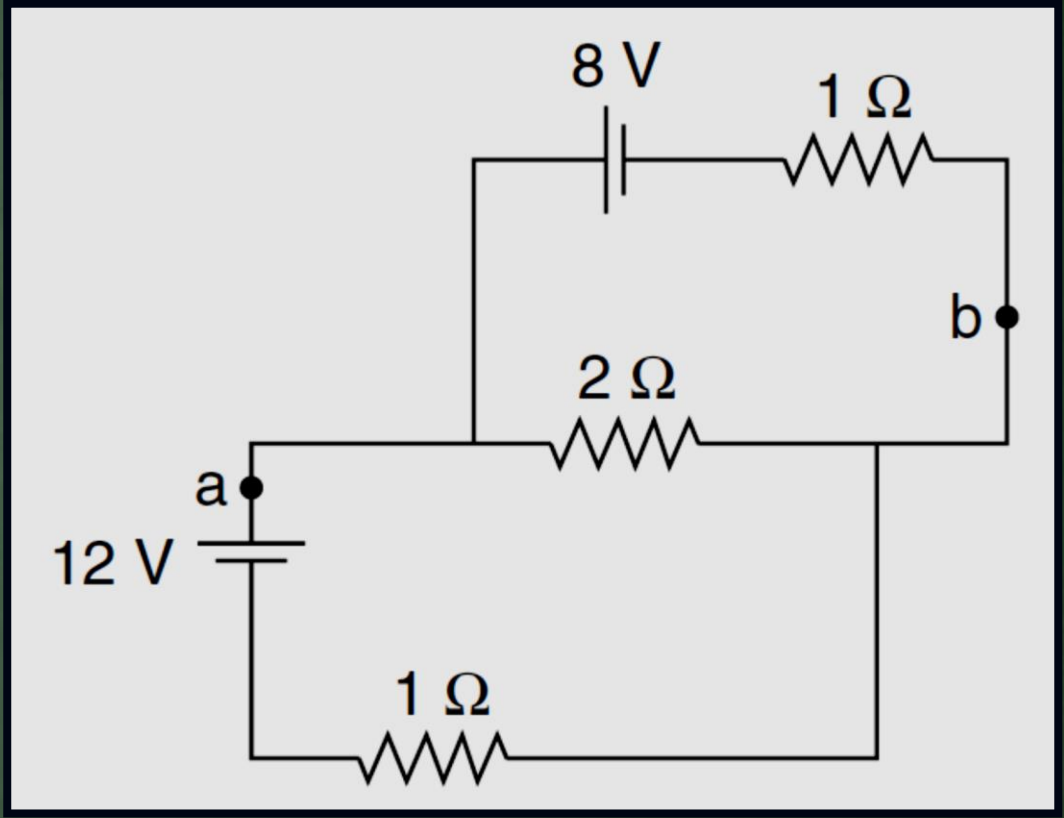

2. **Represent**. Label the forces in your force diagram using this new notation.

# STEM Education Goal:

**Experts prize sense-making**

# Exam Question #1

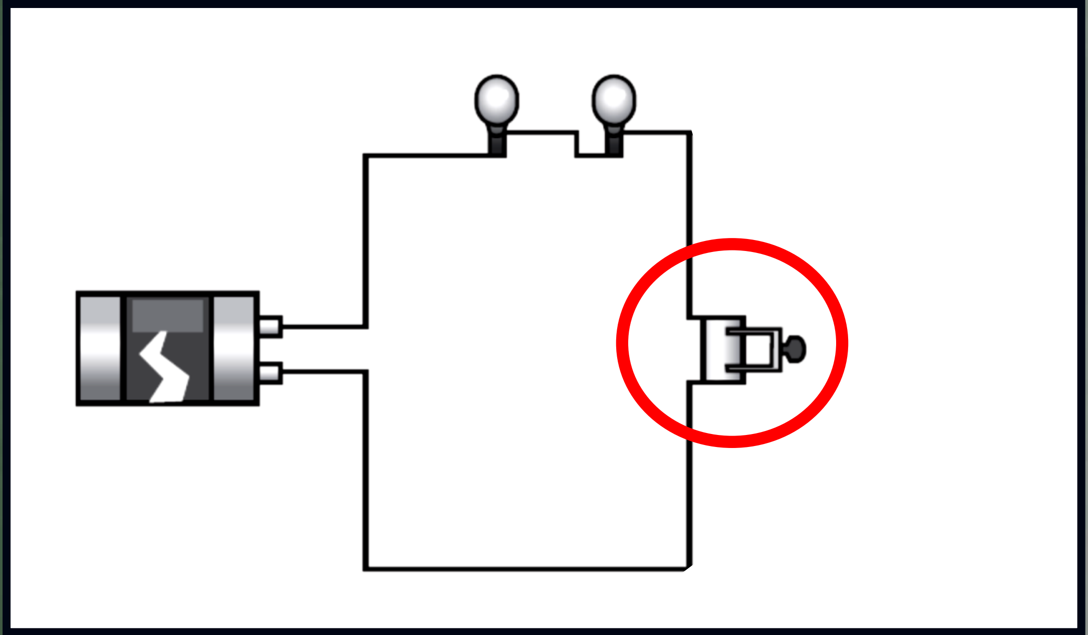
**Find the current through the 2 ohm resistor and the potential difference between point a and b.**




**Average = 75%**

# Exam Question #2

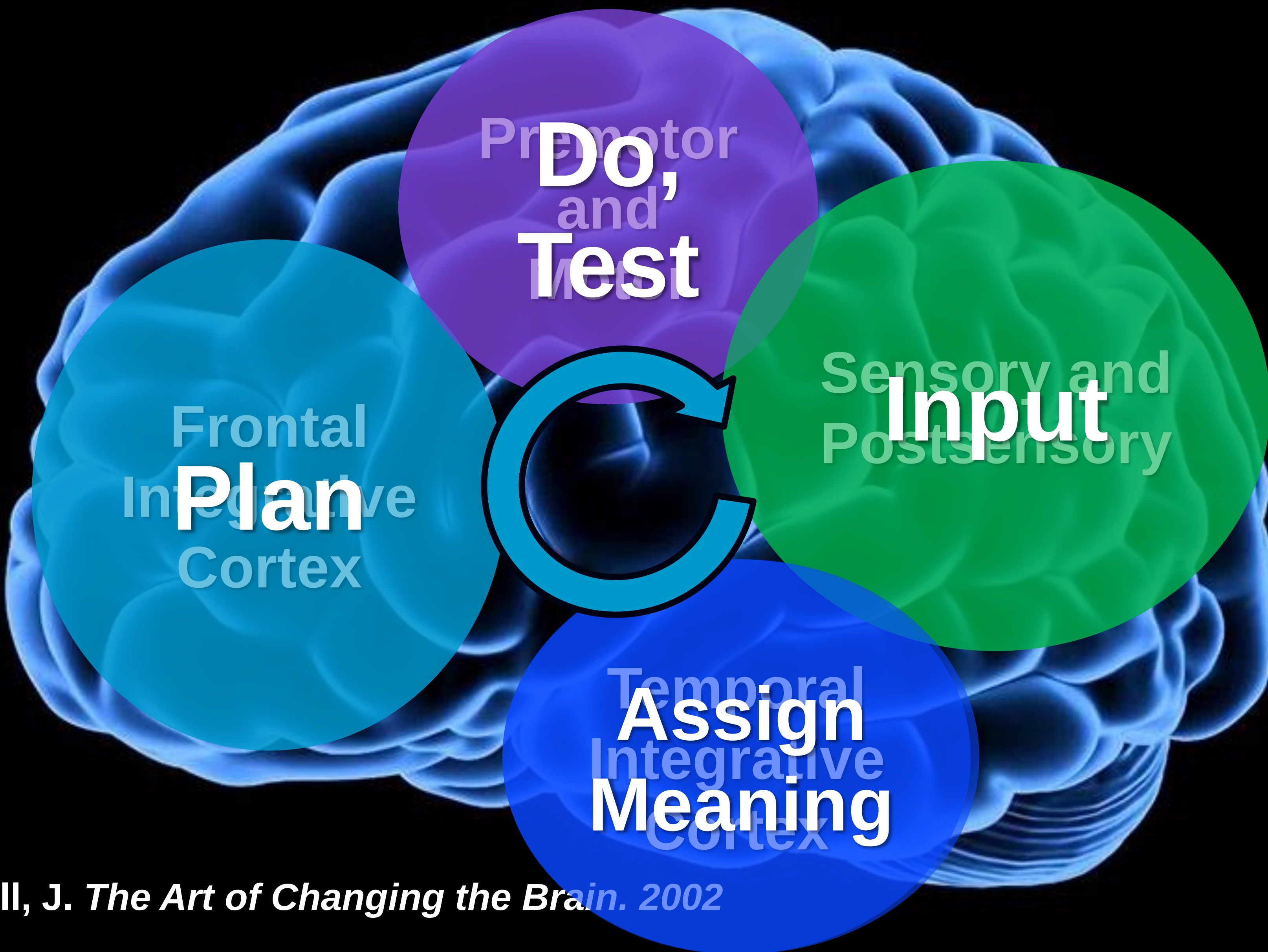
When the switch is closed,
what happens to:
(a) the current through the battery
(b) the brightness of the bulbs



Average = 40%

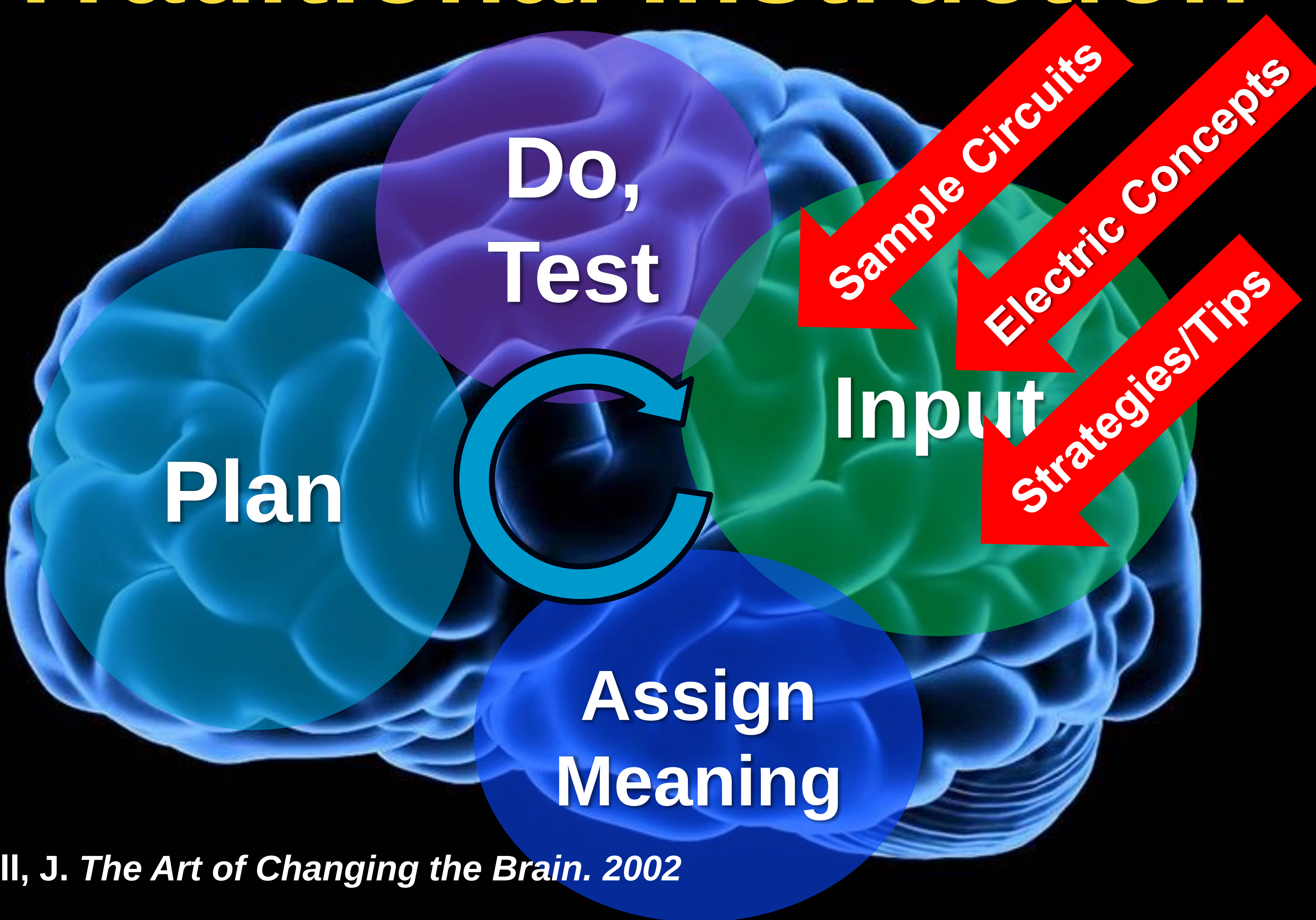
Yikes!

# Cognitive Learning Cycle



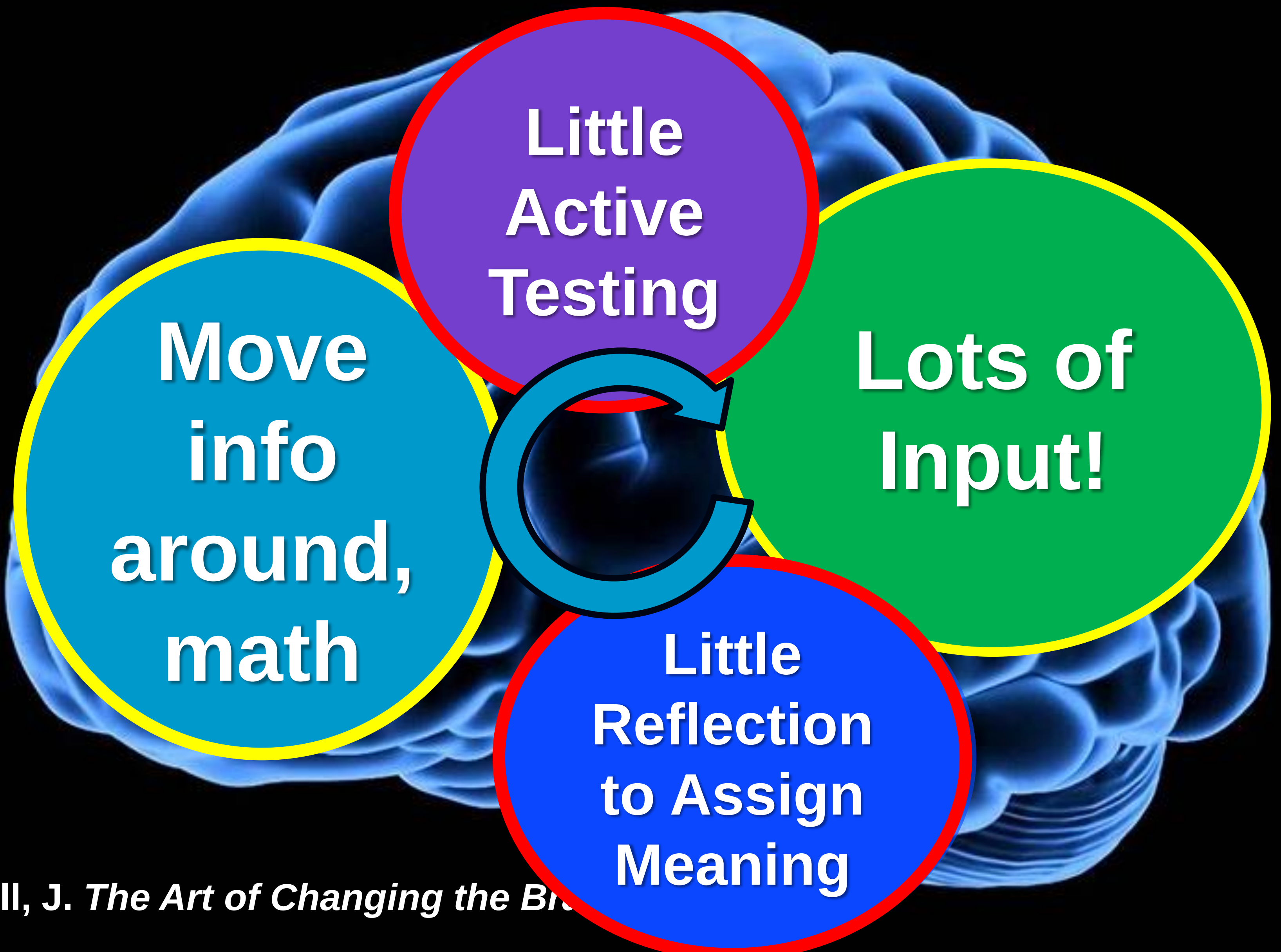

Zull, J. *The Art of Changing the Brain.* 2002

# Traditional Instruction




Zull, J. *The Art of Changing the Brain.* *2002*

# Traditional Instruction




Zull, J. *The Art of Changing the Br*

# Lesson on “Oomph”

# Lesson on "Oomph"

## SPH4U: "Oomph"

Recorder:
Manager:
Speaker:

When you catch a heavy object you feel a lot of "Oomph". What is this mysterious quantity that we all kind of know? Let's find out.

### A: Figuring Out the Formula for Oomph!

The more oomph something has, the harder it is to stop, and the more ability it has to knock ot
out the formula for oomph.

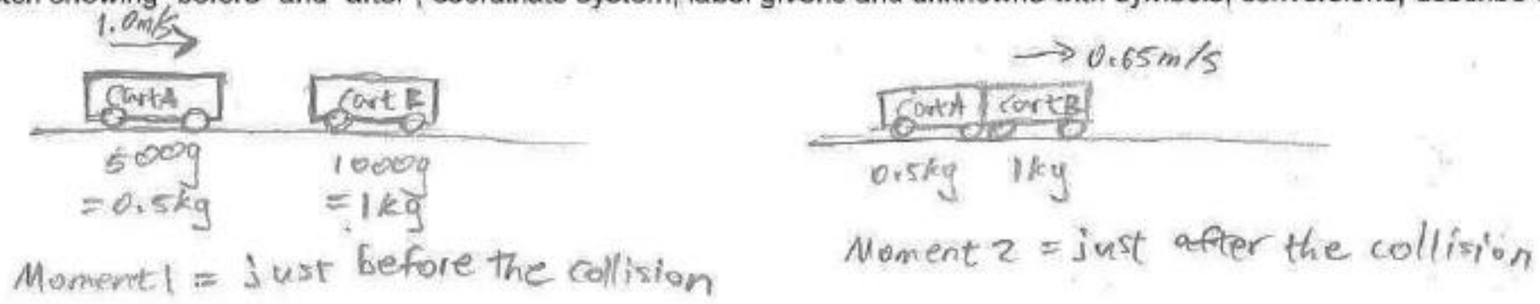
1. **Reason.** A small pebble and a larger rock are thrown at the same speed.
   (a) Which one has more oomph? Why?

   (b) The rock is twice as massive as the pebble. Intuitively, how does the rock's oom
   oomph? Is it twice as big? Half as big? Three times as big?

# Sense-Making Tools

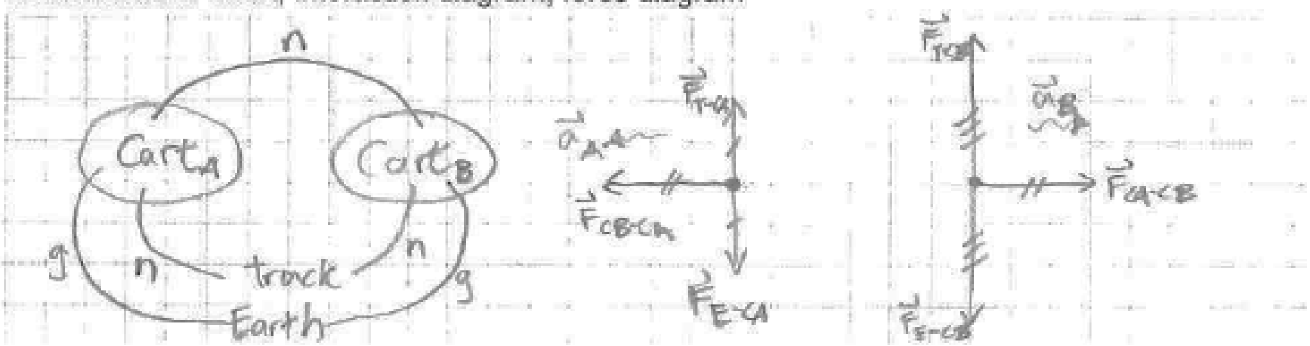
**A: Pictorial Representation**

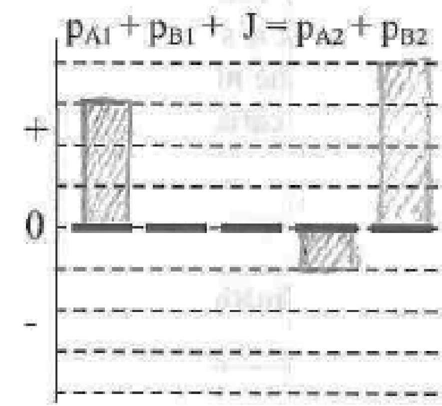
Sketch showing "before" and "after", coordinate system, label givens and unknowns with symbols, conversions, describe events




**B: Physics Representation**

momentum bar chart, interaction diagram, force diagram




**Calculate.** Now calculate the 500 g car's speed and direction of motion after the collision. Use the bar chart to help construct your momentum equation (leave out any

# Sense-Making Before Math

## D: Mathematical Representation

Complete equations, describe steps, algebraic work, substitutions with units, final statement

Find the velocity of cart A after the collision by using momentum equation:

$$p_{A1} = p_{A2} + p_{B2}$$

$$m_A v_{A1} = m_A v_{A2} + m_B v_{B2}$$

$$v_{A2} = \frac{m_A v_{A1} - m_B v_{B2}}{m_A}$$

$$= \frac{(0.5\,kg)(1.0\,m/s) - (1.0\,kg)(0.65\,m/s)}{0.5\,kg}$$

$$= -0.3\,m/s$$

∴ The 500g cart will travel 0.3 m/s west after the collision.

## E: Evaluation

Answer has reasonable size, direction and units? Why?

Answer has reasonable size because the magnitude of the cart's resulting velocity in the negative direction is less than that of the original velocity since the 500g cart gave momentum to the 1000g cart. Answer is negative because cart is traveling in negative direction, and m/s is appropriate for speed.

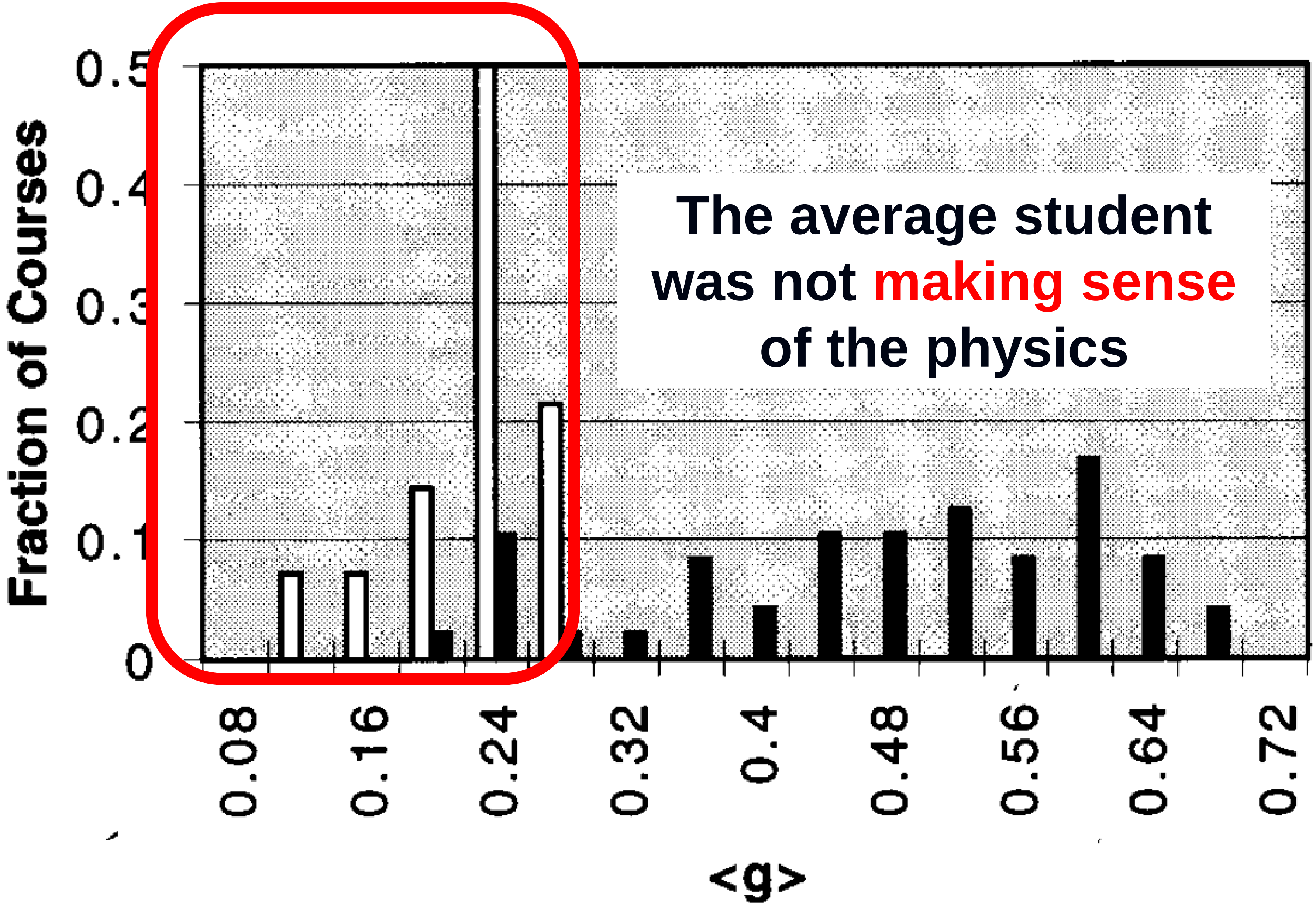
**Test.** Set up this situation on your track and try it out. Does our momentum law work?

The test proved that our momentum law does work.

# Understanding First

## Math Second

**(math makes understanding more precise)**



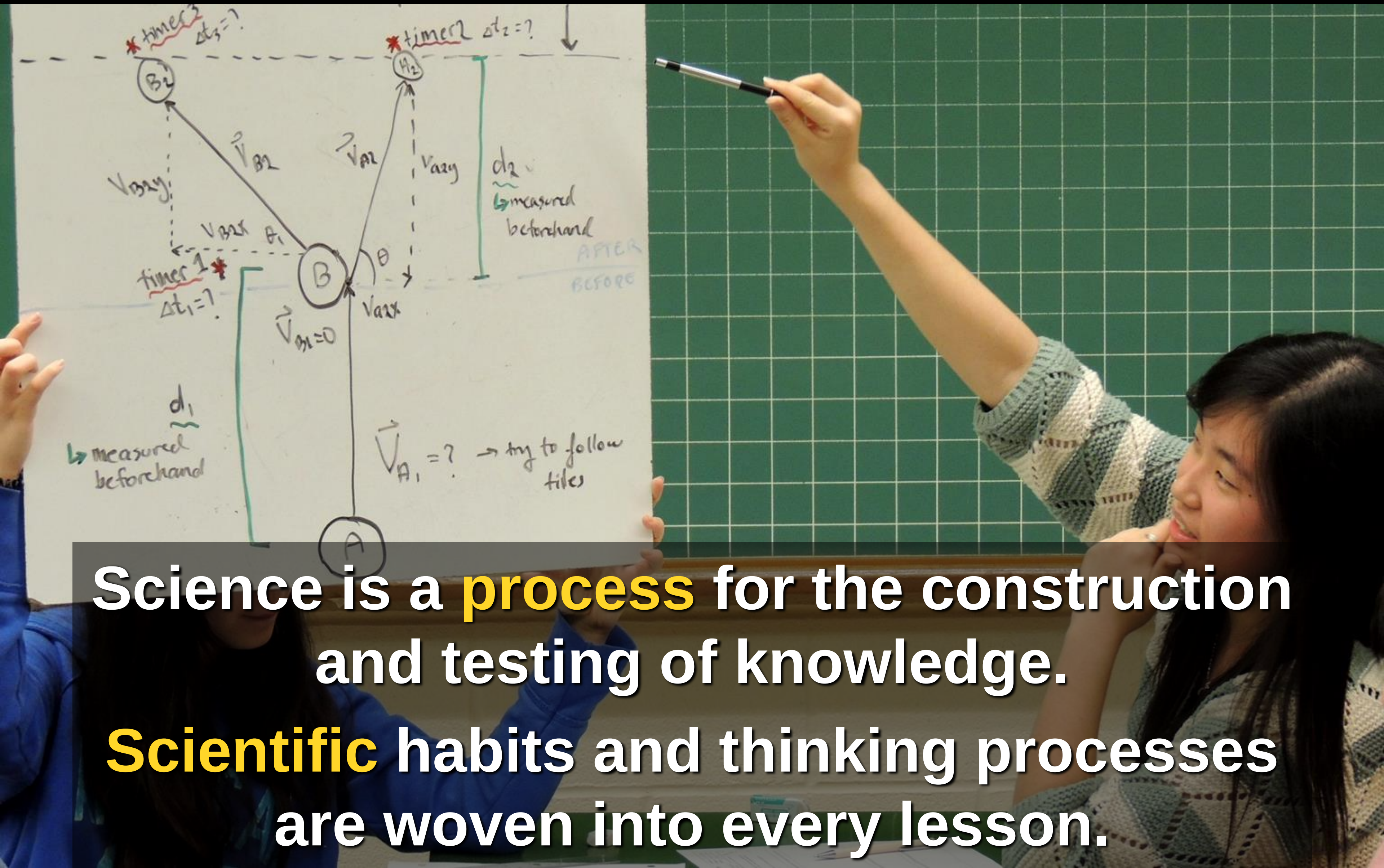

Hake, Richard R. "Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses." *American journal of Physics* 66.1 (1998): 64-74.

# Understanding First

Teachers can't **give** students understanding.

Students must **explore** and **construct** their own understanding.

# Bonus: Doing Science!



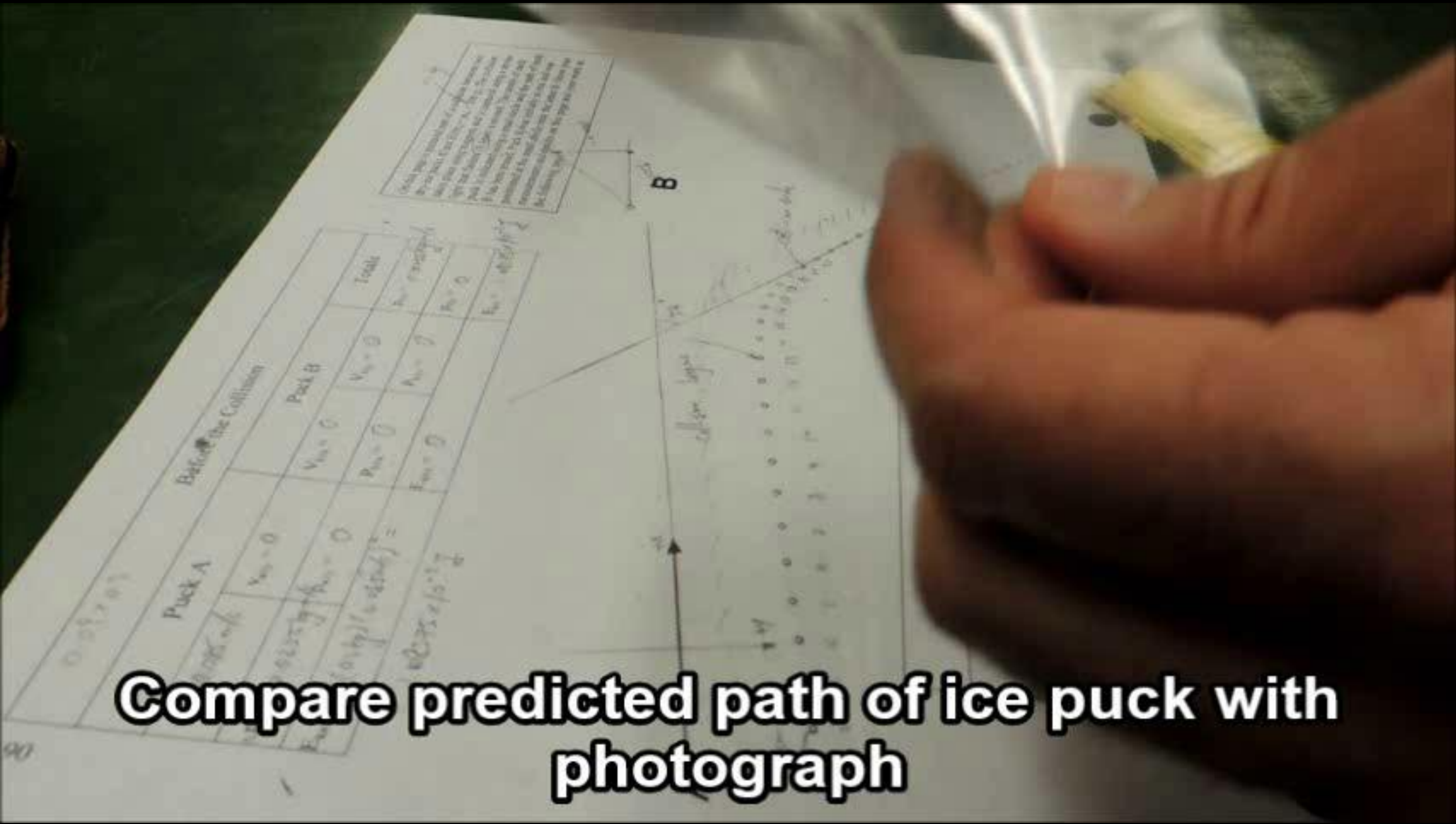

**Science is a process for the construction and testing of knowledge.**

**Scientific habits and thinking processes are woven into every lesson.**

# STEM Education Goal:

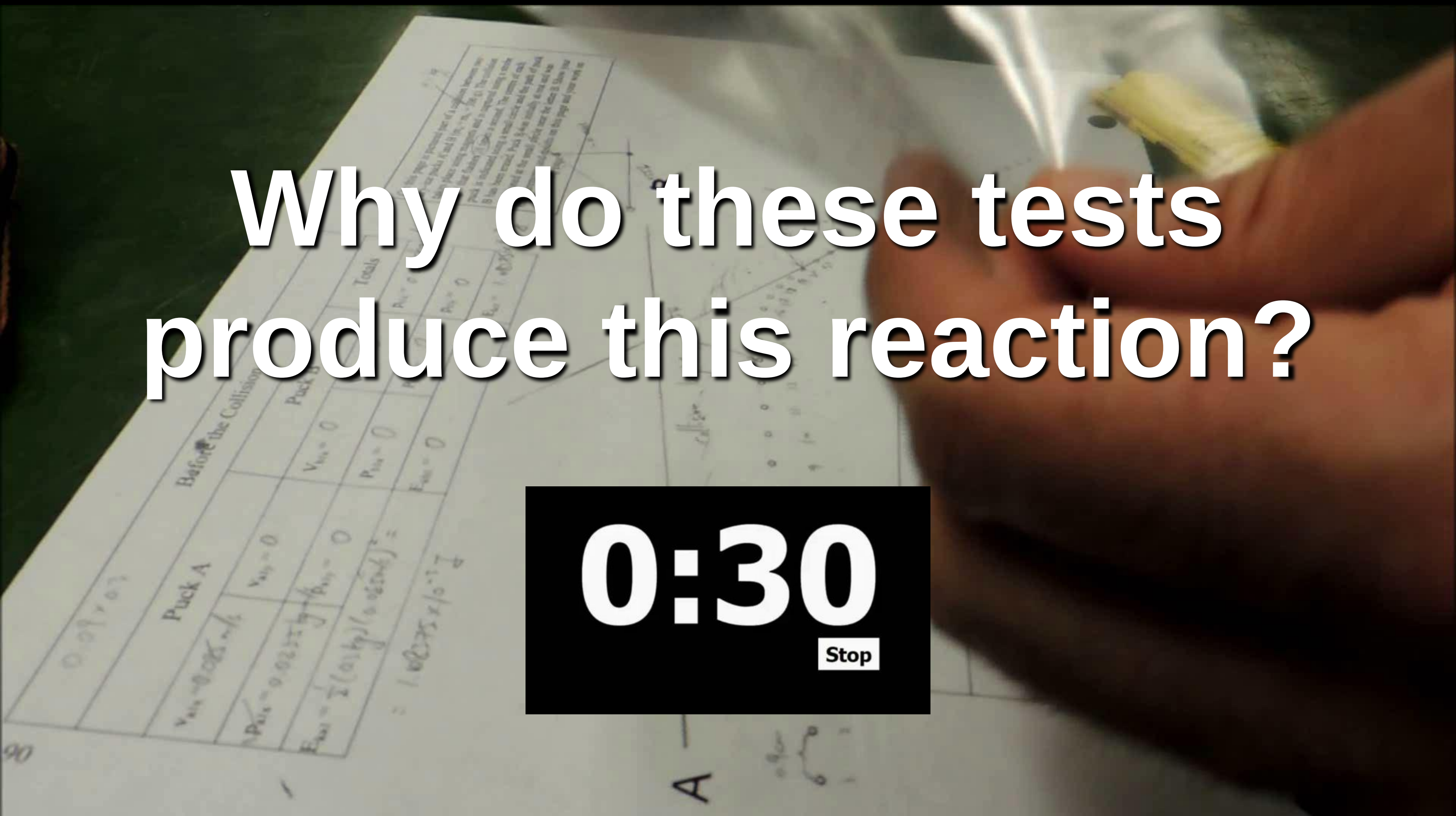
## Experts test and refine own knowledge

# Test!




**Compare predicted path of ice puck with photograph**

# Test!

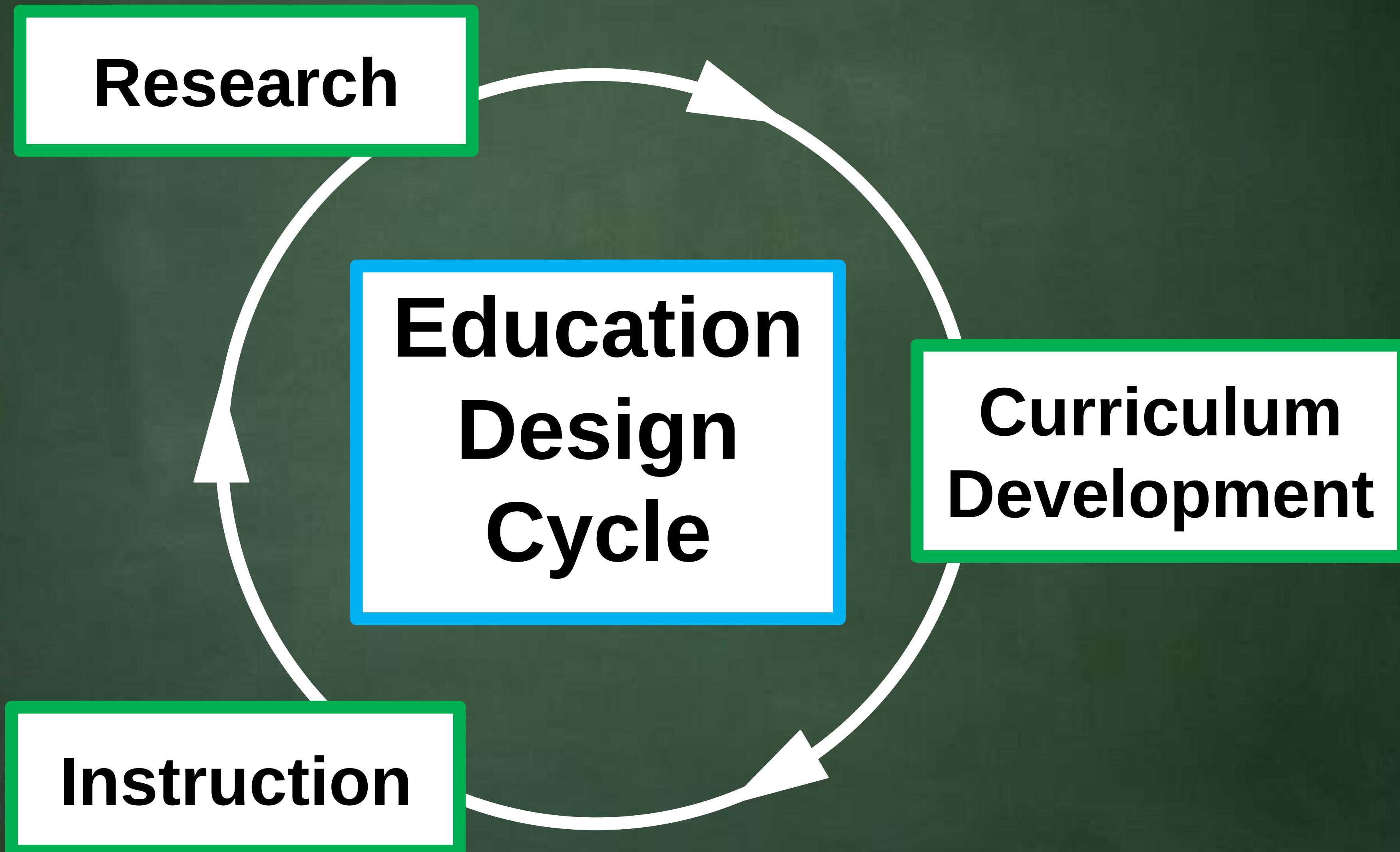


## Why do these tests produce this reaction?

0:30

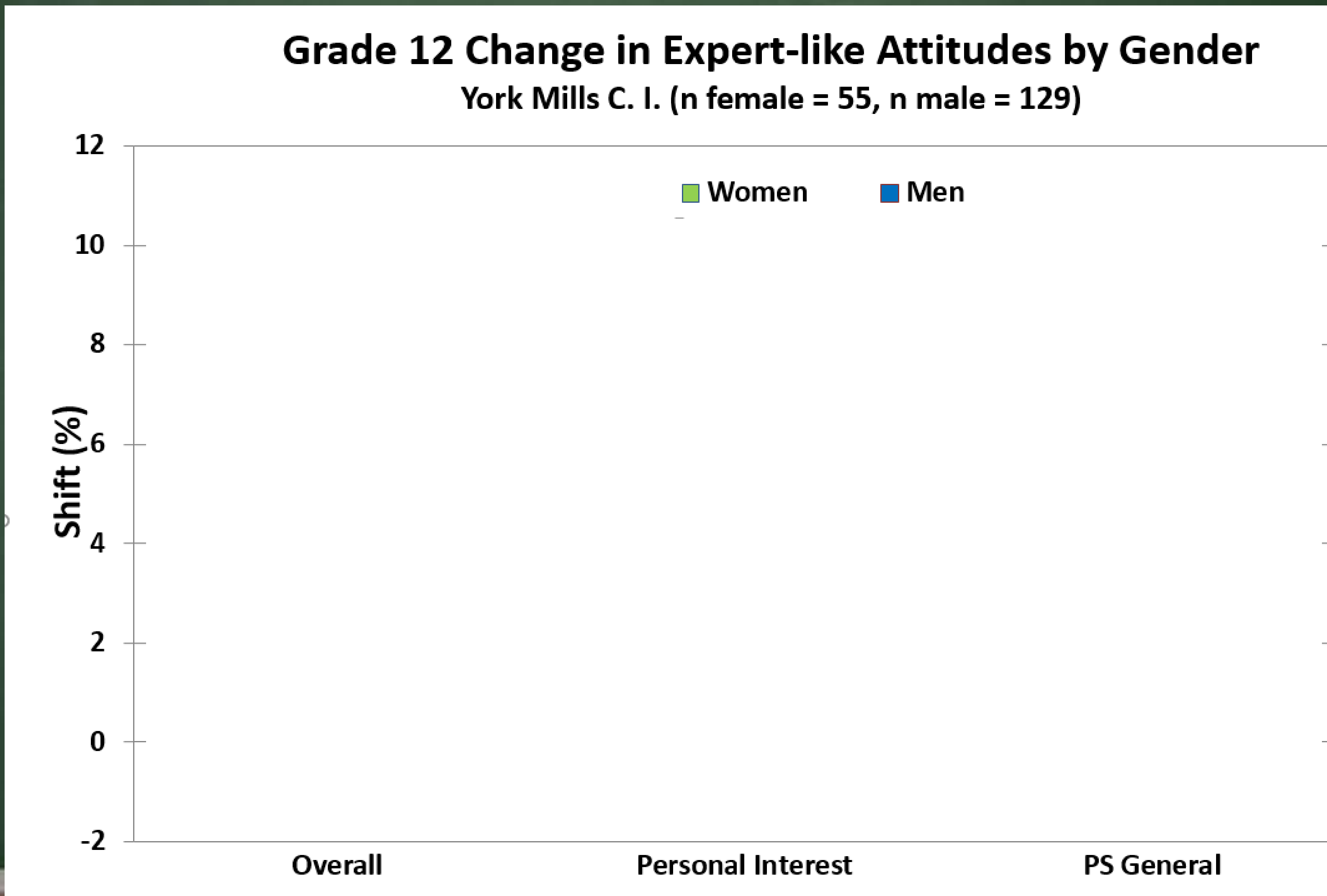
Stop

# Does All This Work?

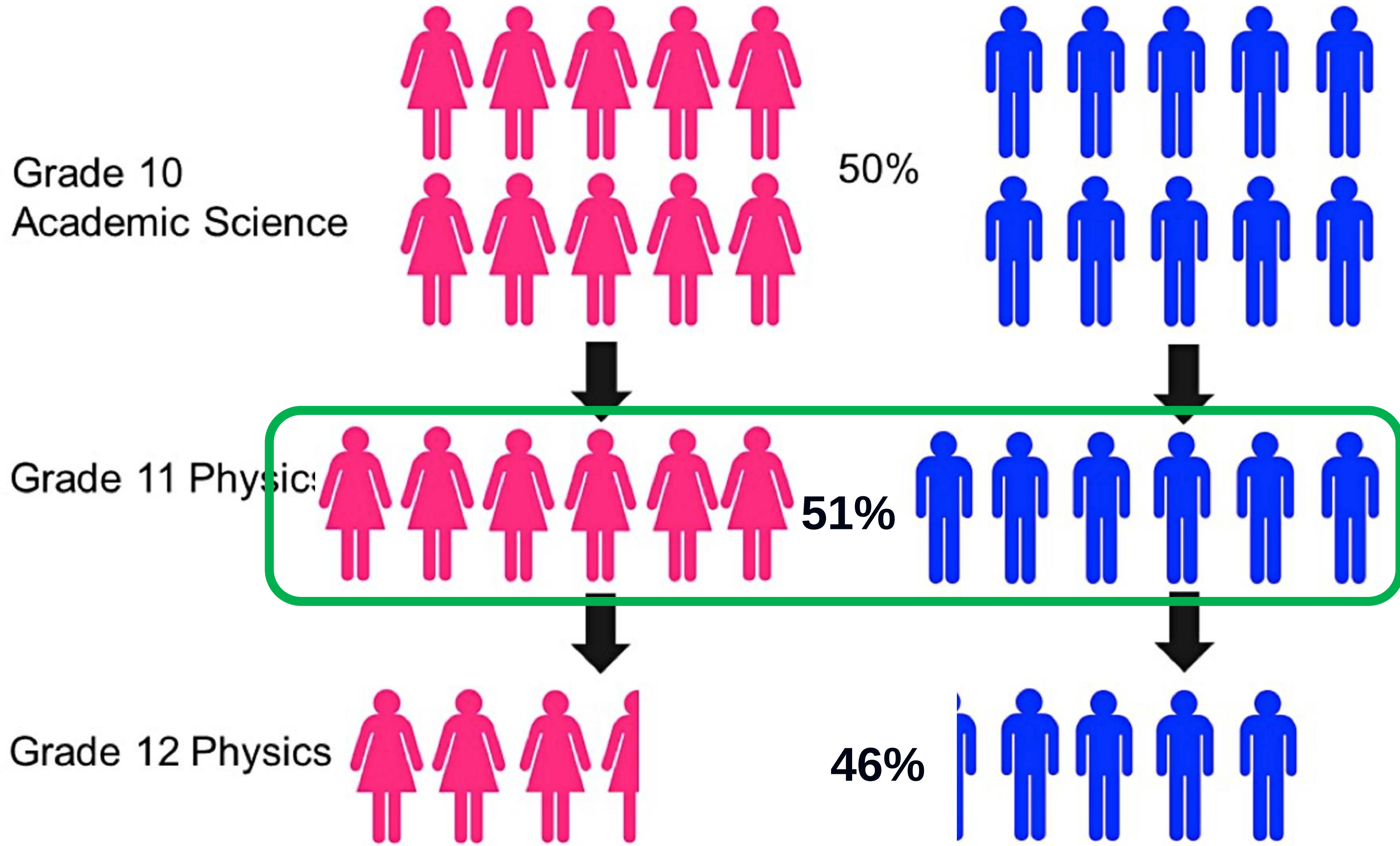


# Attitudes About Physics

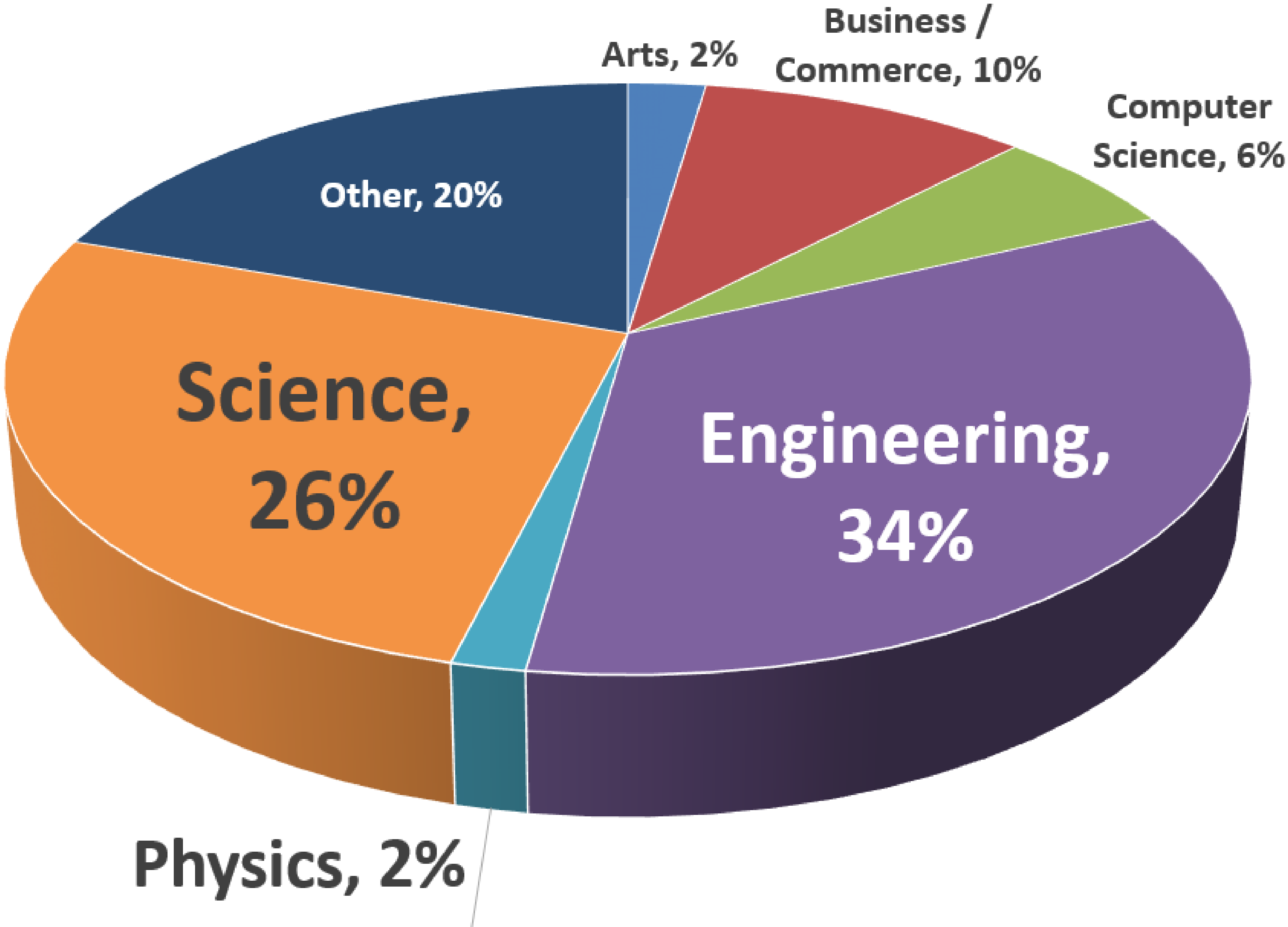
## Colorado Learning Attitudes Survey for Science



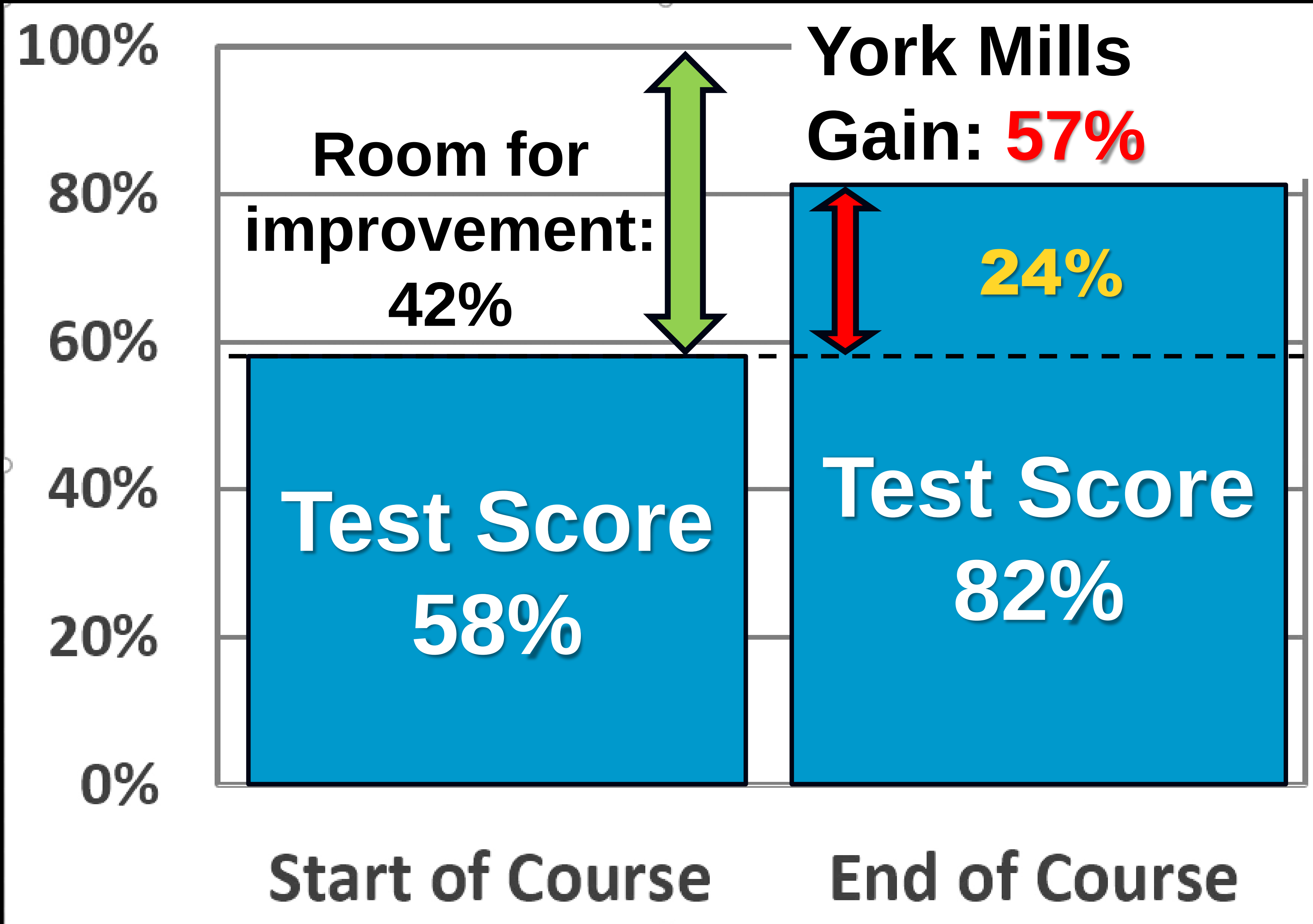
# Physics at York Mills 2018

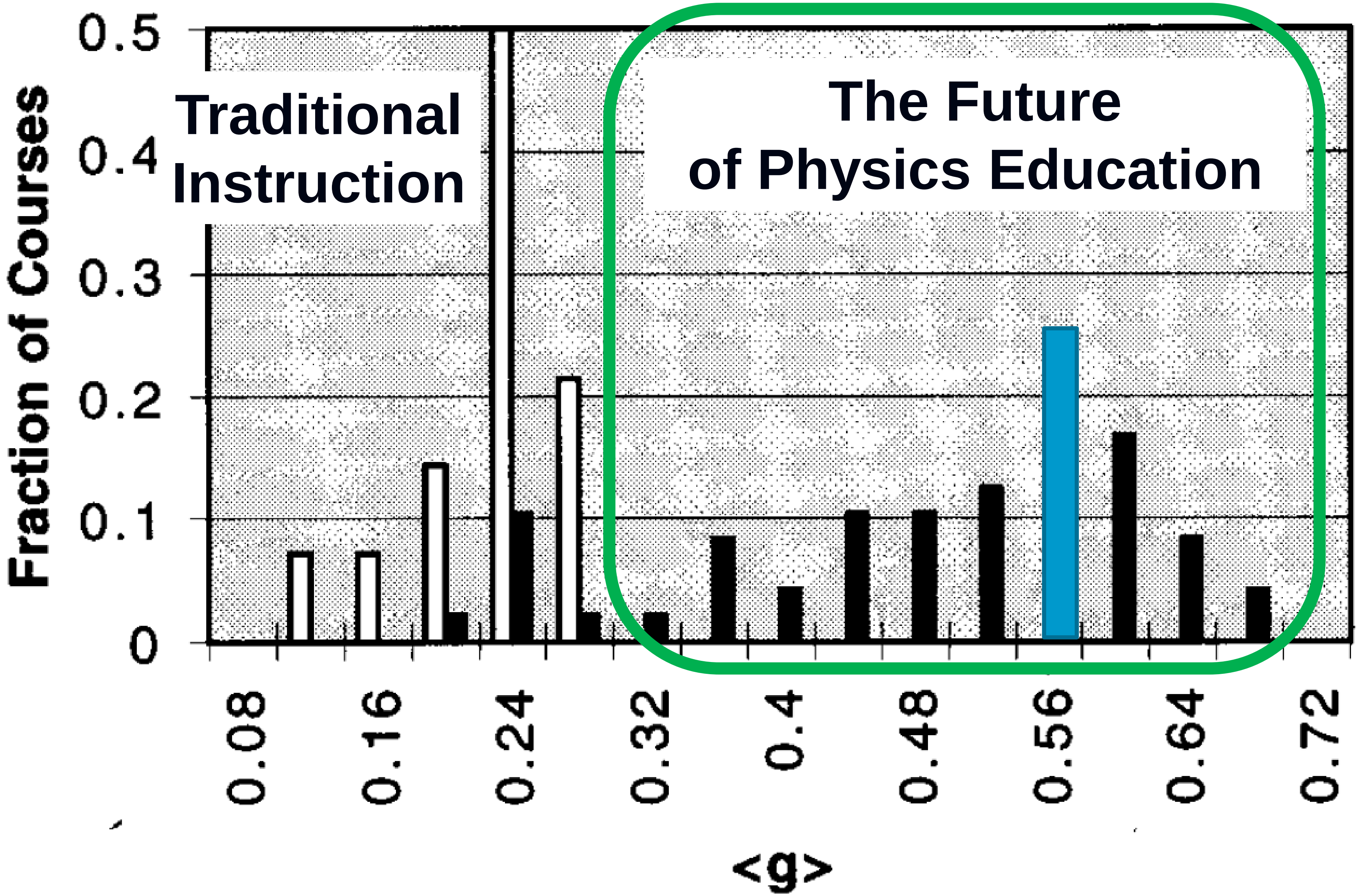


# York Mills Physics Student Career Paths



# Force Concept Inventory Scores



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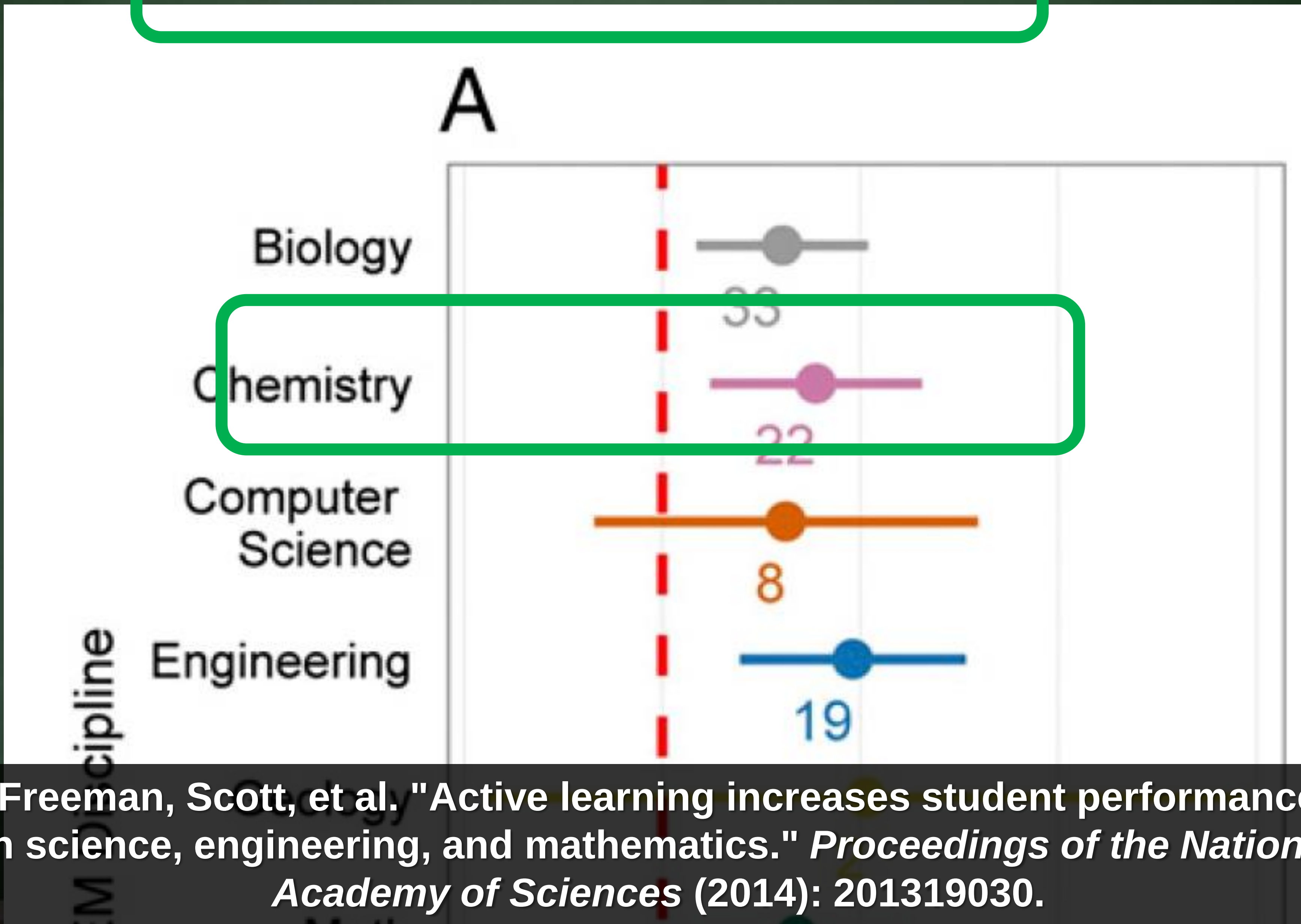
# Good For All STEM Disciplines

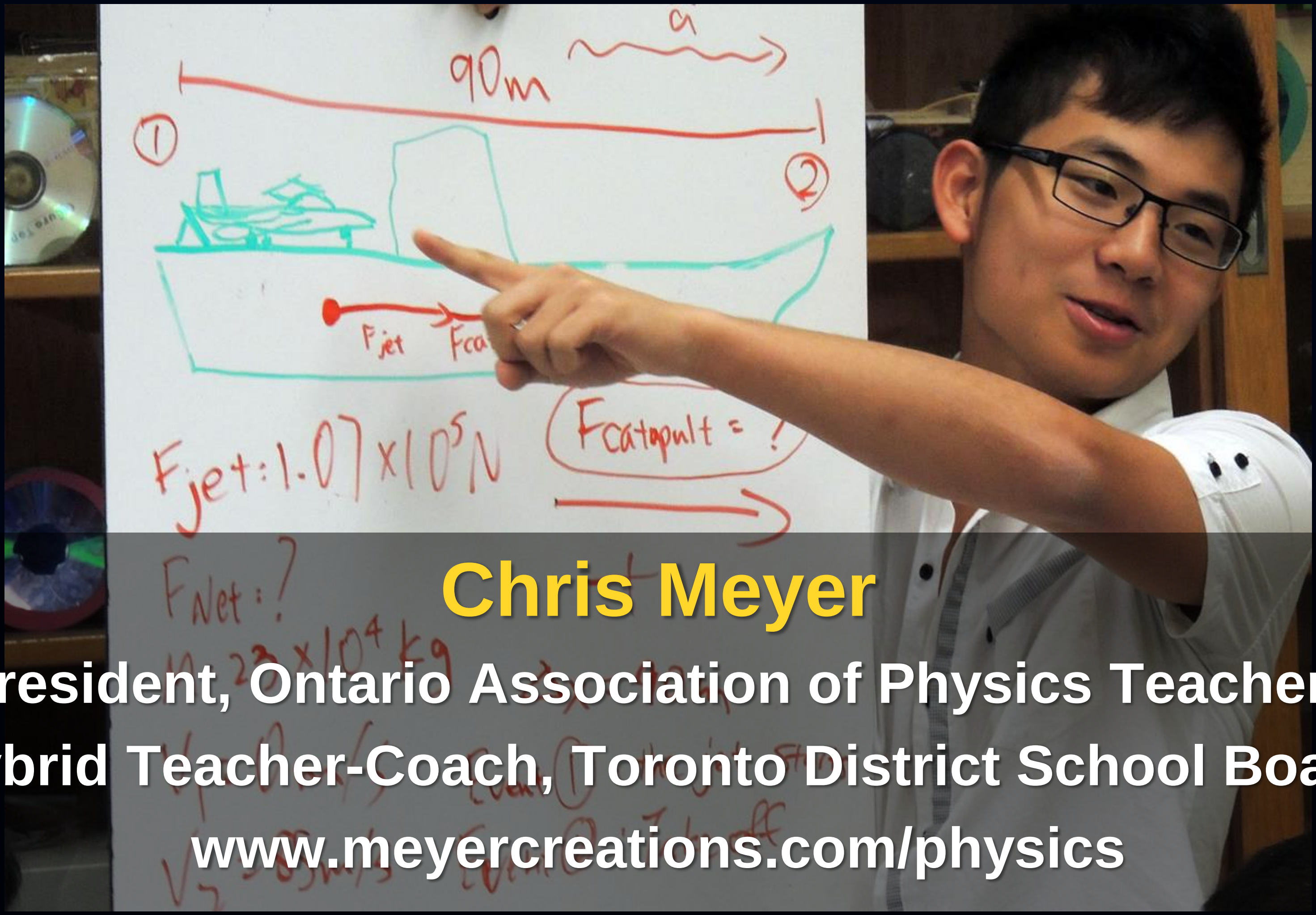



**Freeman, Scott, et al. "Active learning increases student performance in science, engineering, and mathematics." *Proceedings of the National Academy of Sciences* (2014): 201319030.**

# Advice for PEO and STEM

- Advocate for scientifically-informed pedagogy
- Connect with physics courses and teachers
- Target grade 10 students for immediate results

# The Future of Physics Education




**Chris Meyer**

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