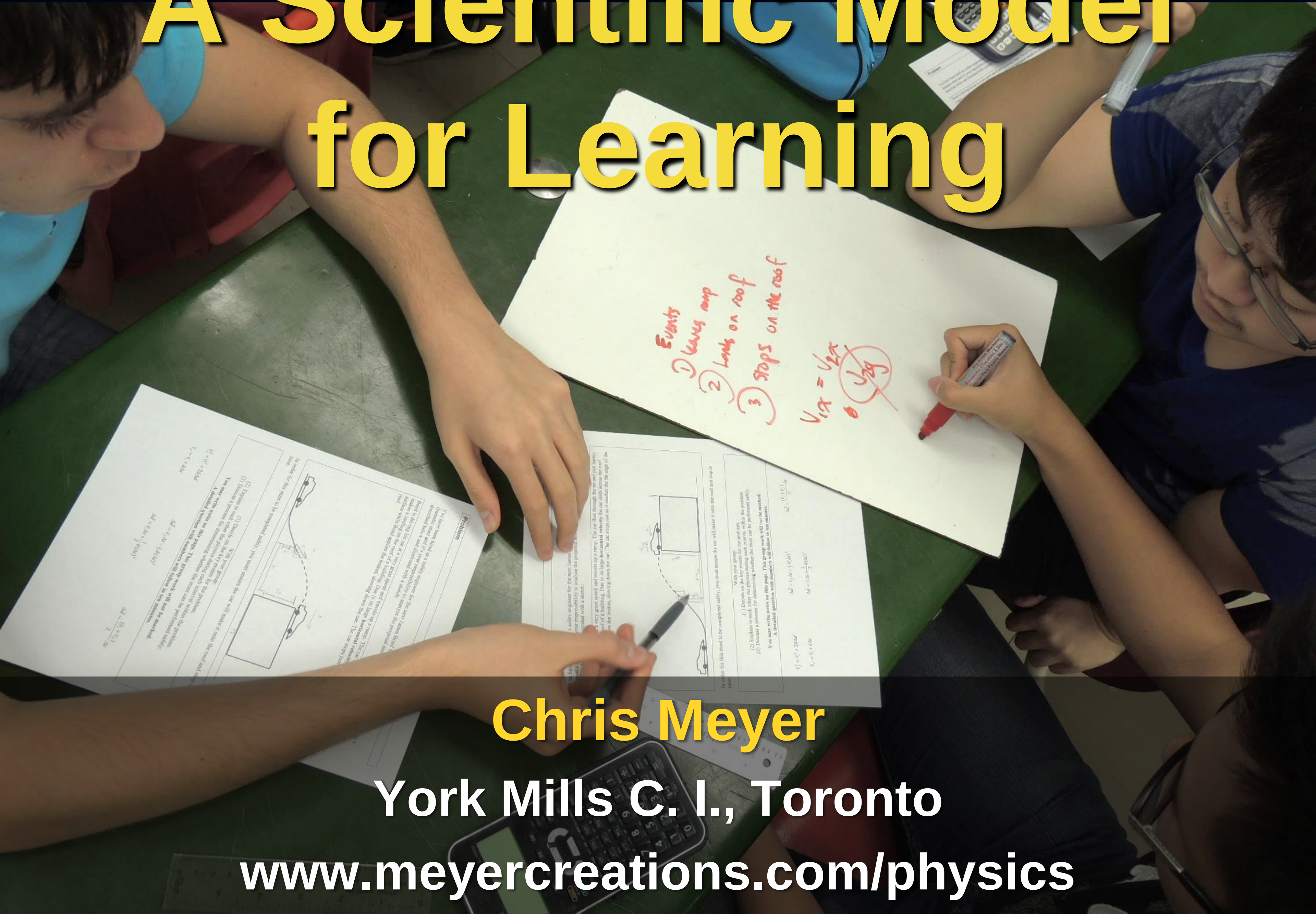
A Scientific Model for Learning



Chris Meyer

York Mills C. I., Toronto

www.meyercreations.com/physics


You just finished your physics training …

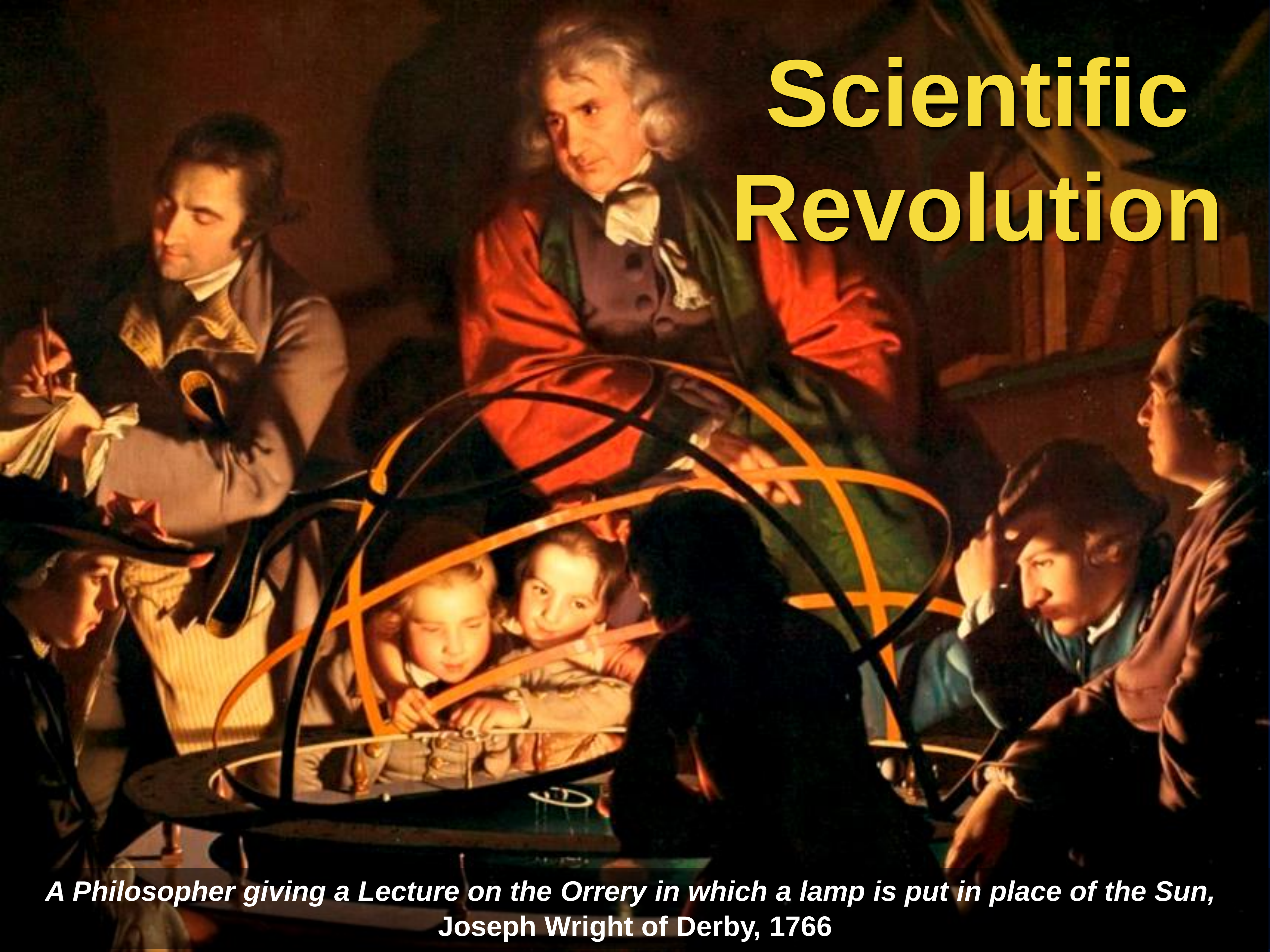
Casting Fortunes

The Dance of Death/Astrologer,
Hans Holbein, 1524

The Astrologer, Albrecht Durer, 1498

Tycho Brahe

Scientific Revolution

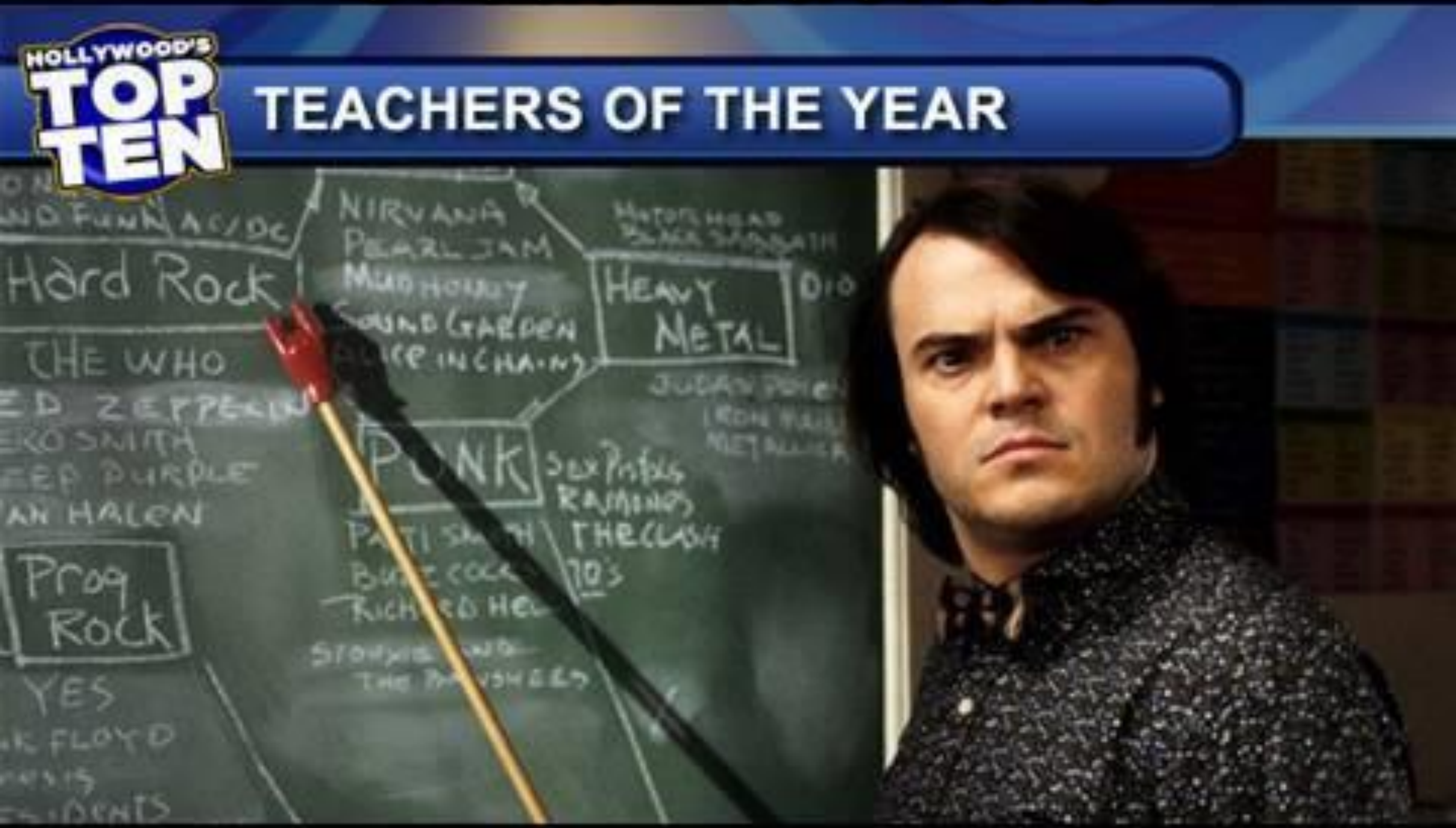


A Philosopher giving a Lecture on the Orrery in which a lamp is put in place of the Sun,
Joseph Wright of Derby, 1766

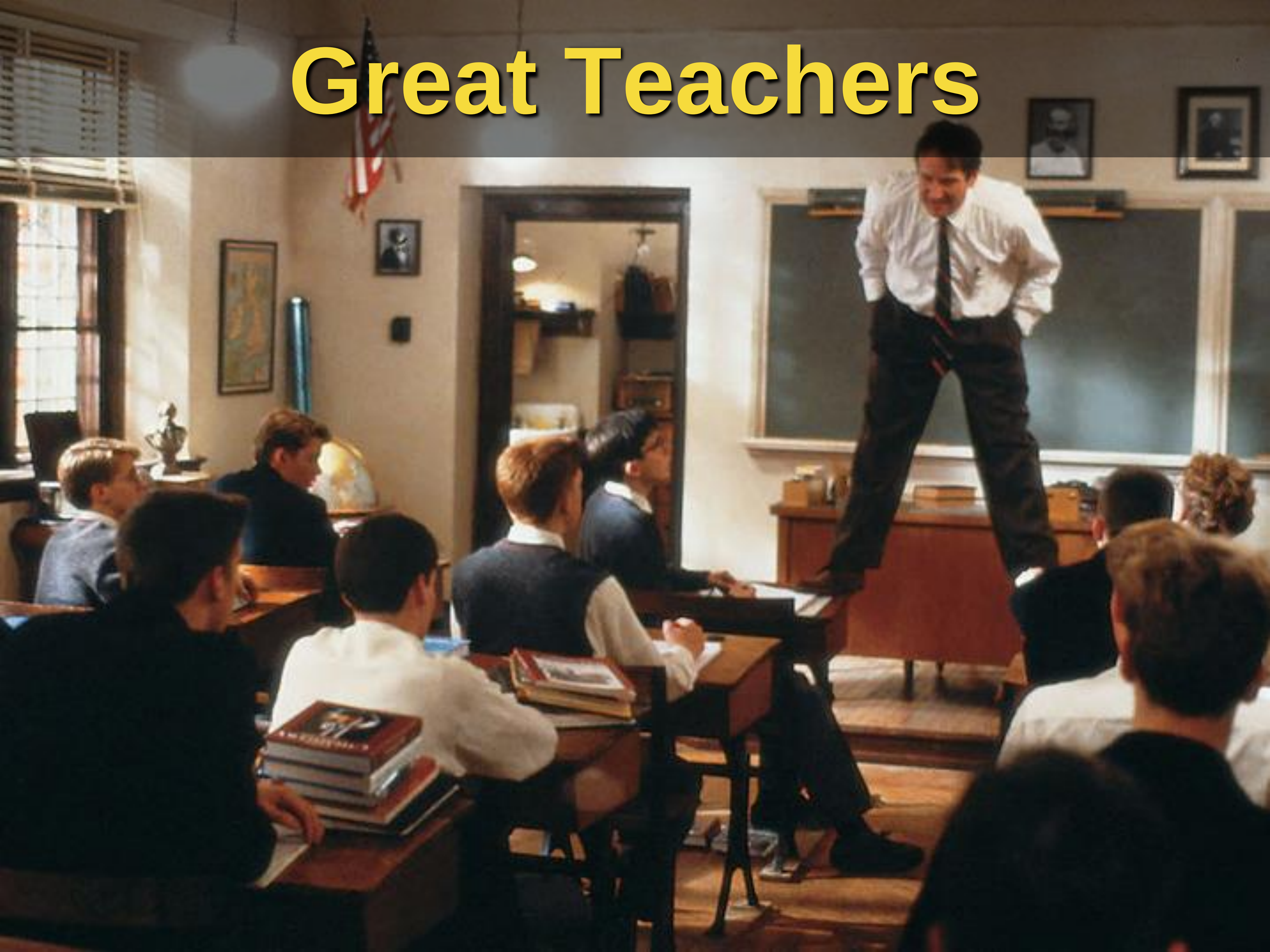
Sobriety of Empiricism

"The Noble Profession": Teaching

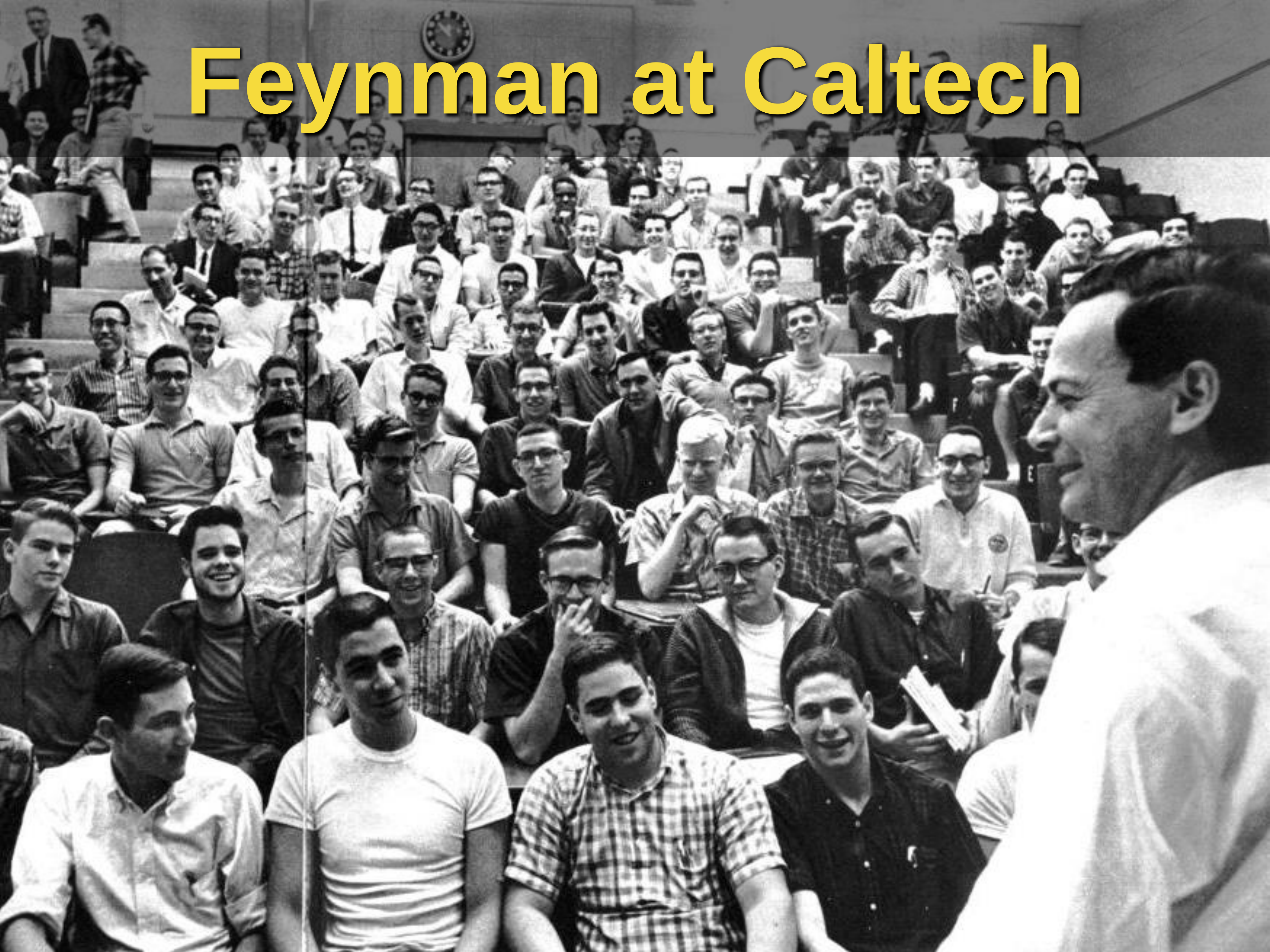
Great Teachers

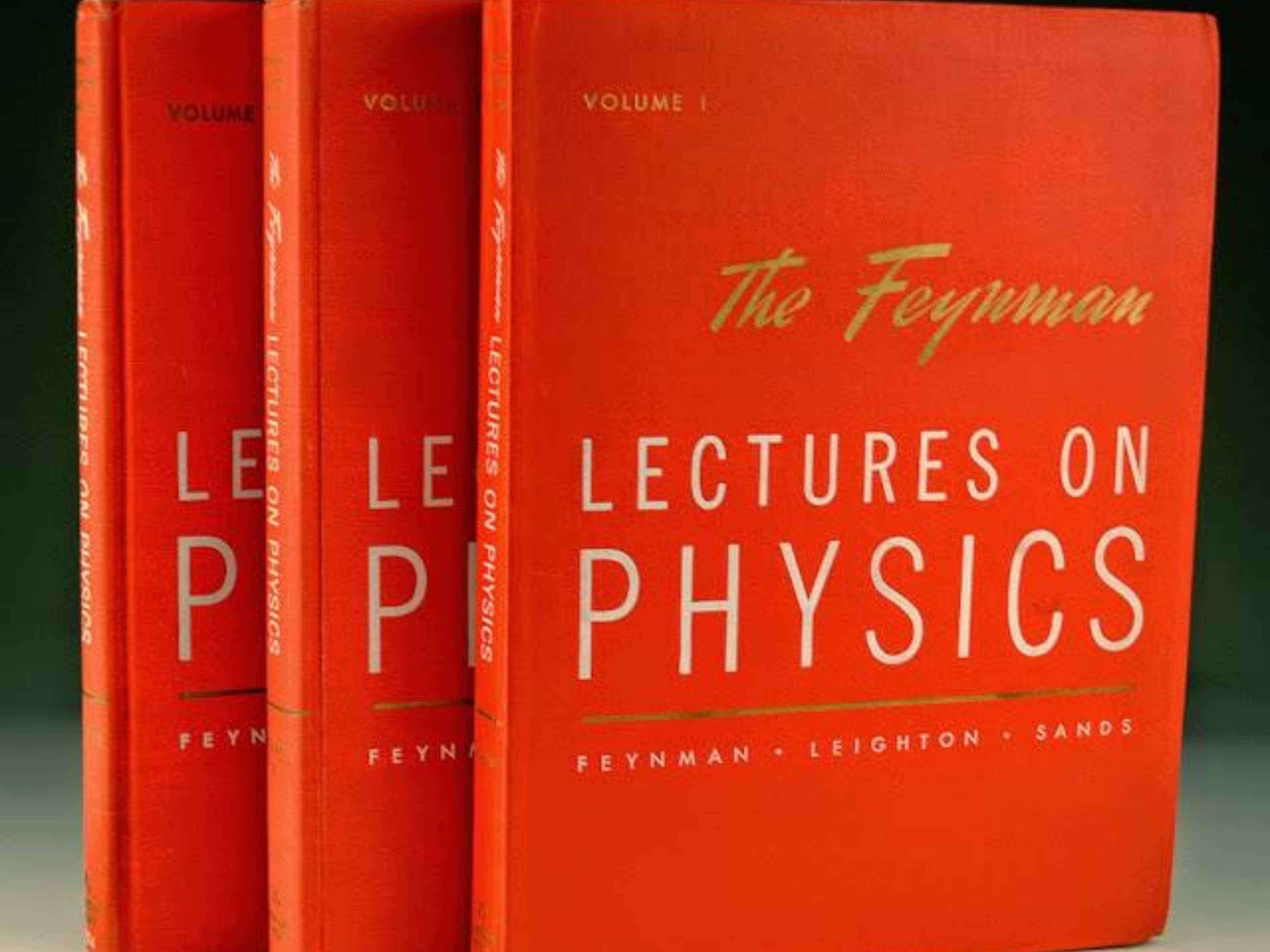


Great Teachers



Feynman at Caltech




VOLUME I
The Feynman
LECTURES ON PHYSICS
FEYNMAN · LEIGHTON · SANDS
The Feynman LECTURES ON PHYSICS
The Feynman LECTURES ON PHYSICS

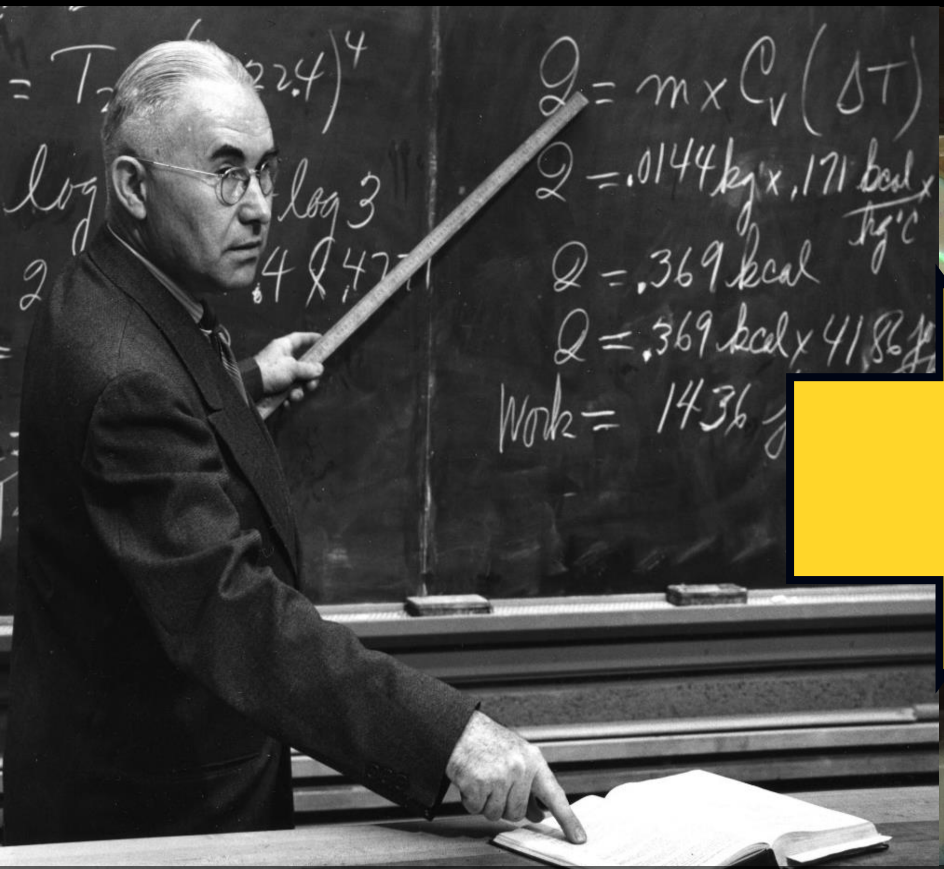
"… When I look at the examinations, I think that **the system is a failure.**"

"… there were **one or two dozen students** who—very surprisingly—understood almost everything … and they are, after all, **the ones I was trying to get at.**"

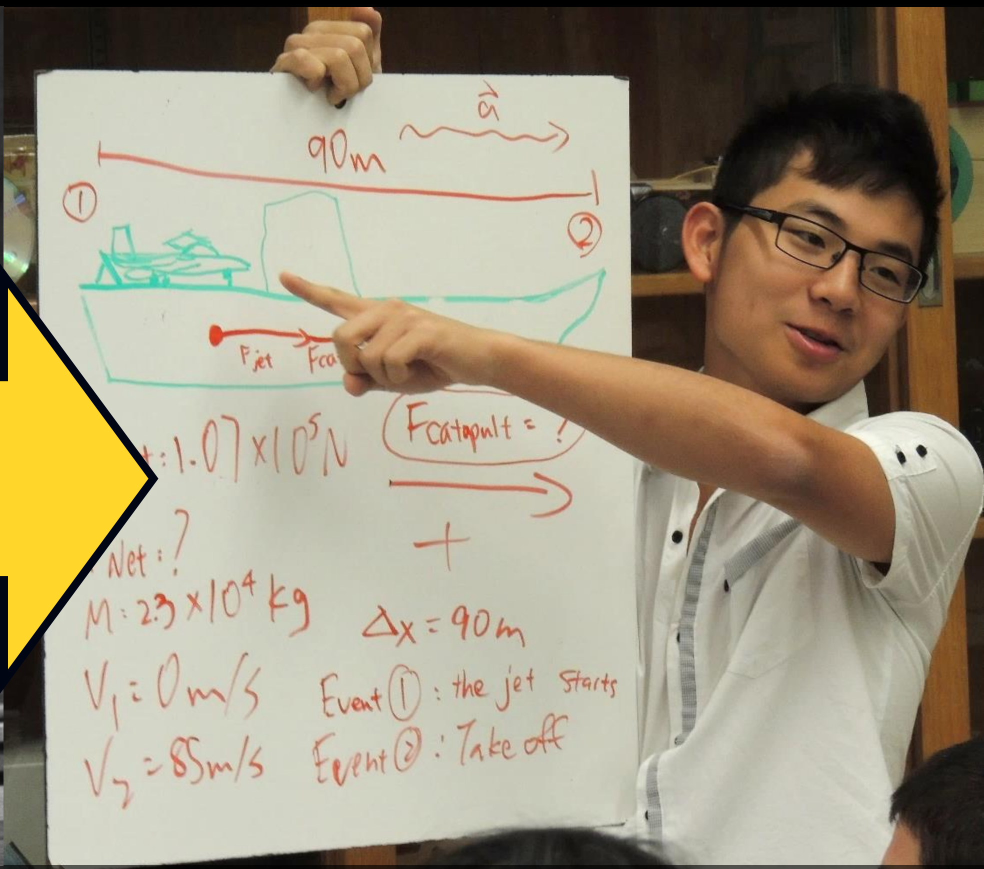
Success Criteria

How well is the material presented?

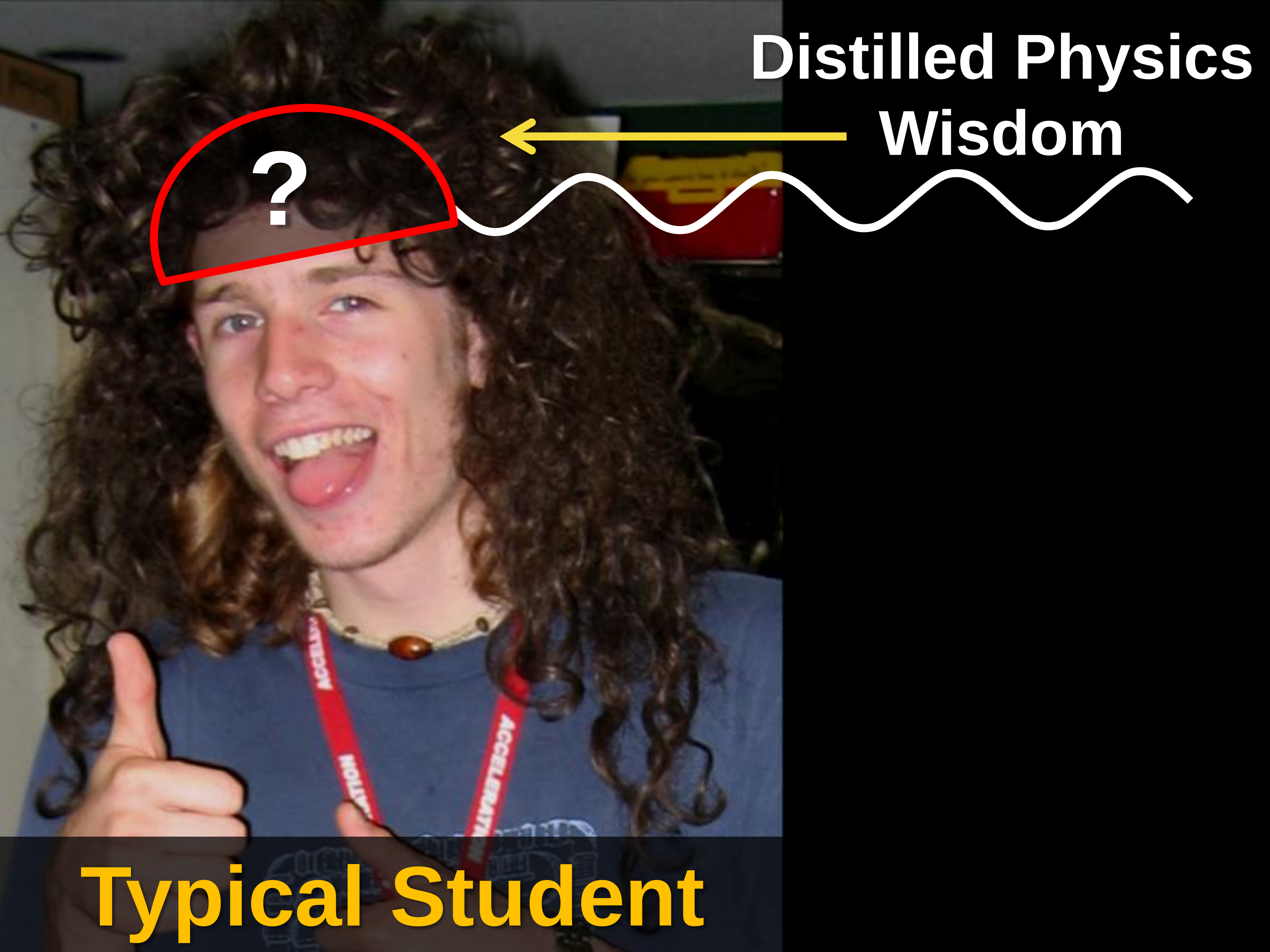
How well are students learning?



Internal logic = Aristotelian



Empirical results = Galilean

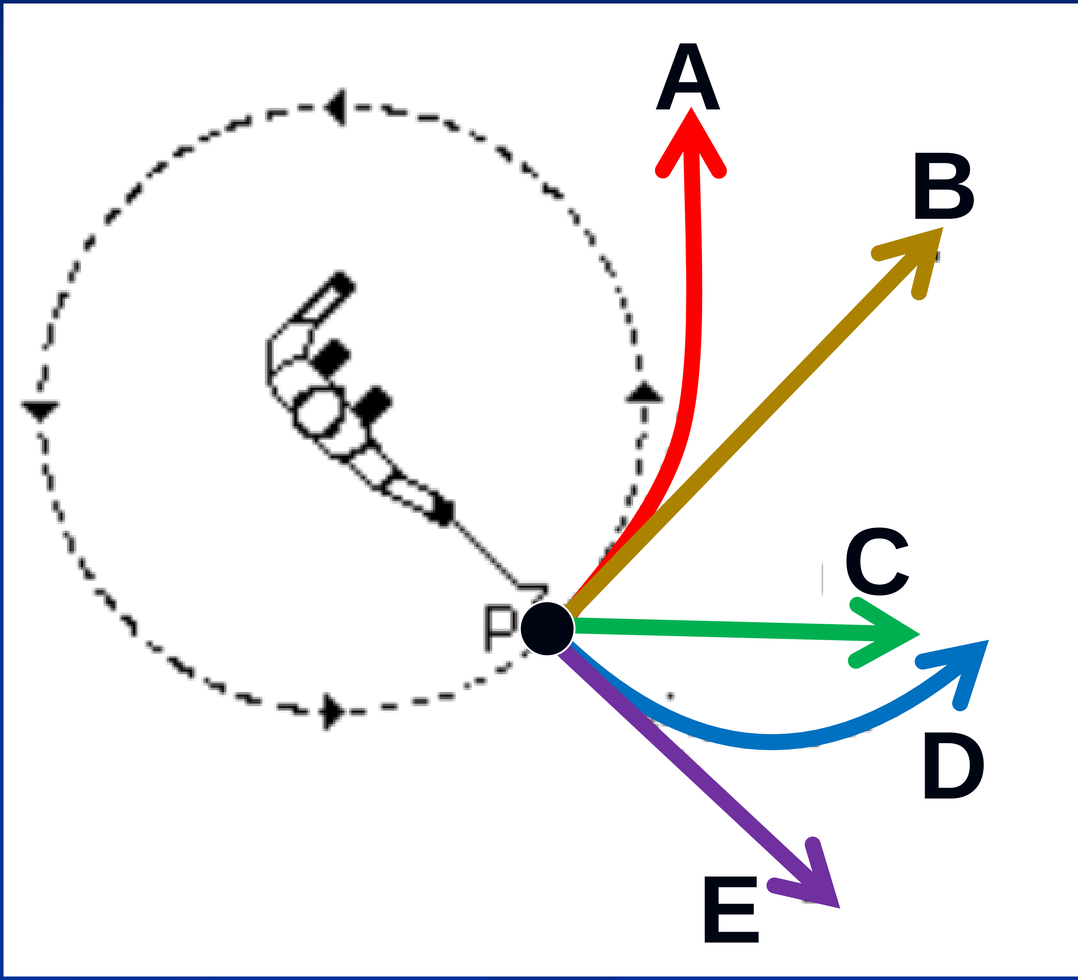

Distilled Physics
Wisdom
?
Typical Student

Question Time!

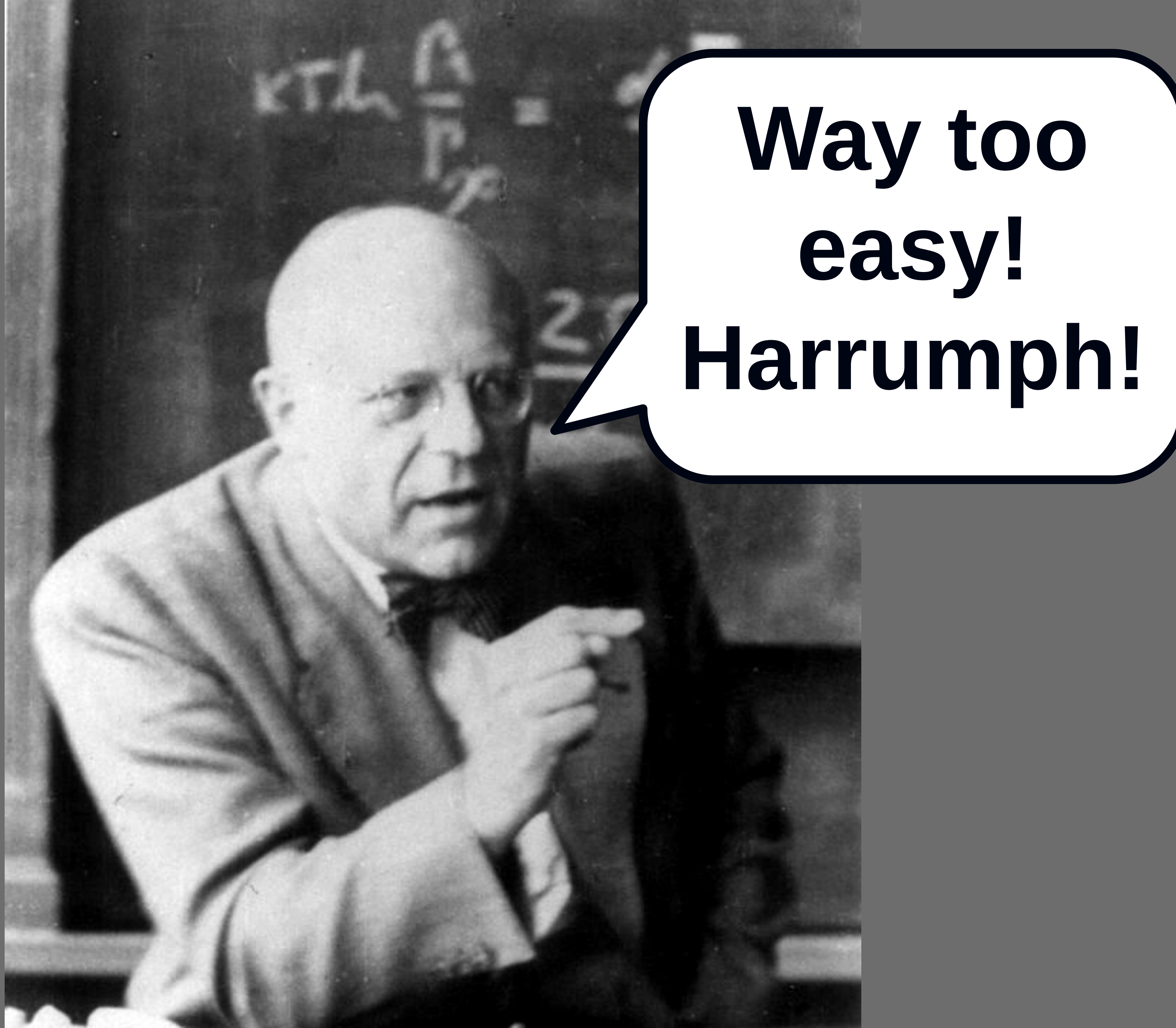
A ball on a string is swung in a horizontal circle.

At point P, the string breaks.

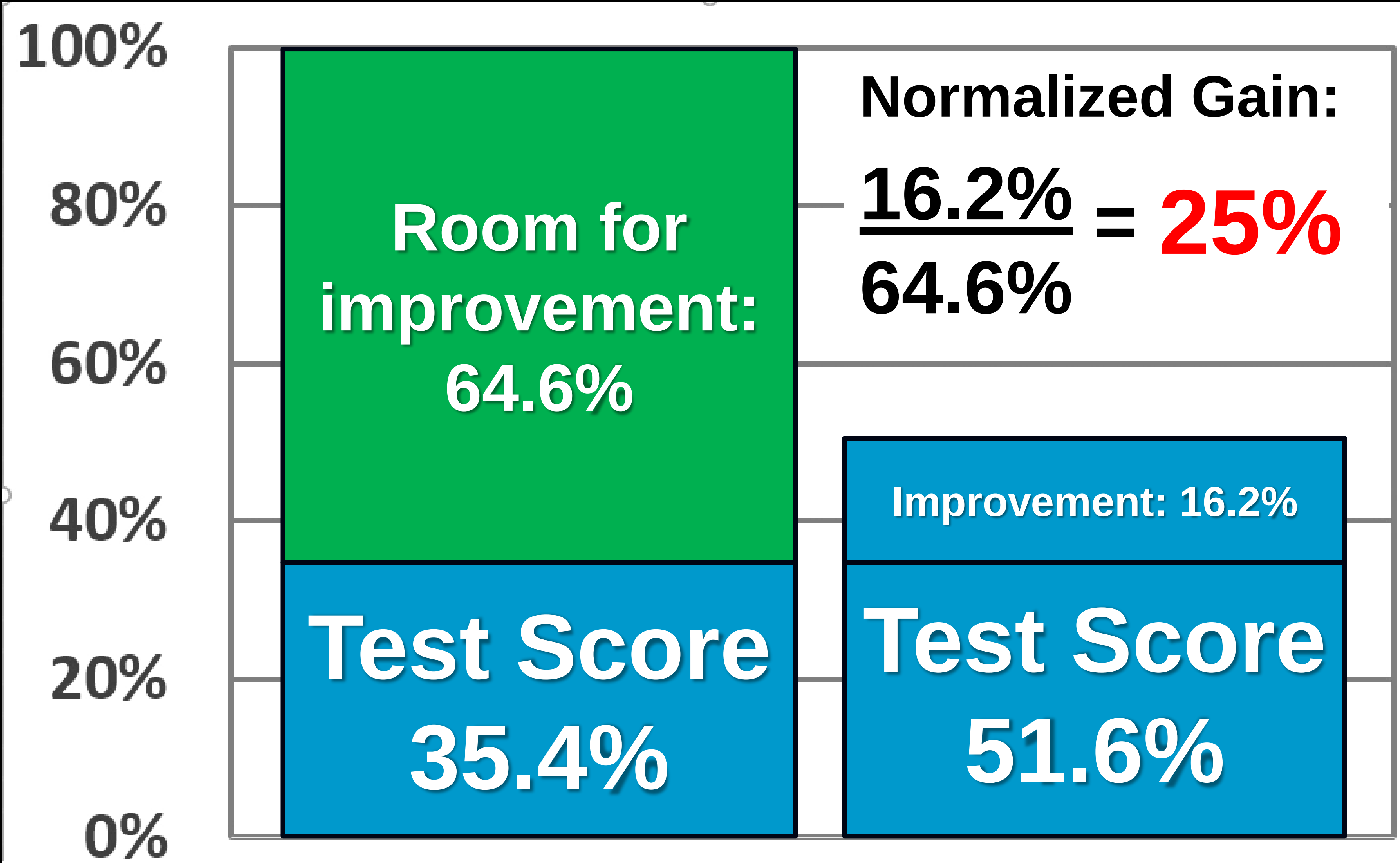
Which path would the ball most closely follow, observed from above?



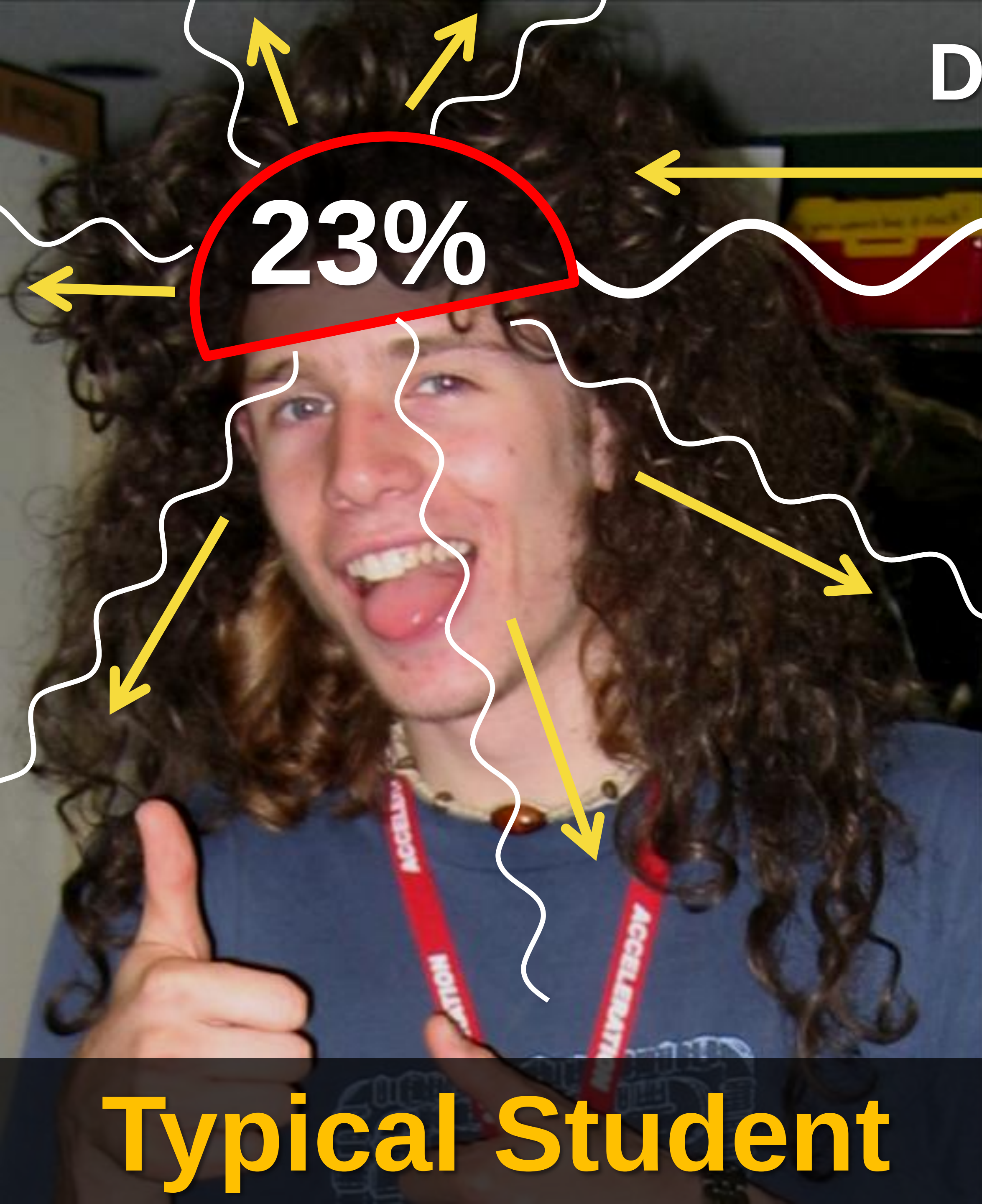
Hestenes, D., Wells, M., & Swackhamer, G. (1992). Force concept inventory. *The physics teacher*, *30*(3), 141-158.


Way too
easy!
Harrumph!

Force Concept Inventory Scores



Milner-Bolotin, Marina, et al. "Attitudes about science and conceptual physics learning in university introductory physics courses." *Physical Review Special Topics-Physics Education Research* 7.2 (2011): 020107.

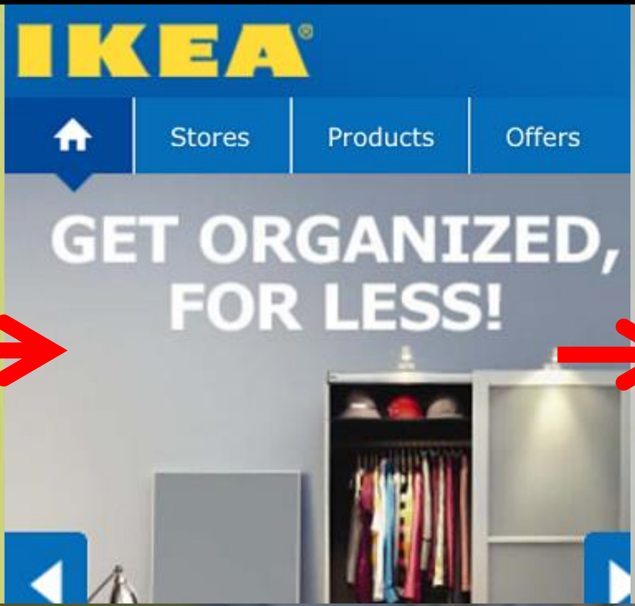


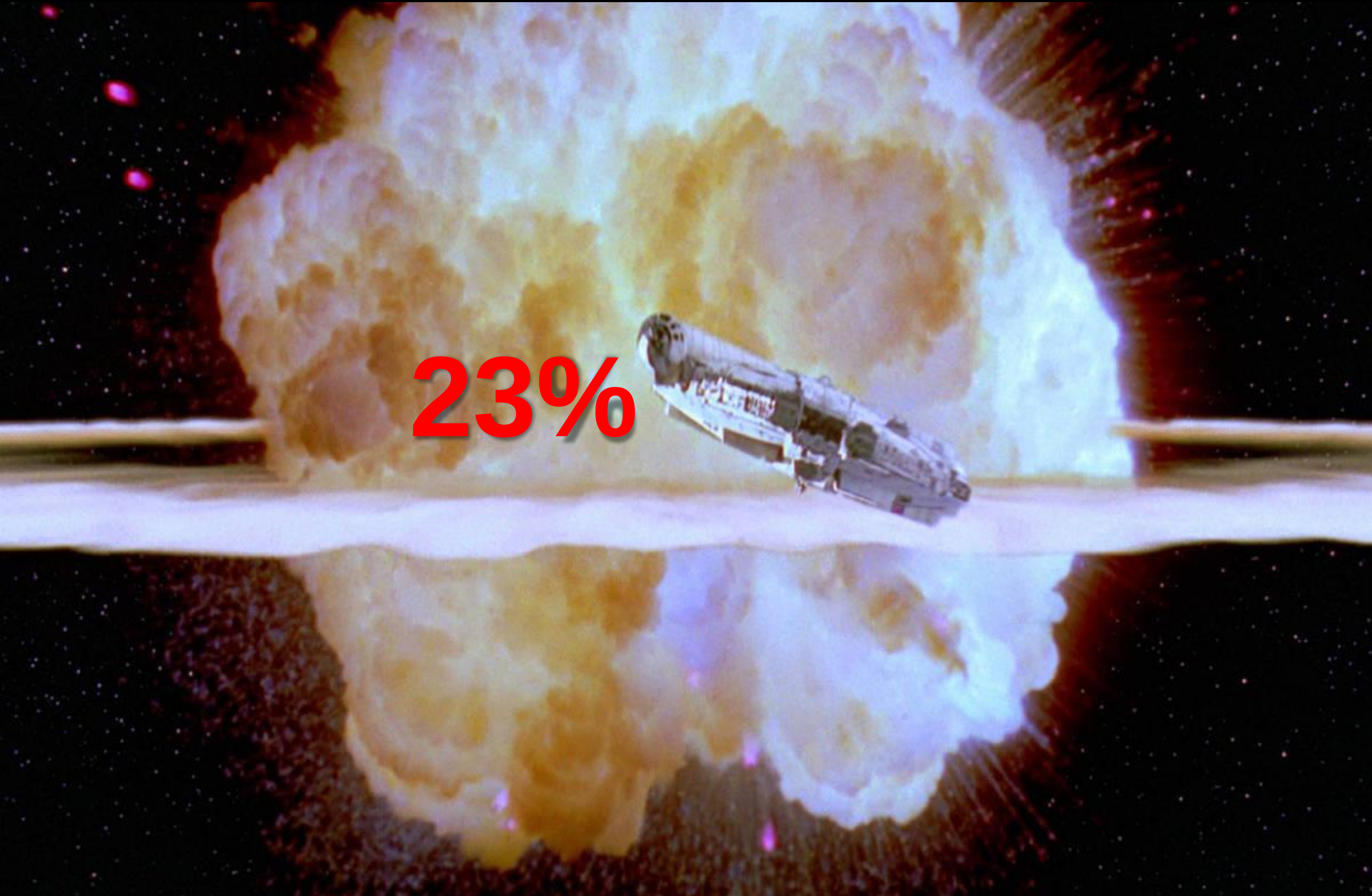
Distilled Physics Wisdom

77% Scattered

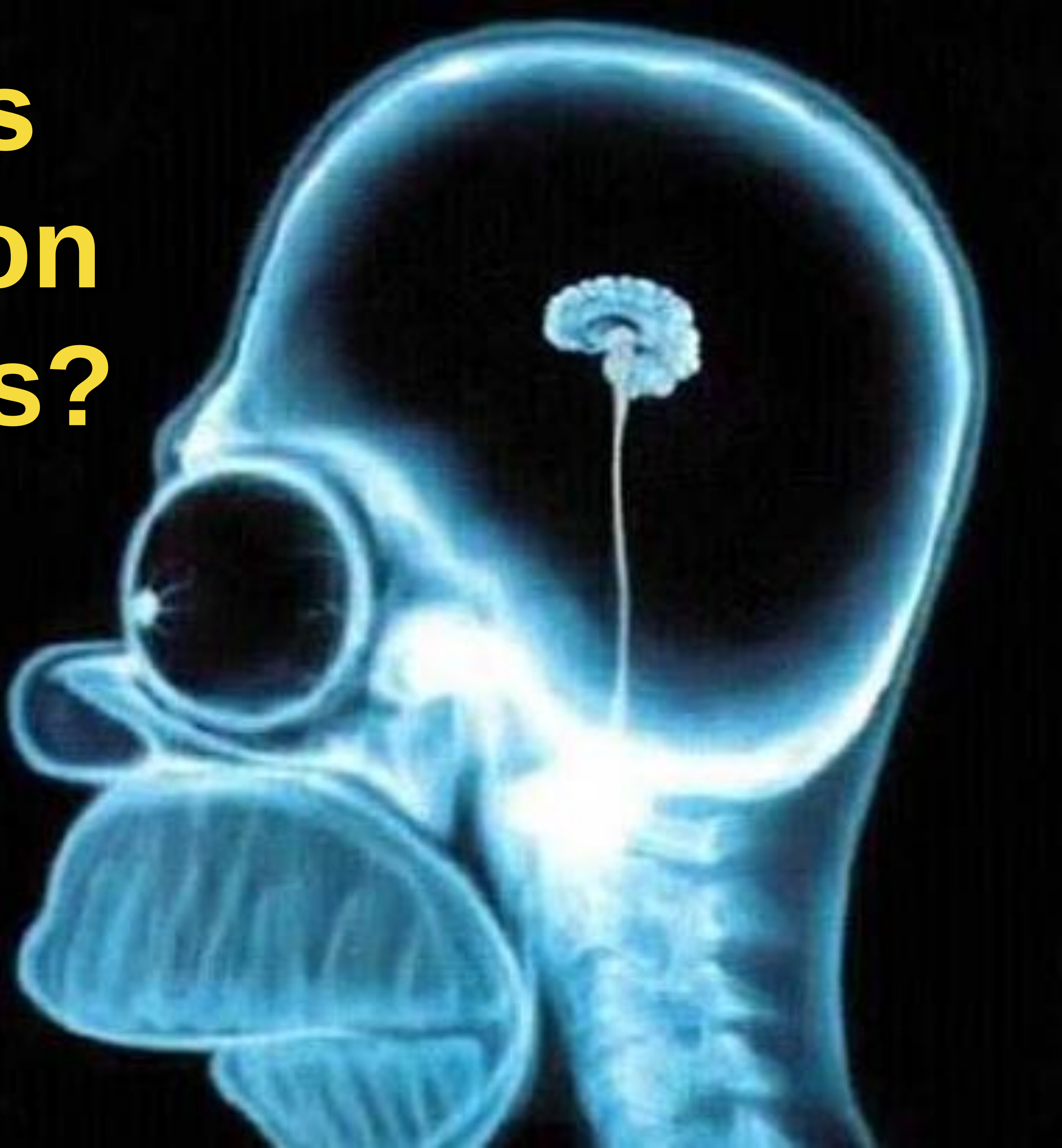
Hake, Richard R. "Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses." *American journal of Physics* 66.1 (1998): 64-74.

Best Lesson Ever

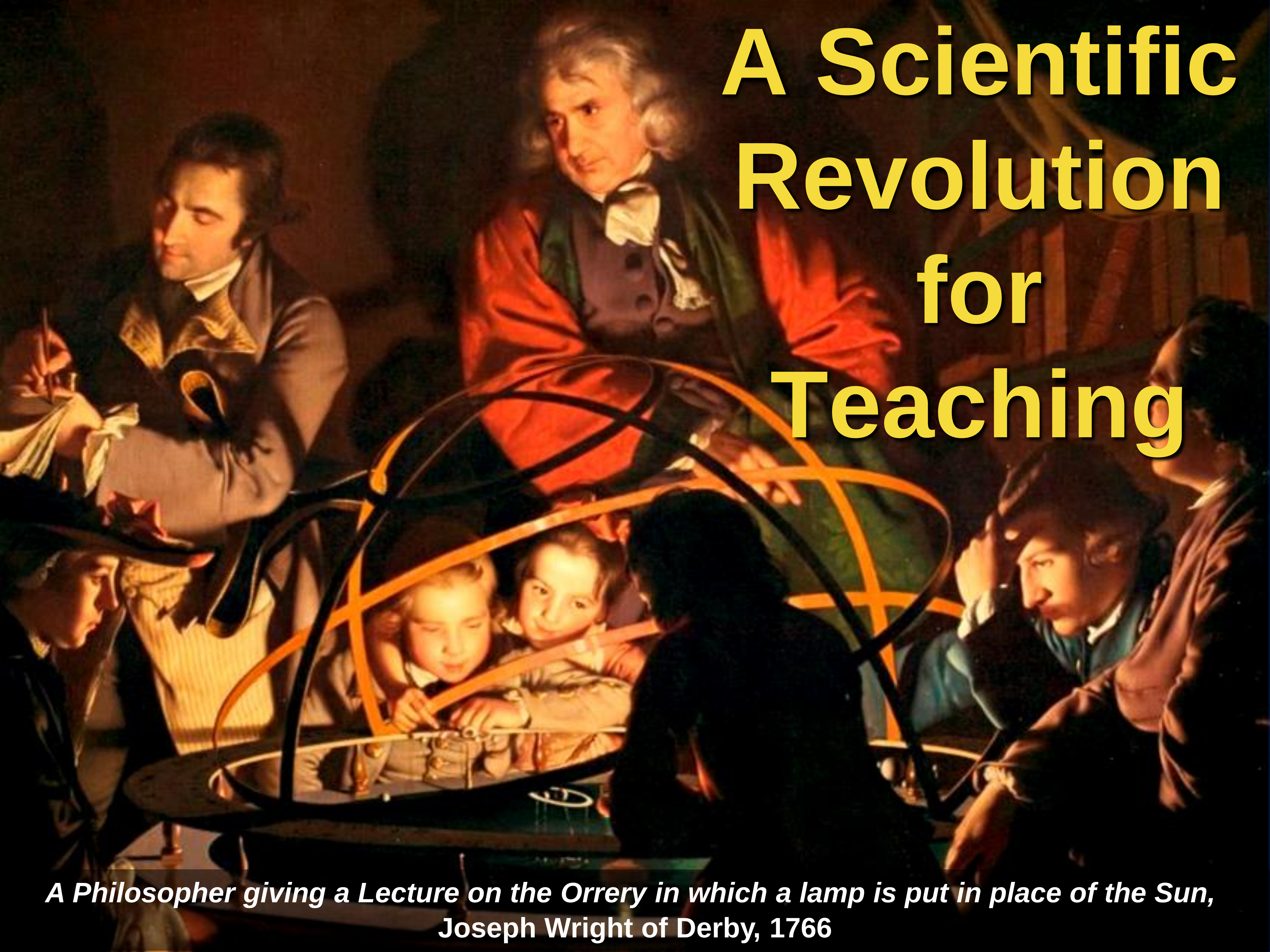



23%

What's Going on Upstairs?

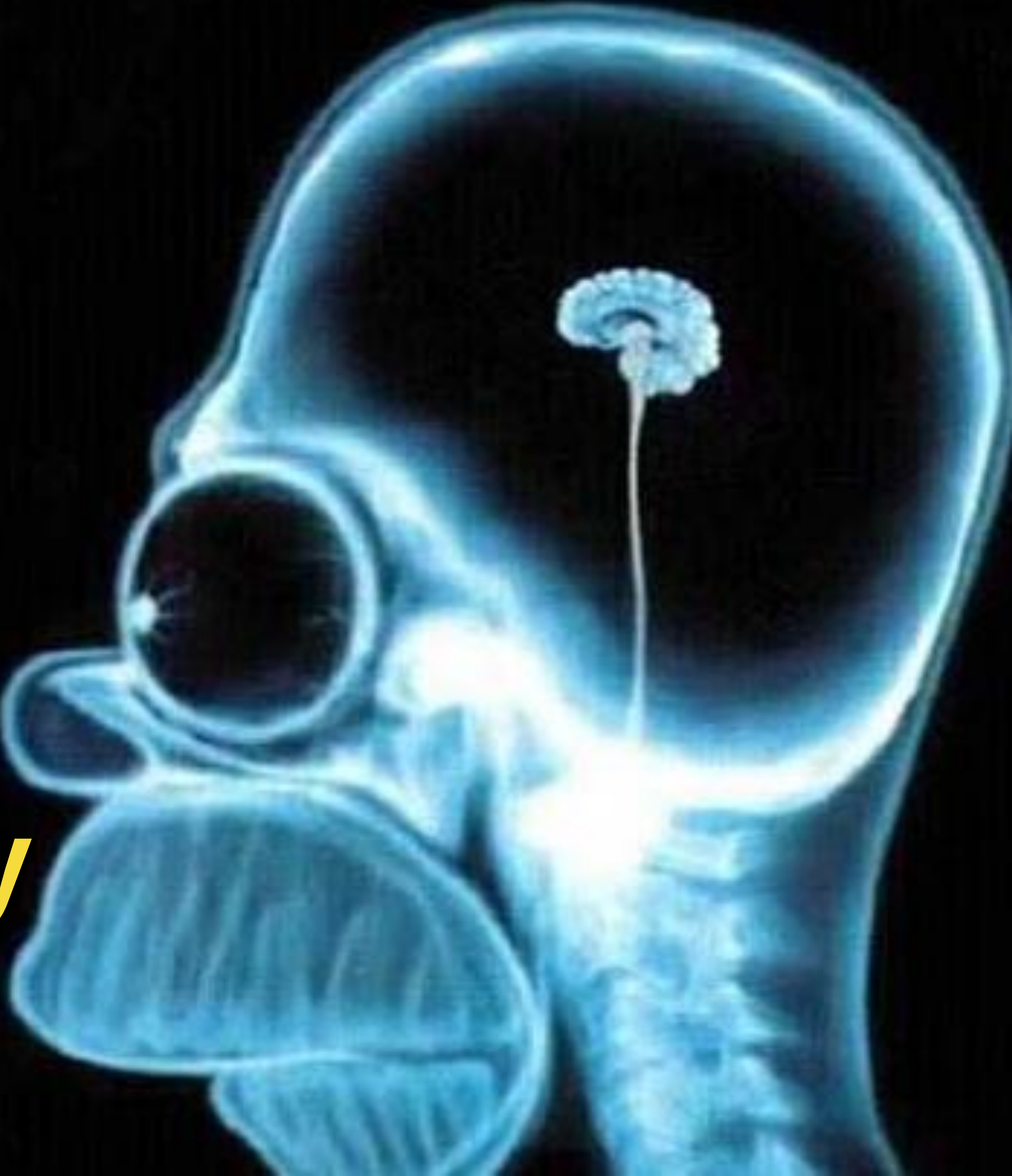


A Scientific Revolution for Teaching



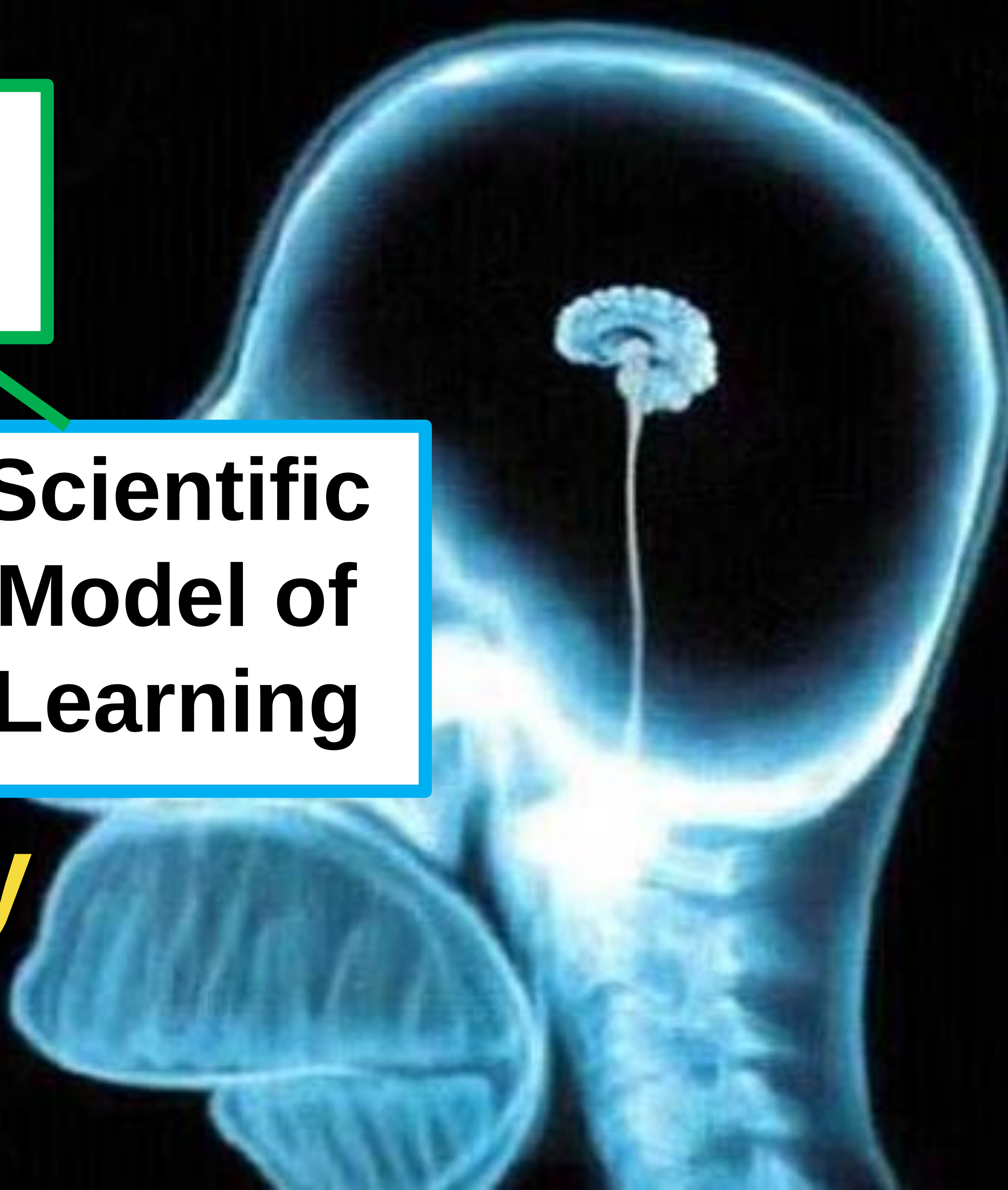
***A Philosopher giving a Lecture on the Orrery in which a lamp is put in place of the Sun,* Joseph Wright of Derby, 1766**

What happens in students' brains when they learn?

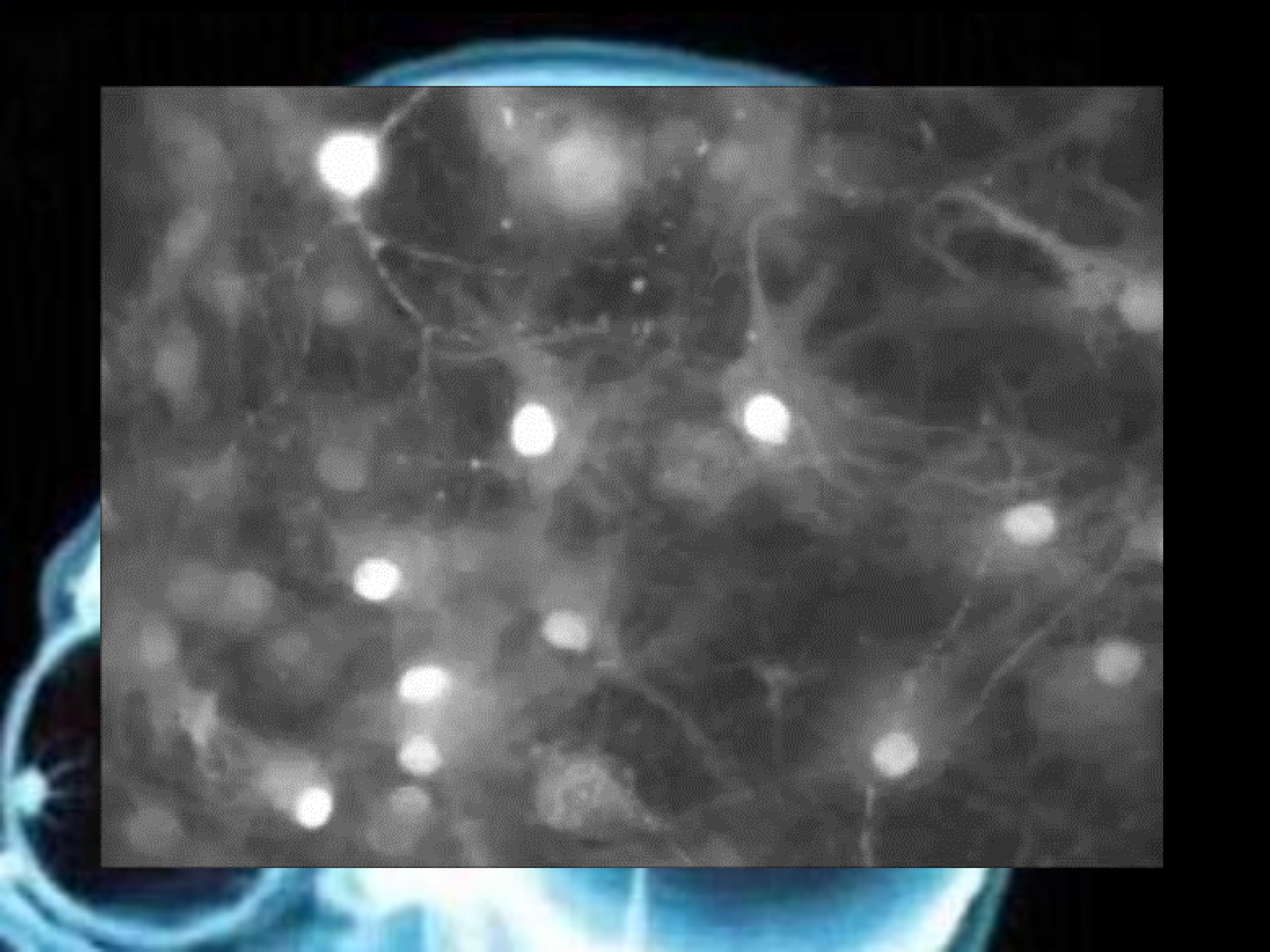


Physical Workings

in
student
brains
when they
learn?

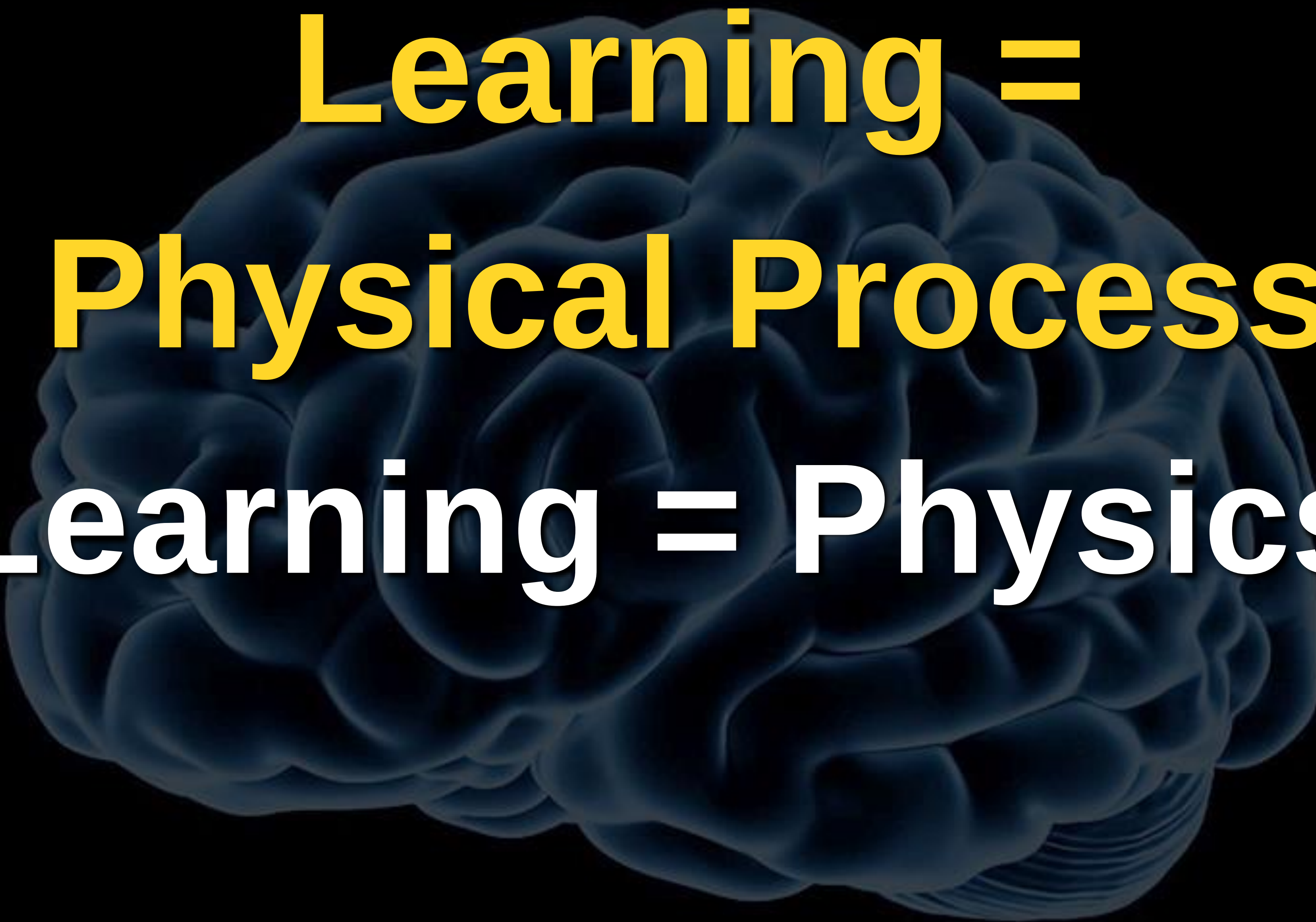


Scientific Model of Learning



Grey Matter Grows with Learning

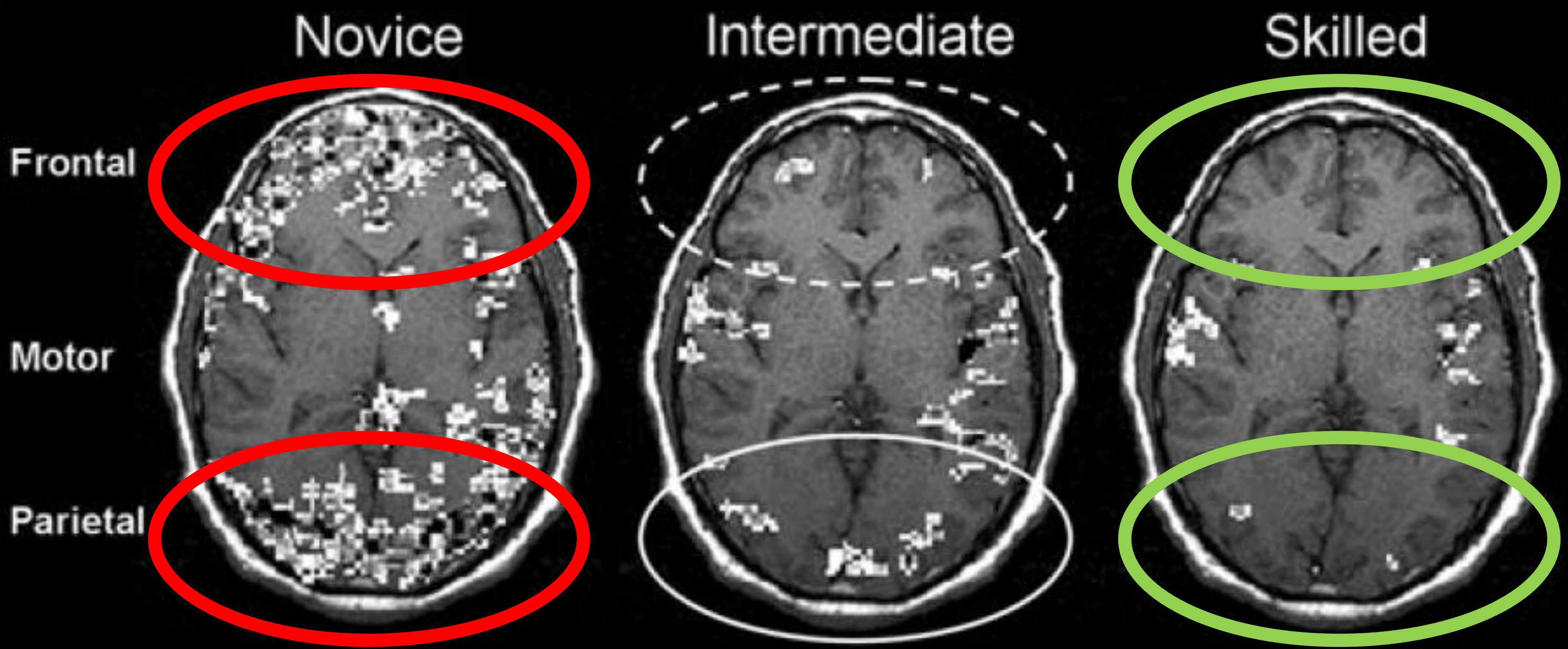
Zatorre, R. J., Fields, R. D., & Johansen-Berg, H. (2012). Plasticity in gray and white: neuroimaging changes in brain structure during learning. *Nature neuroscience*, *15*(4), 528-536.



Learning = Physical Process

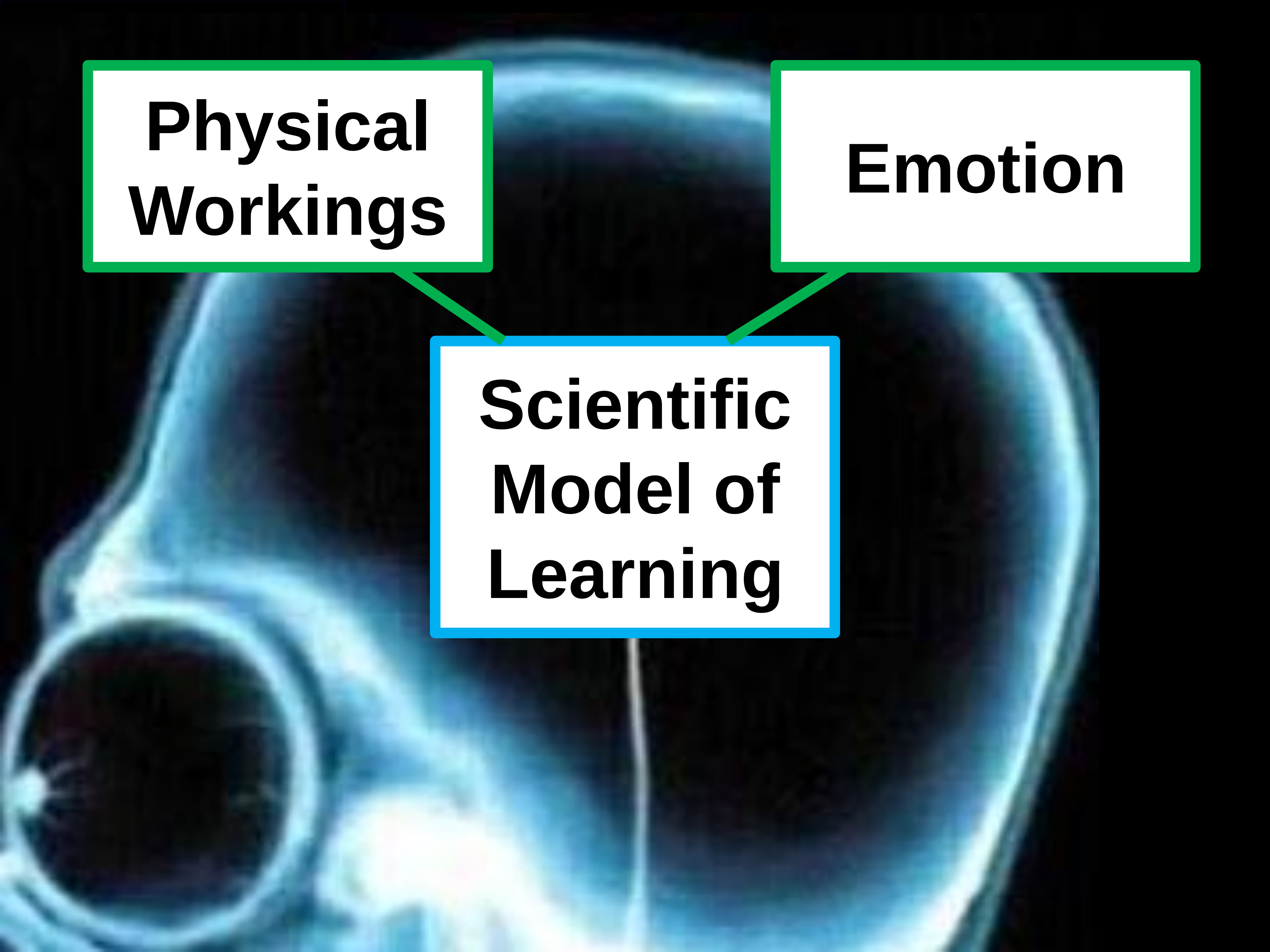
Learning = Physics!

Brain Workload

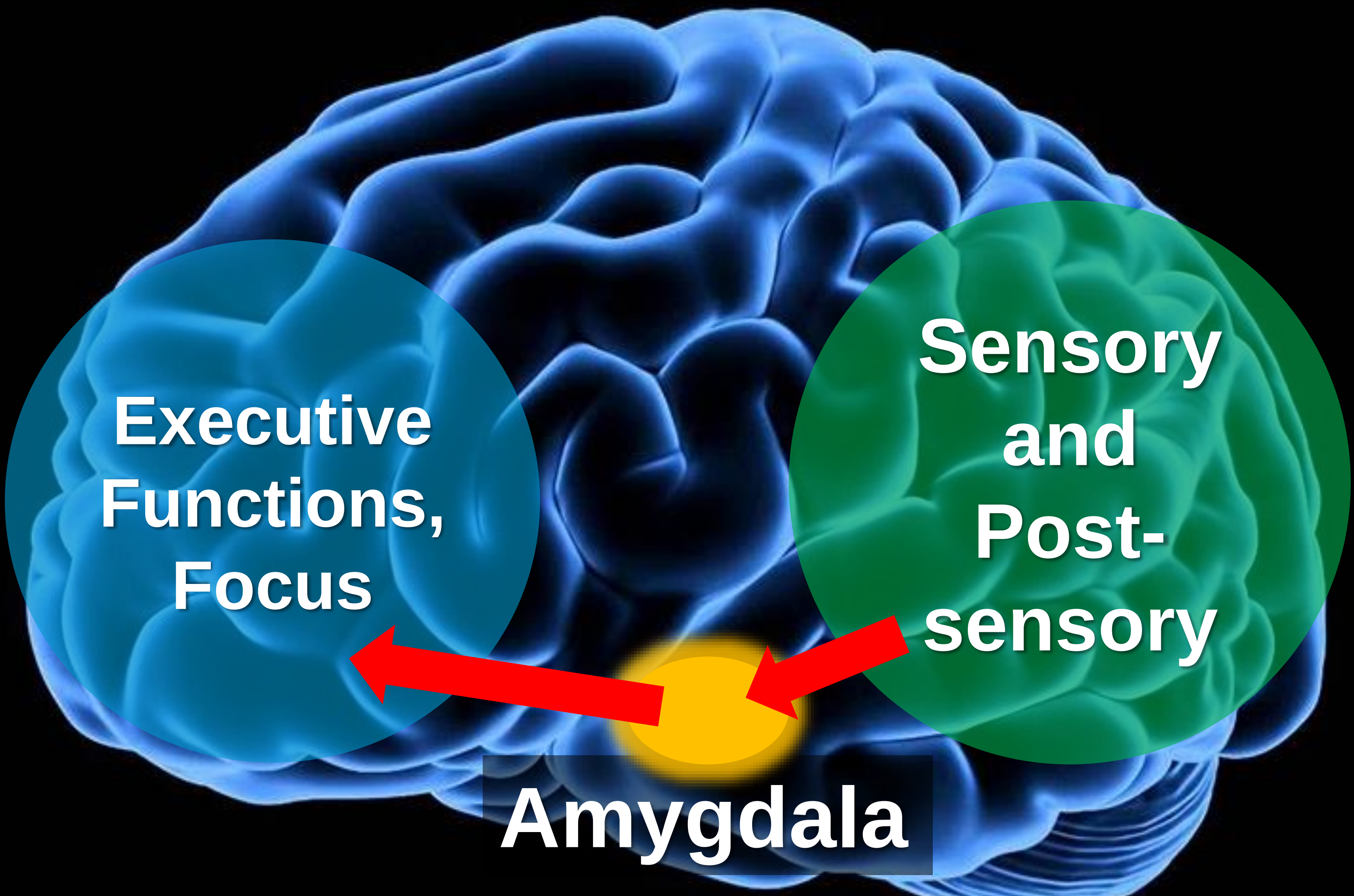


Learning something new is energy intensive = tiring

Ericsson, K. Anders, et al., eds. *The Cambridge handbook of expertise and expert performance.* Cambridge University Press, 2006.


Physical Workings
Emotion
Scientific Model of Learning

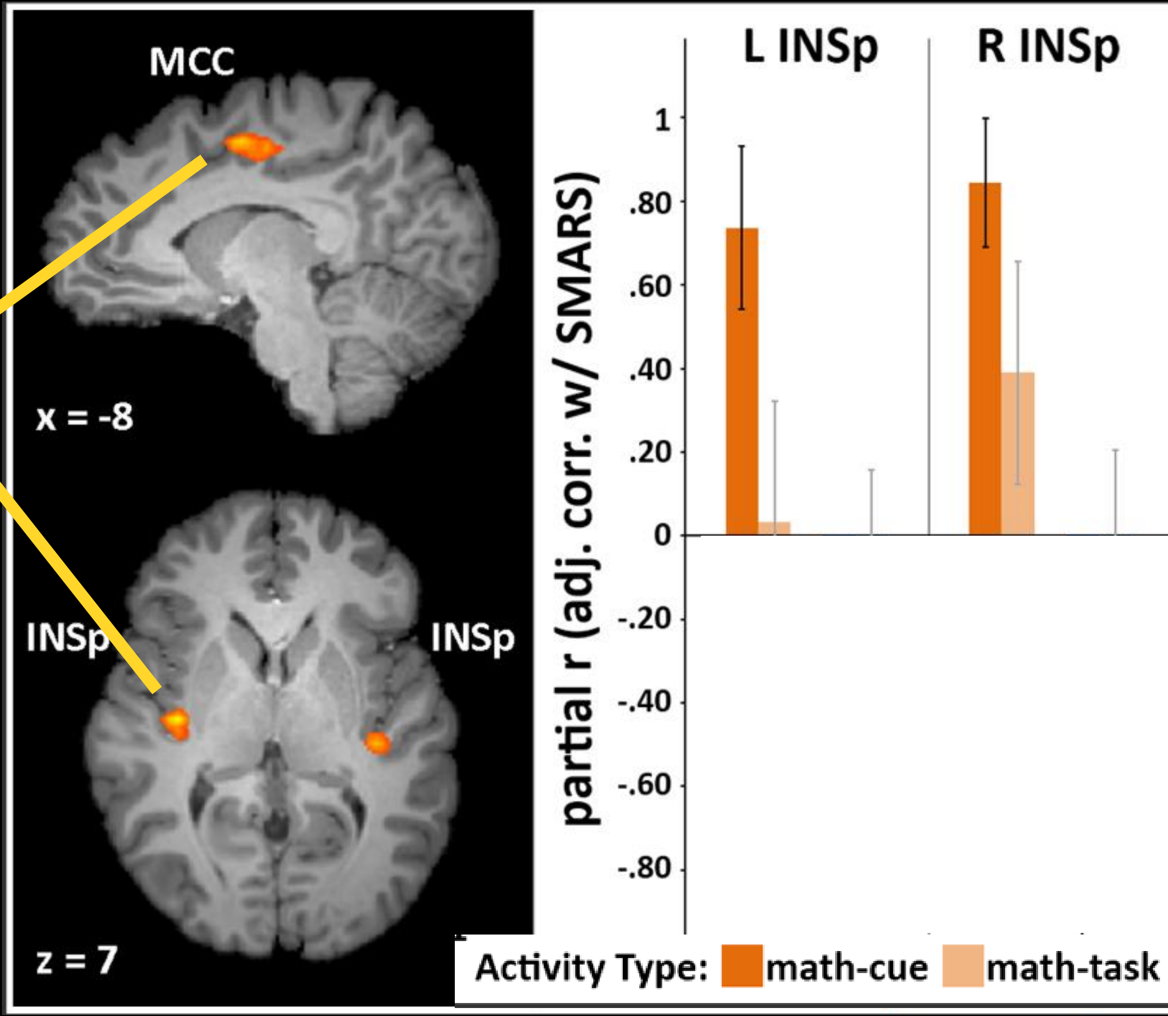
Emotions and the Brain



Anxiety!

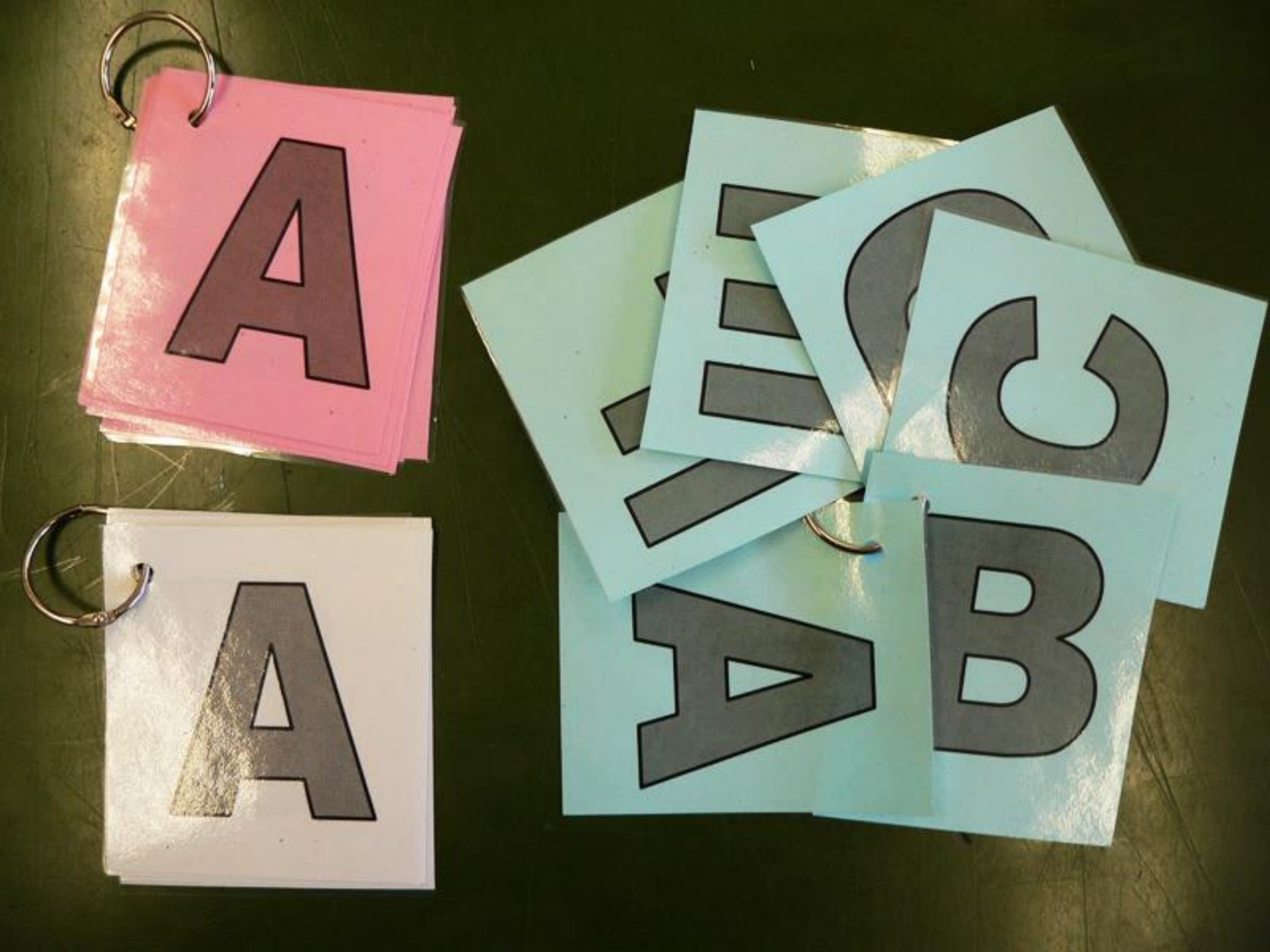
Anxiety!

Activation of brain regions associated with **physical pain perception** is strongest when **anticipating** a math task.



Lyons, I. M., & Beilock, S. L. (2012). When math hurts: math anxiety predicts pain network activation in anticipation of doing math. PloS one, 7(10), e48076

Anxiety!


A
A
C
A
B

Learning Check-Up

How was your learning today?

A: I'm confident about what I learned. I can explain it well to my neighbours.

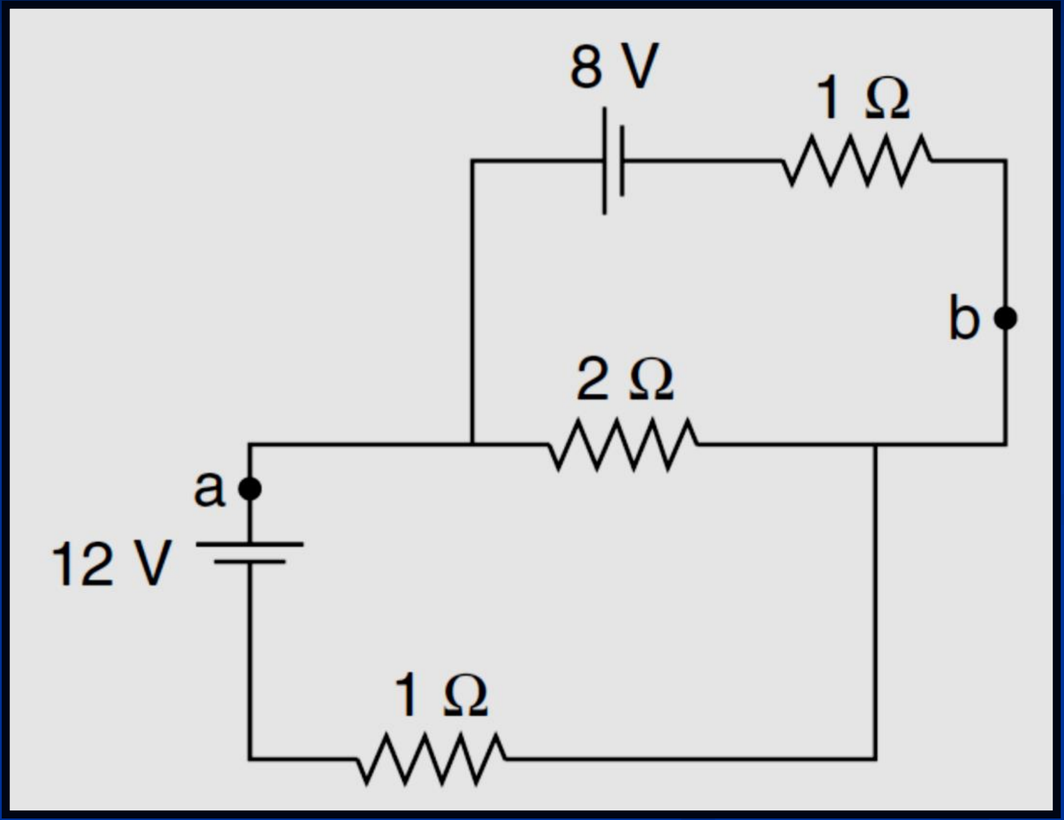
B: I'm pretty good with what I learned. I'm OK at explaining it.

C: I'm not too sure about what I learned. It would be tough to explain it!

D: I think I had difficulties with some of what I learned. I am not yet able to explain it.

Measuring Understanding?

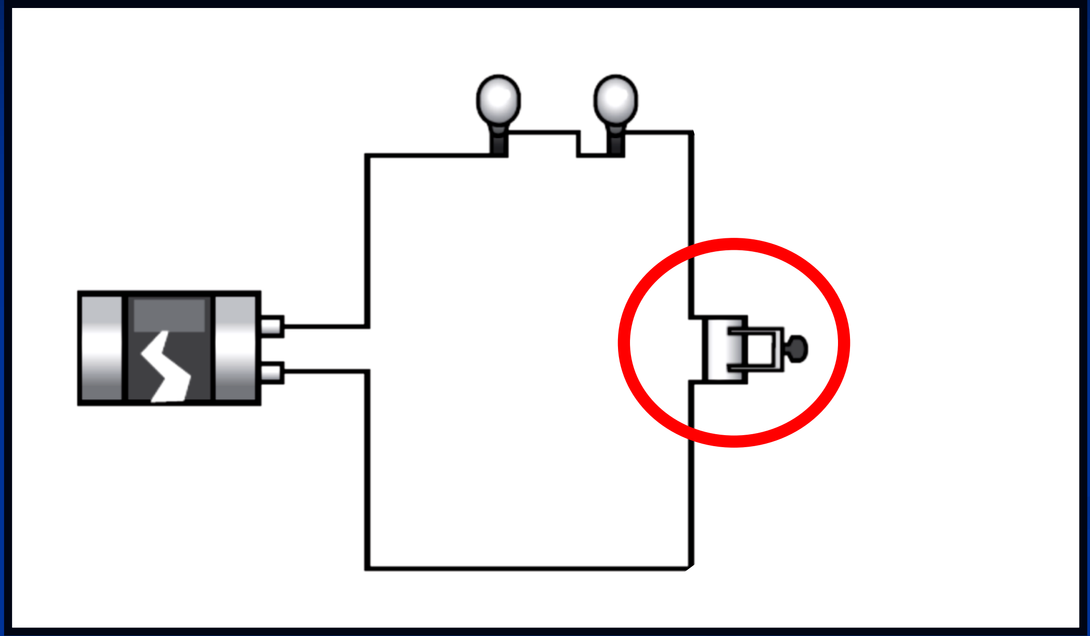
Find the current through the 2 ohm resistor and the potential difference between point a and b.



Average = 75%

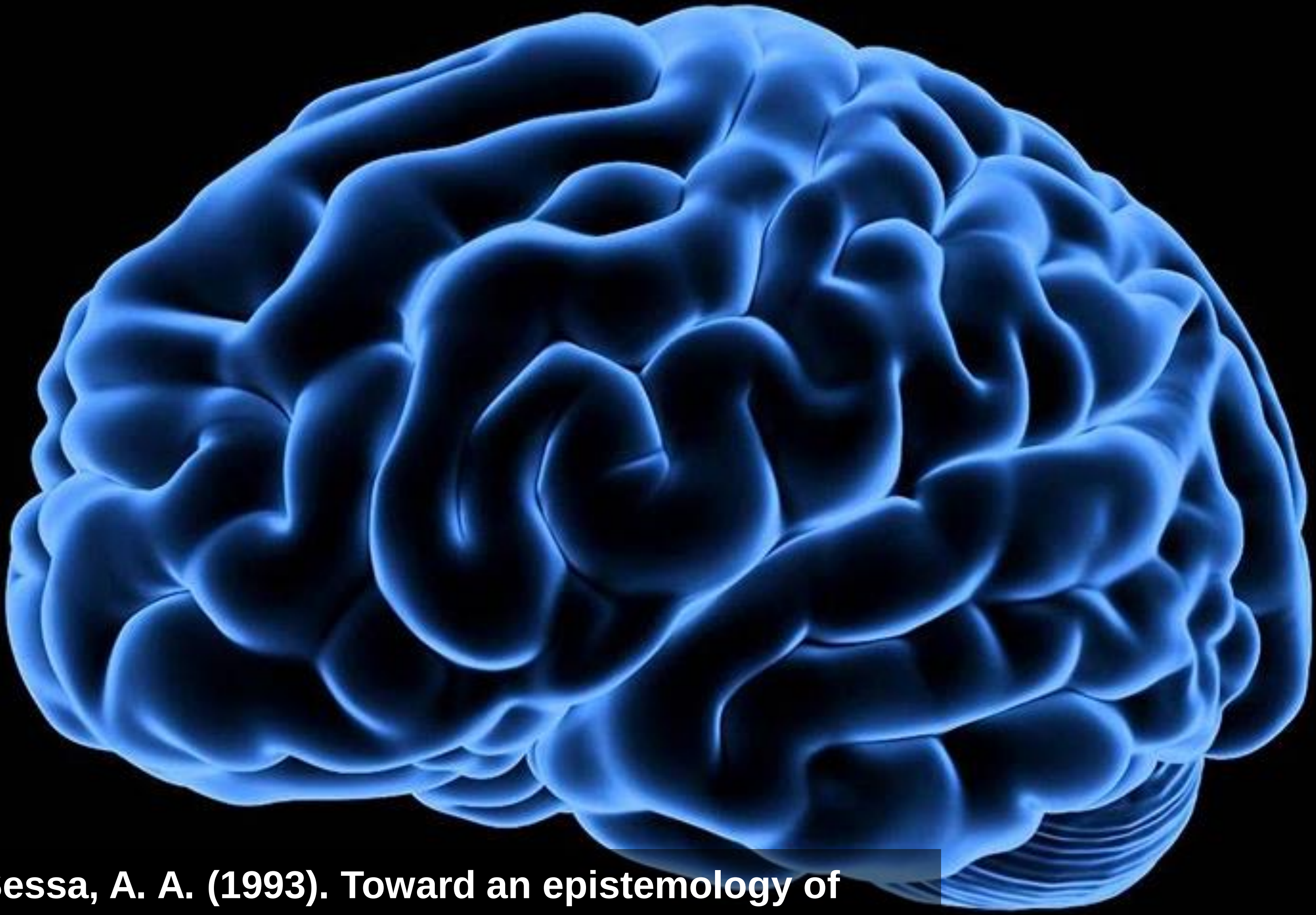
Measuring Understanding!

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



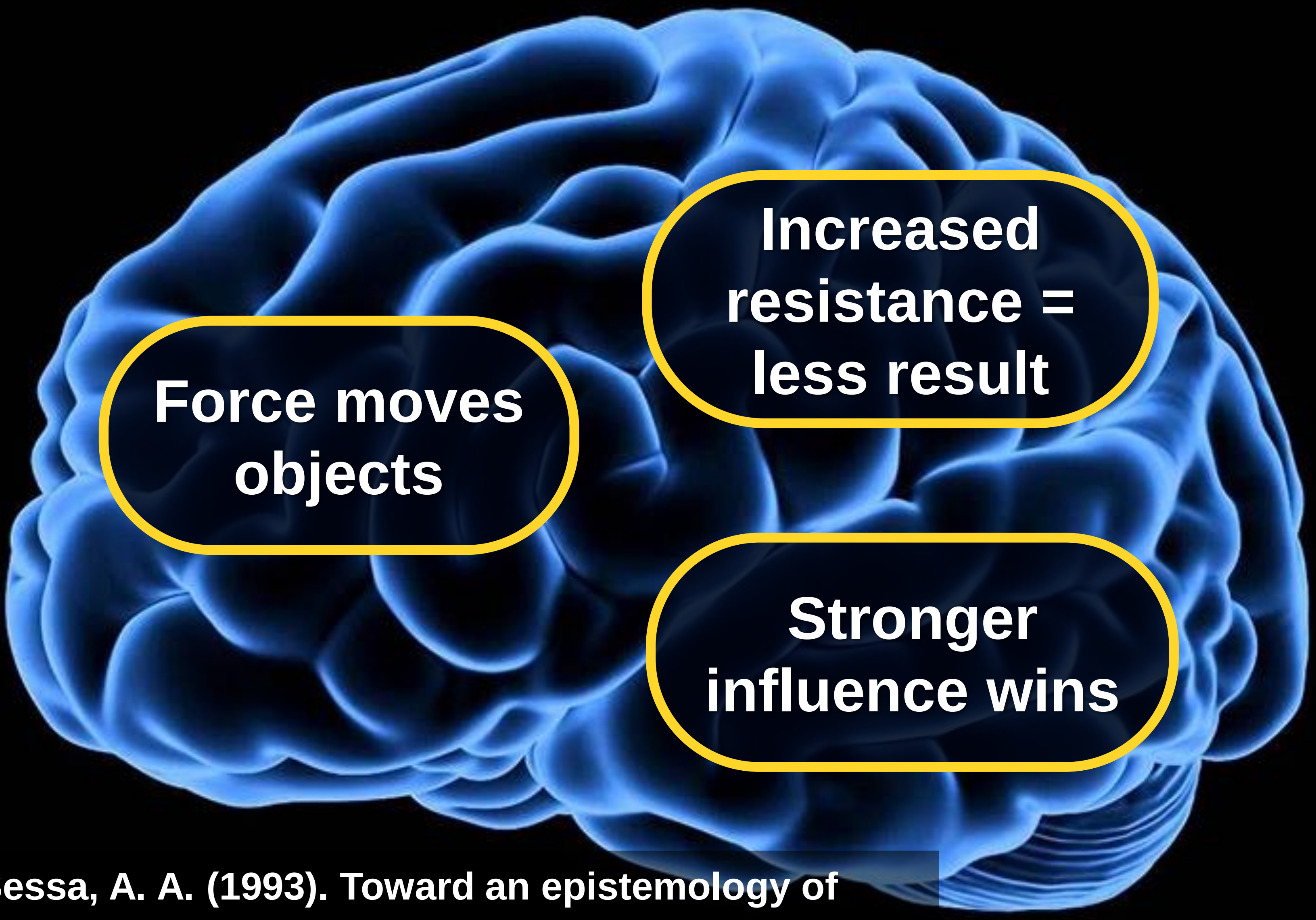
Average = 40%

Cognitive Resource Model



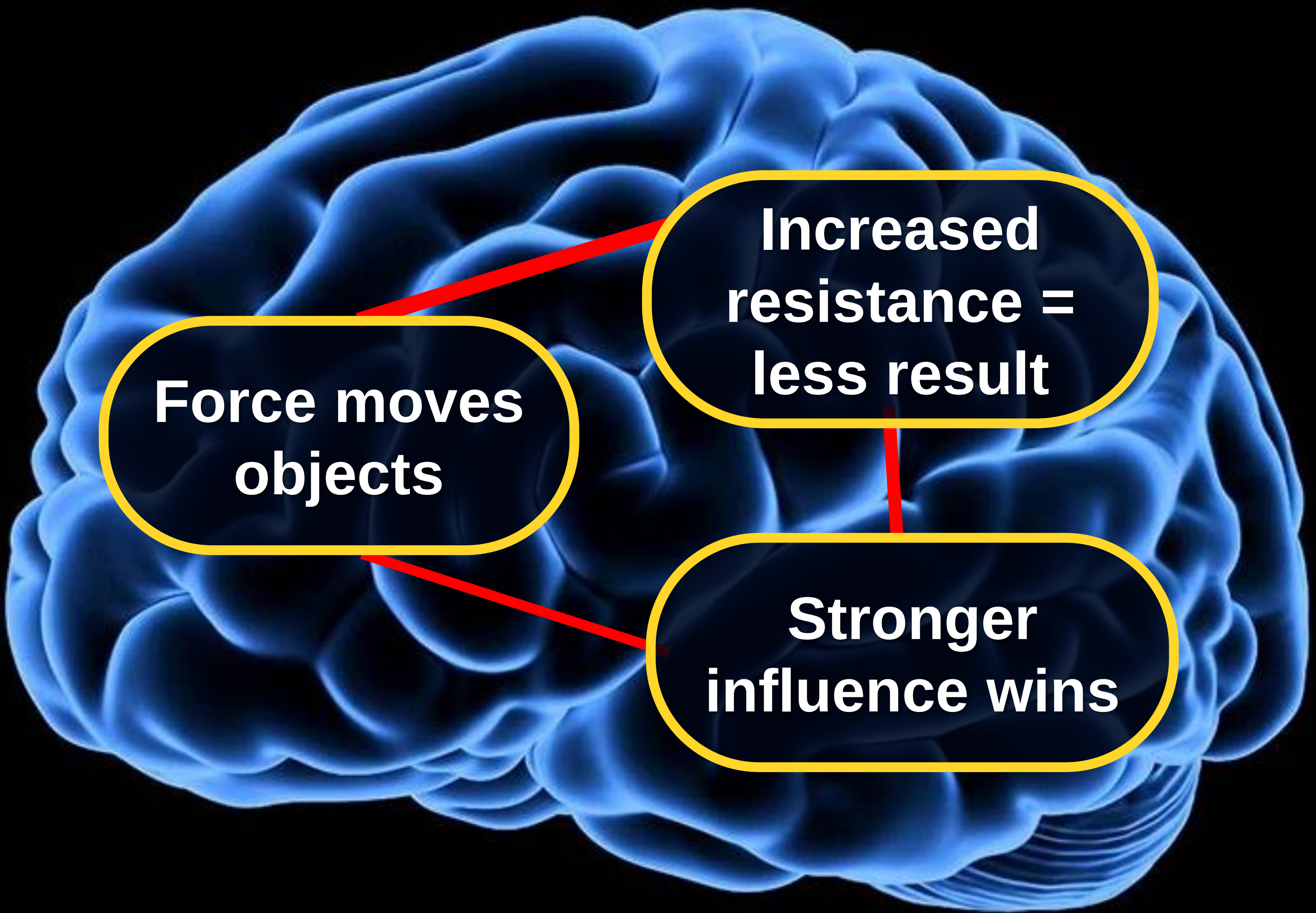
DiSessa, A. A. (1993). Toward an epistemology of physics. *Cognition and instruction*, *10*(2-3), 105-225.

Knowledge is built from primitive pieces

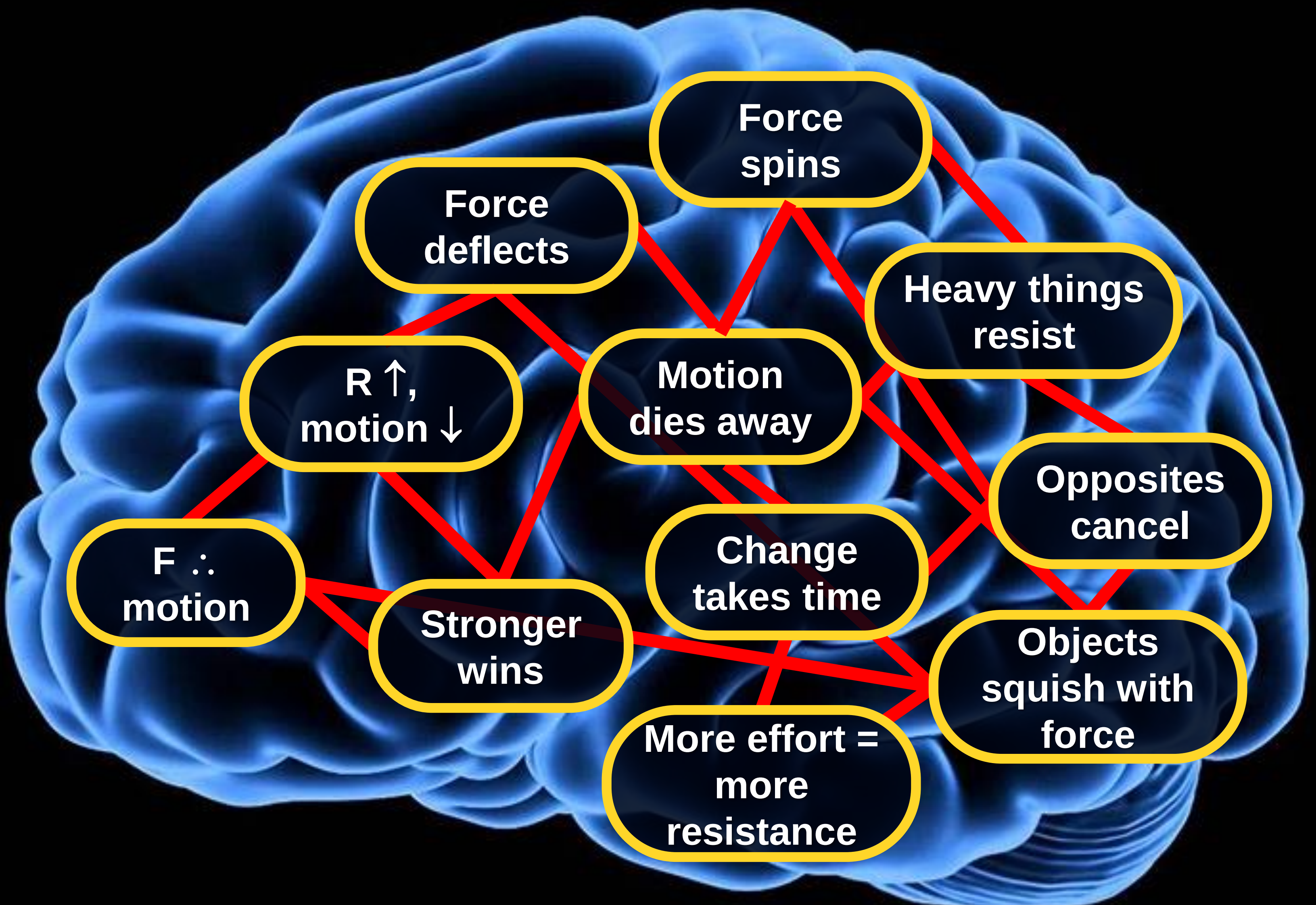


DiSessa, A. A. (1993). Toward an epistemology of physics. *Cognition and instruction*, *10*(2-3), 105-225.

As we learn, connections grow



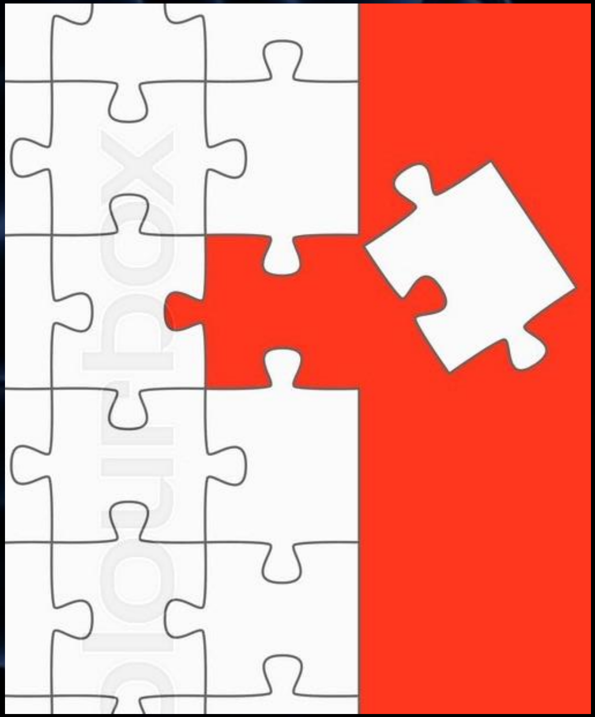
Networks of knowledge resources form



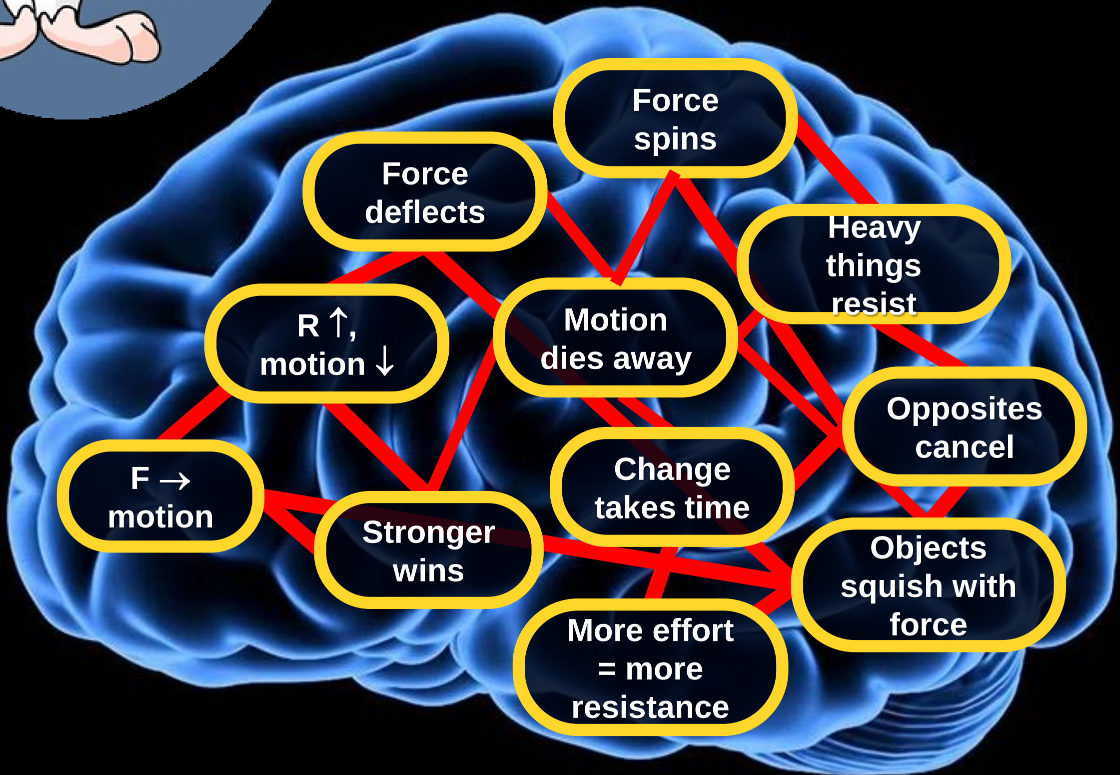
Prior Knowledge

We make sense of new ideas by making connections to our prior knowledge

If prior knowledge is not ready, students cannot make use of expert knowledge.



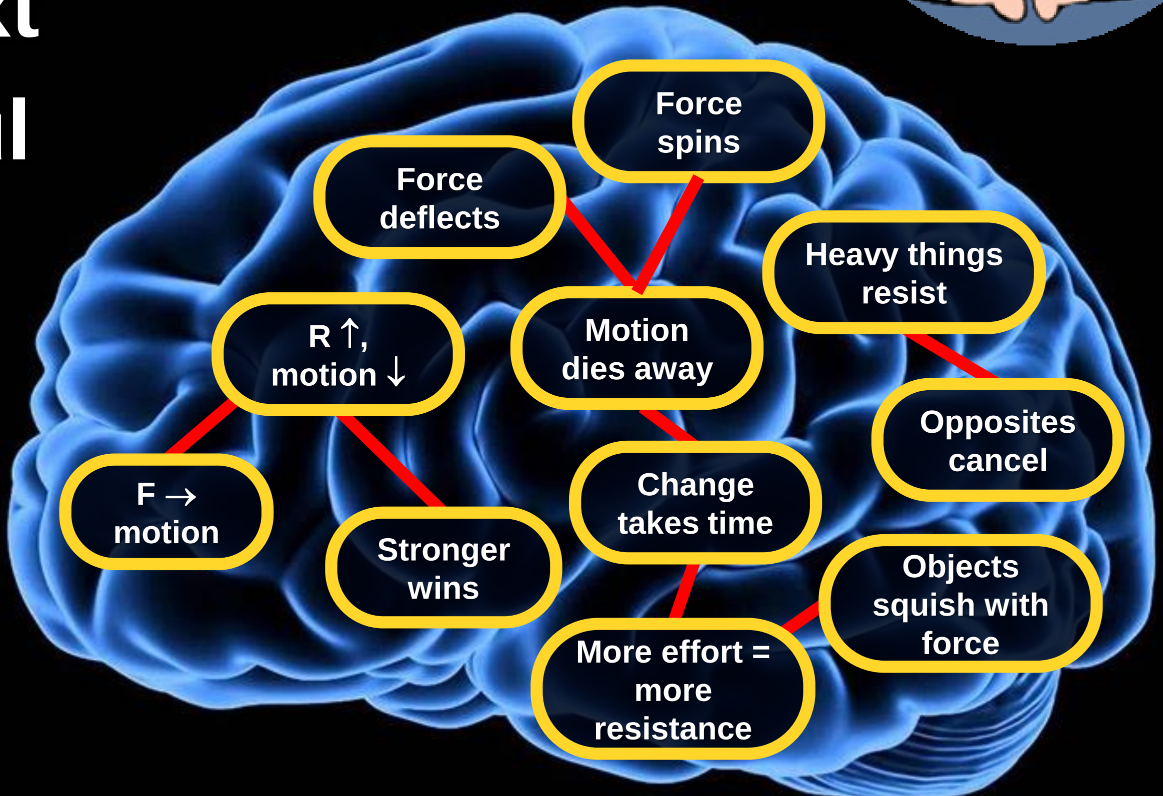
The Expert

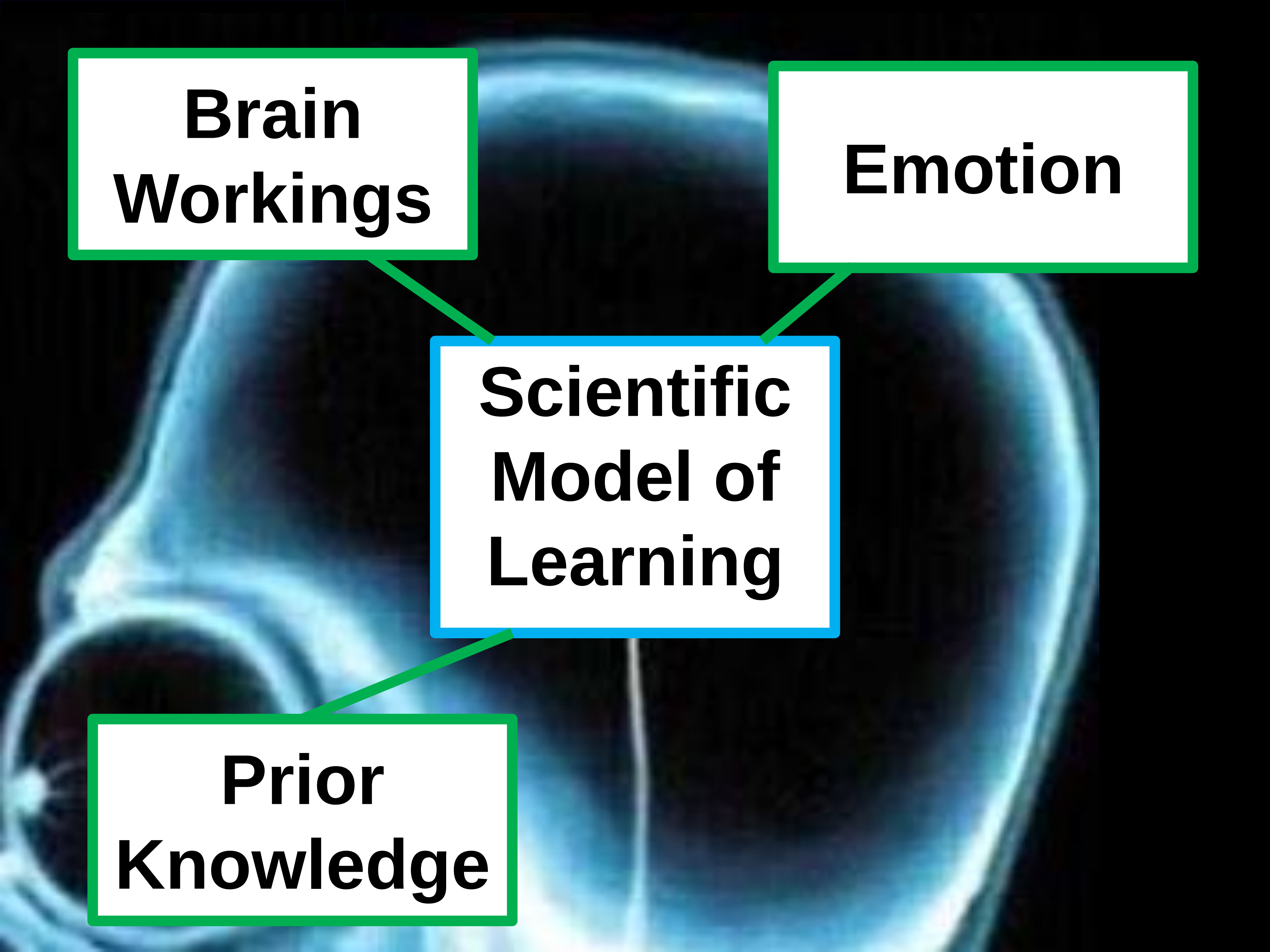


- Rich webs of connections
- Highly contextual
- See “big picture”
- Fluent / invisible skills

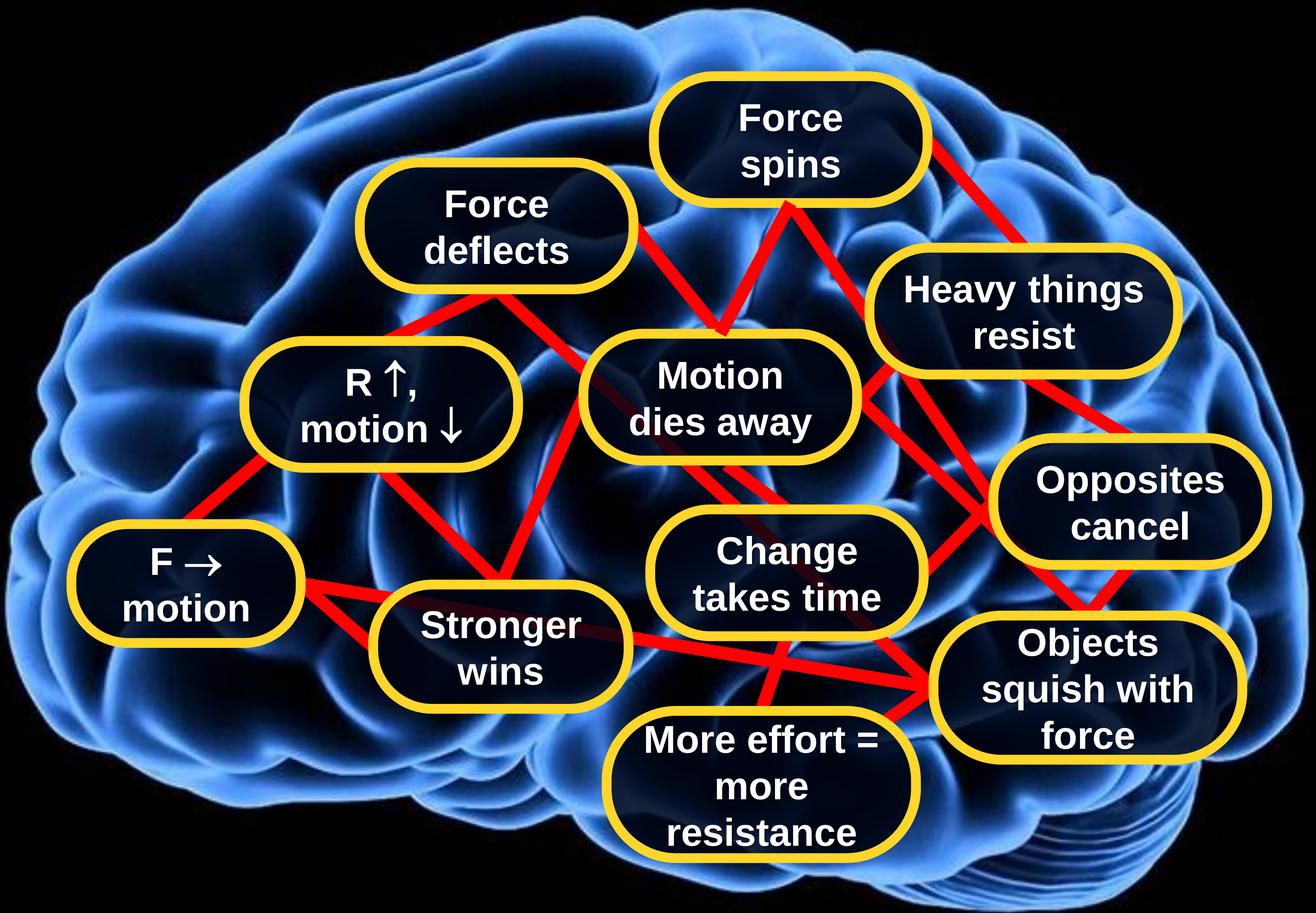
The Novice

- Scientific knowledge fragmented
- Little context
- Fewer useful "hooks" to attach new ideas
- Skills are effortful

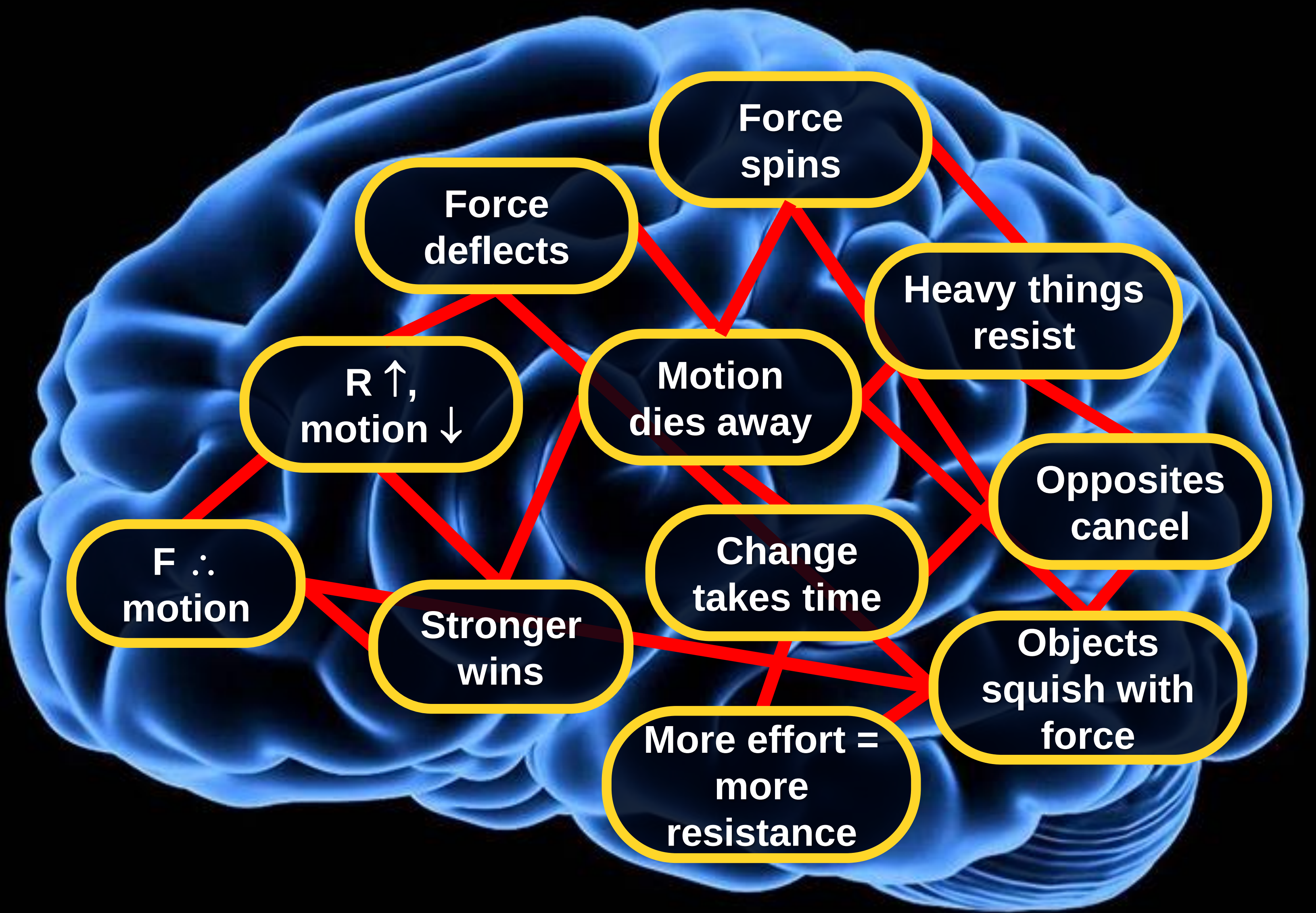



Brain Workings
Emotion
Scientific Model of Learning
Prior Knowledge

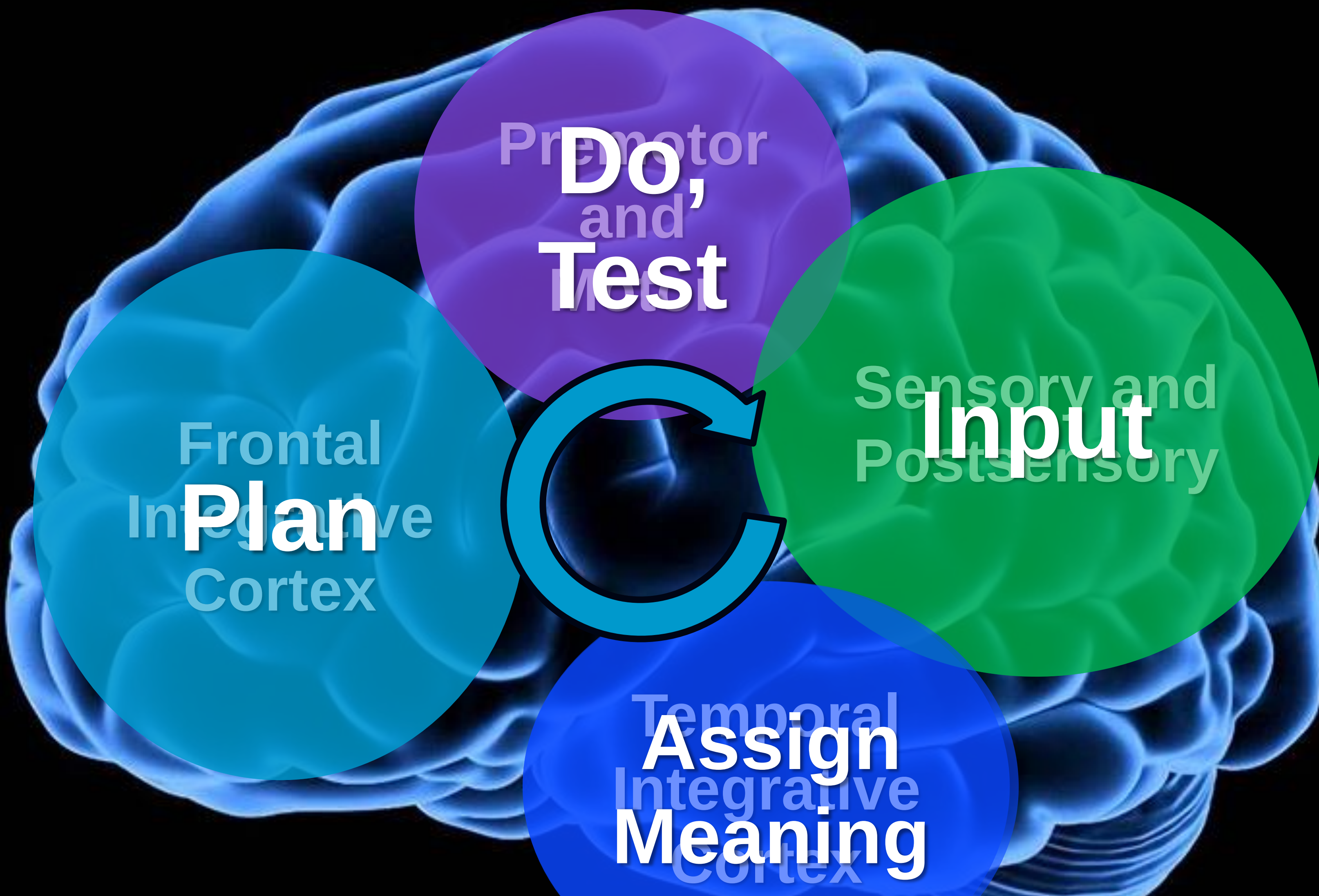
Teaching is a Wiring Problem



How to make connections?

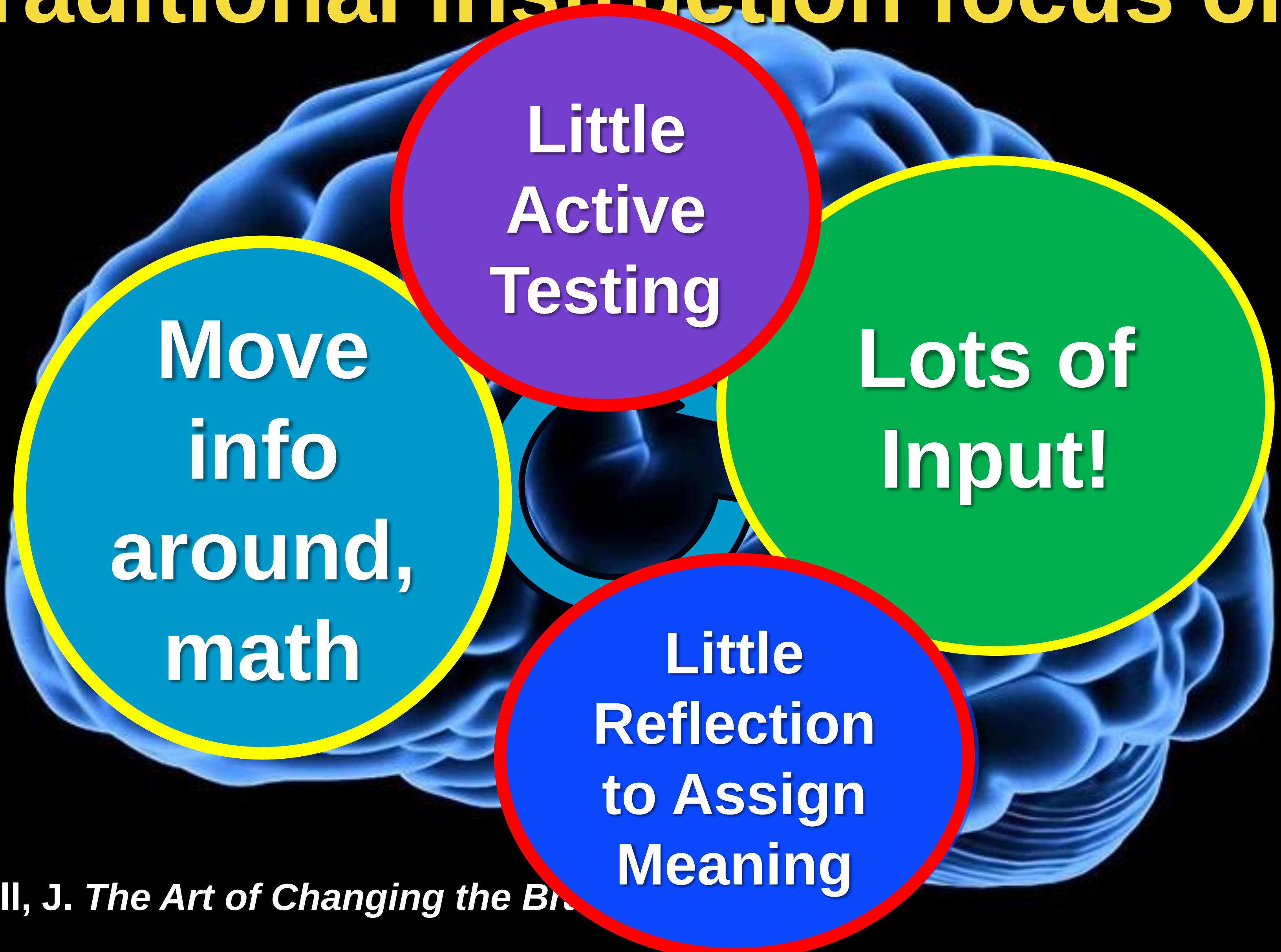


Cognitive Learning Cycle

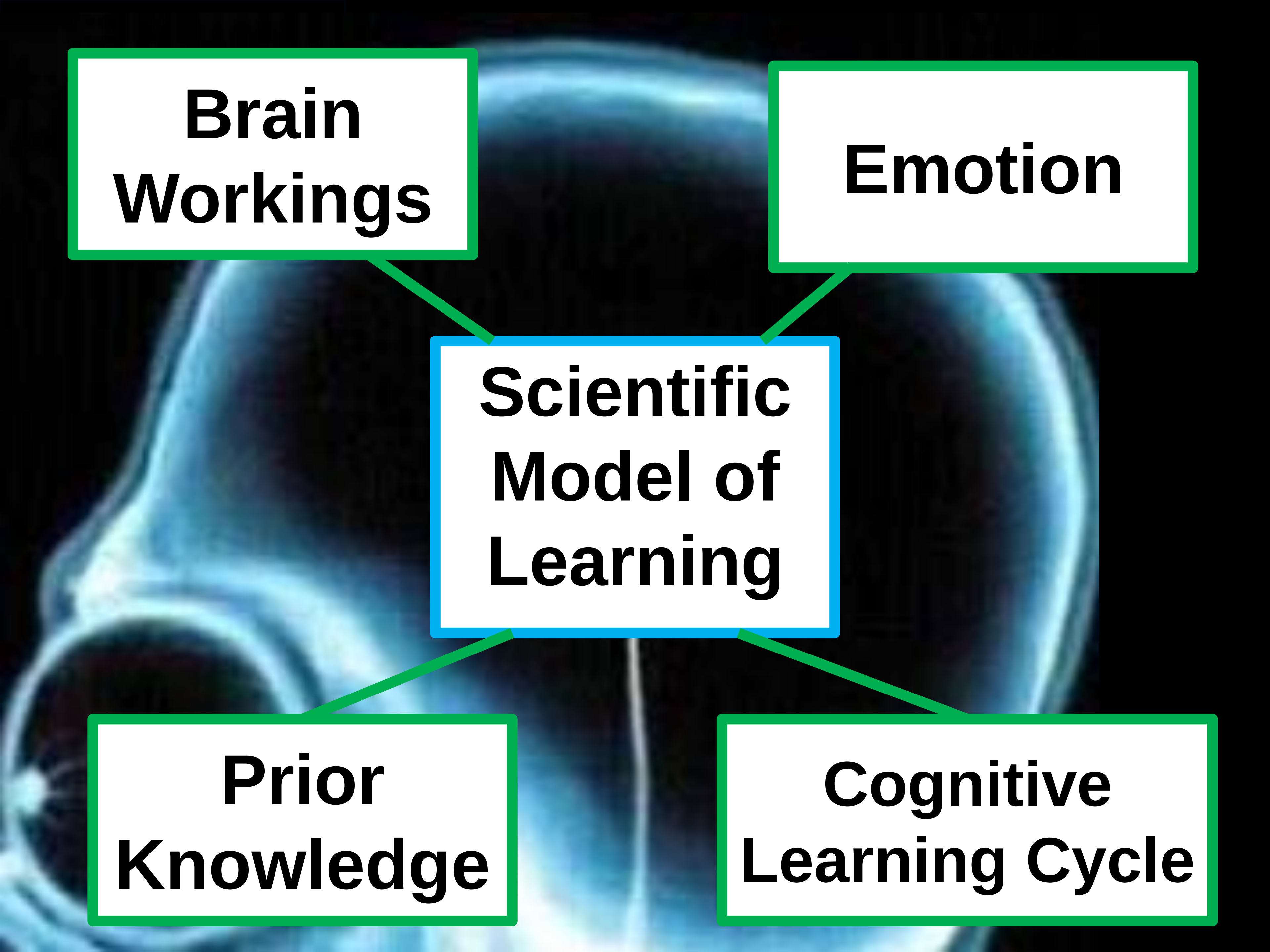


Zull, J. *The Art of Changing the Brain. 2002*

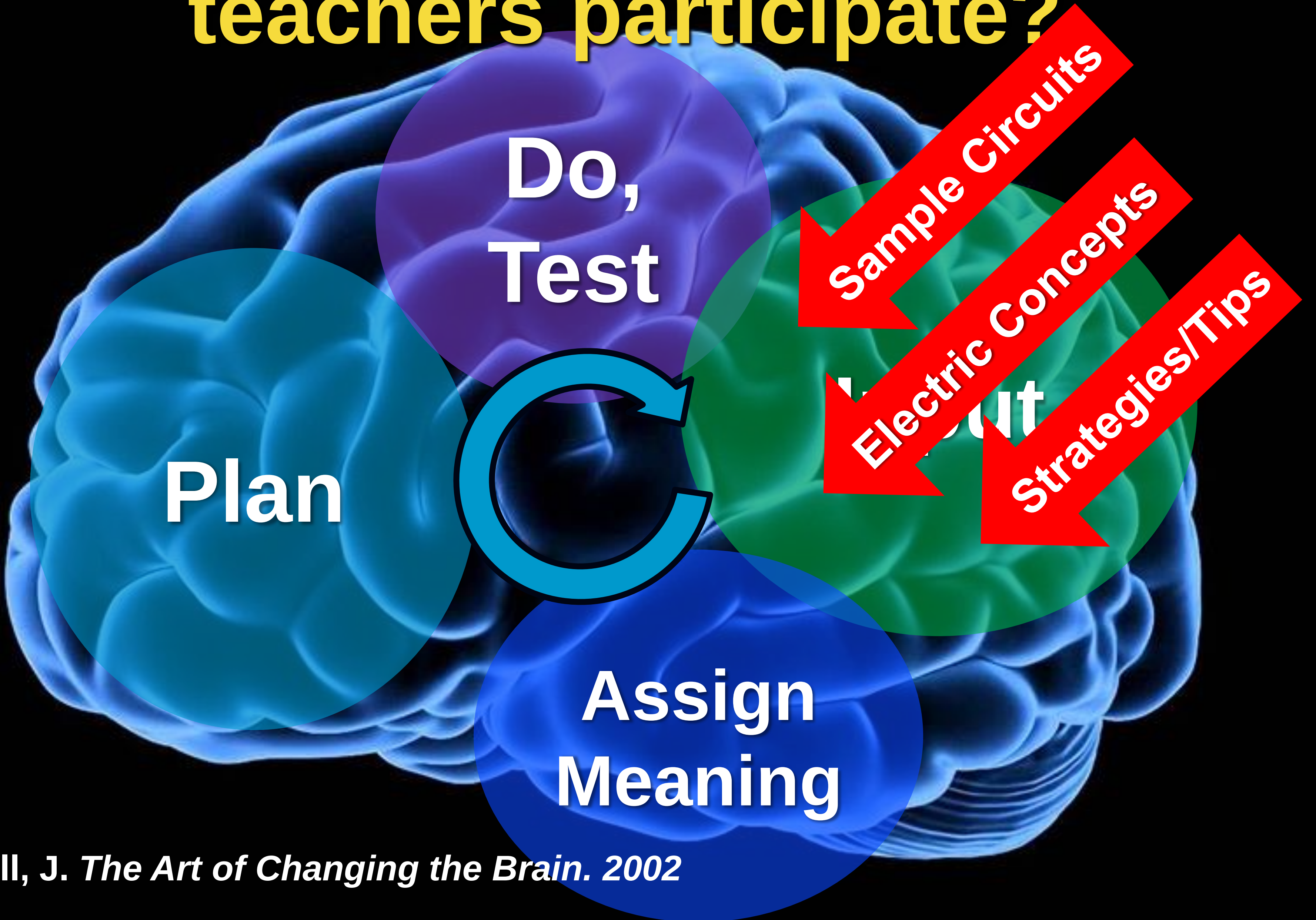
Which parts of the cycle does traditional instruction focus on?



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

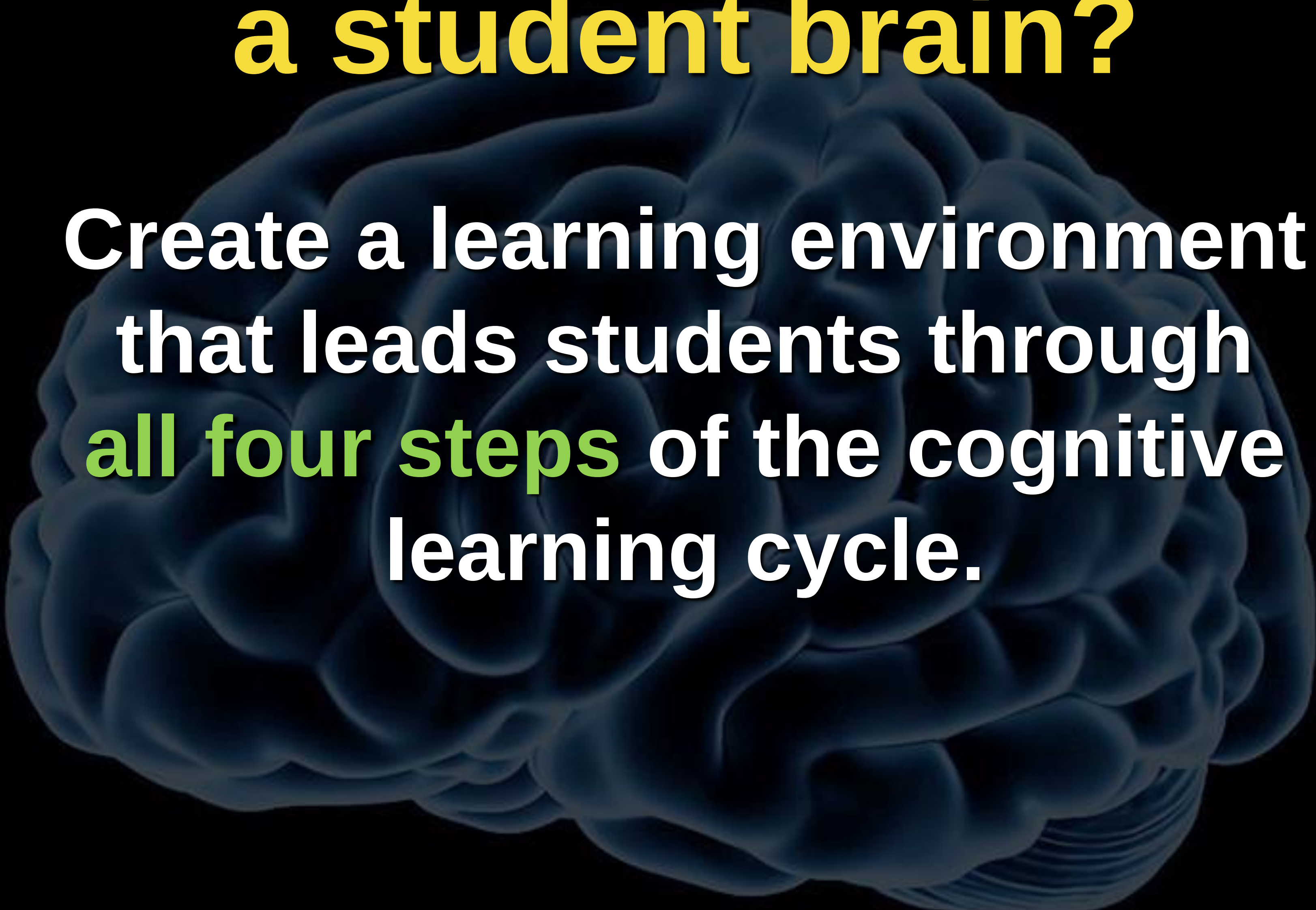

Brain Workings
Emotion
Scientific Model of Learning
Prior Knowledge
Cognitive Learning Cycle

In which part of this cycle can teachers participate?



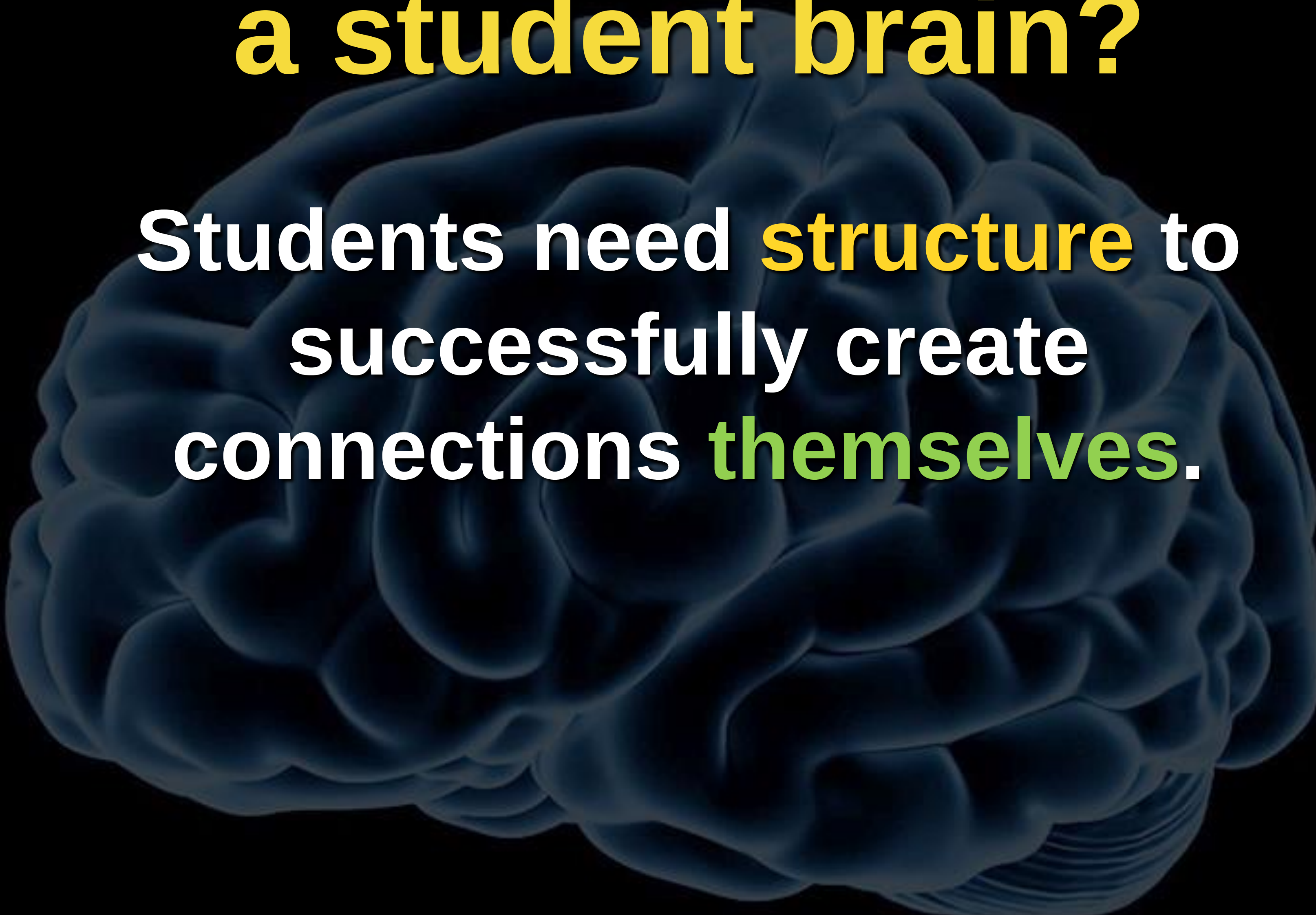
Zull, J. *The Art of Changing the Brain. 2002*

How to rewire a student brain?



Create a learning environment that leads students through all four steps of the cognitive learning cycle.

How to rewire a student brain?



Students need structure to successfully create connections themselves.

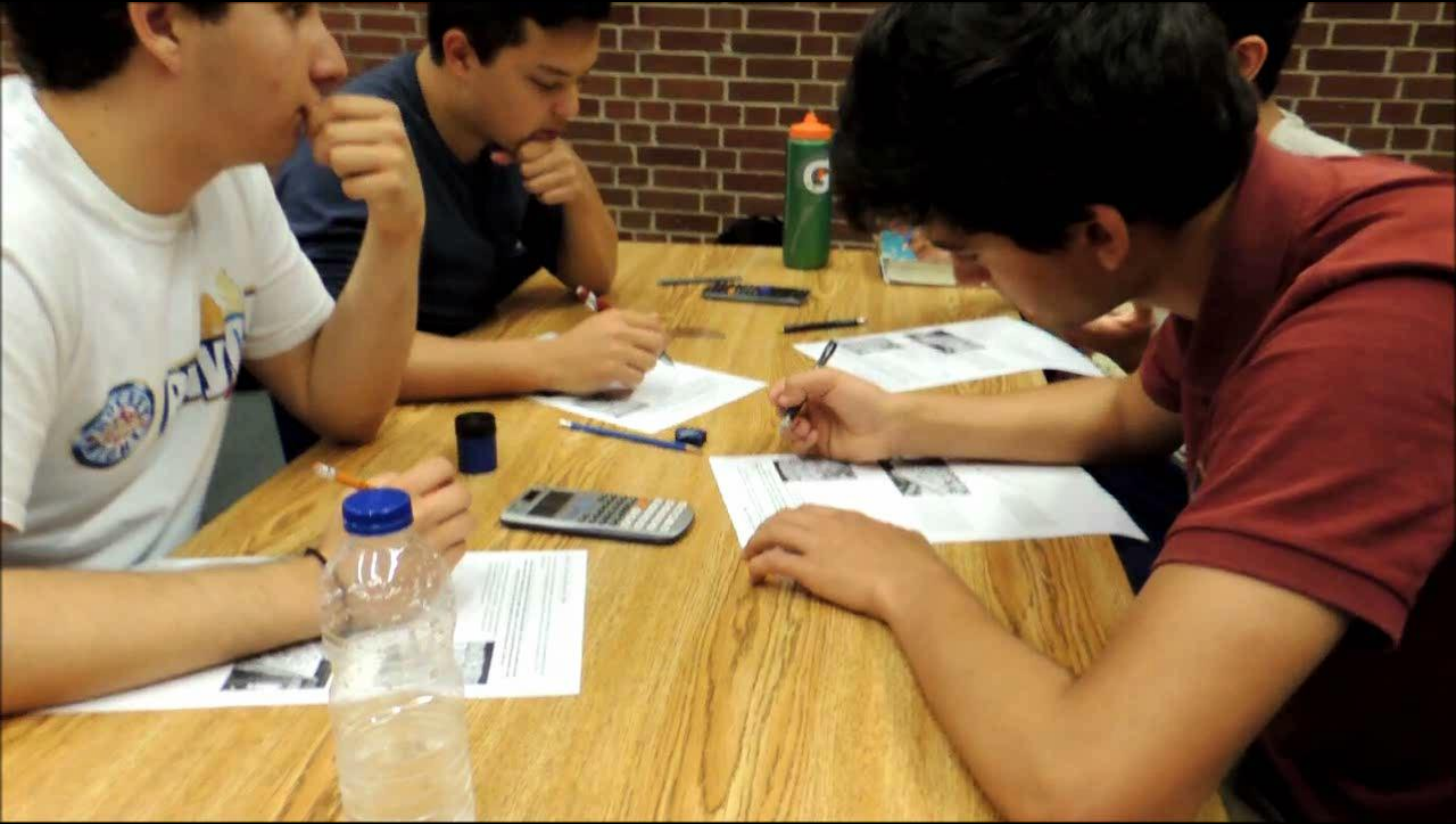
What Environment Doesn’t Do This?


fiscal

I am doing <u>my</u> job:
teaching

Why aren’t my students doing <u>their</u> job:
learning?

York Mills Students



What Does? Active Learning

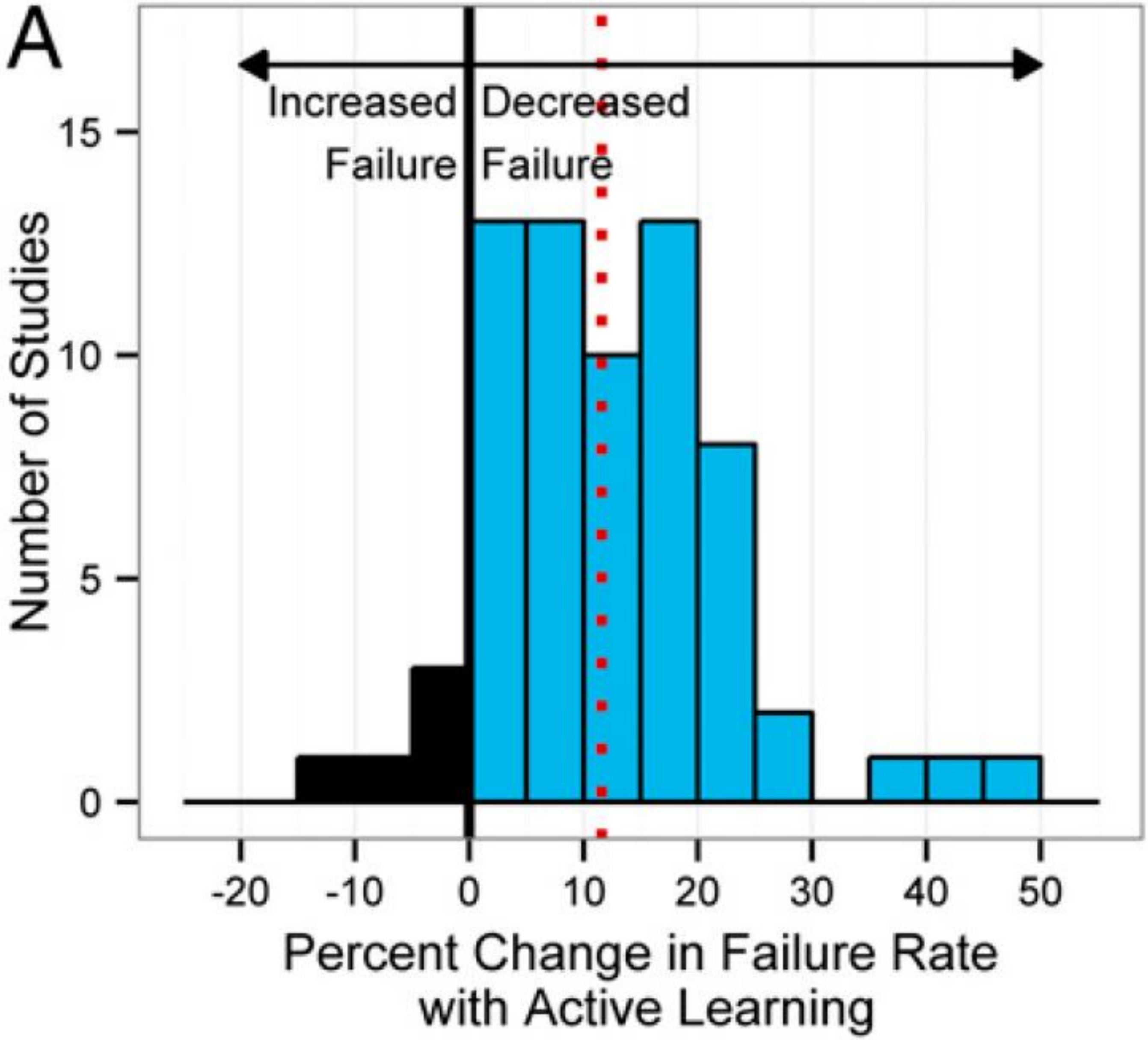
York Mills Students

Active Learning

Emphasizes discussion higher-order thinking and often involves group work.

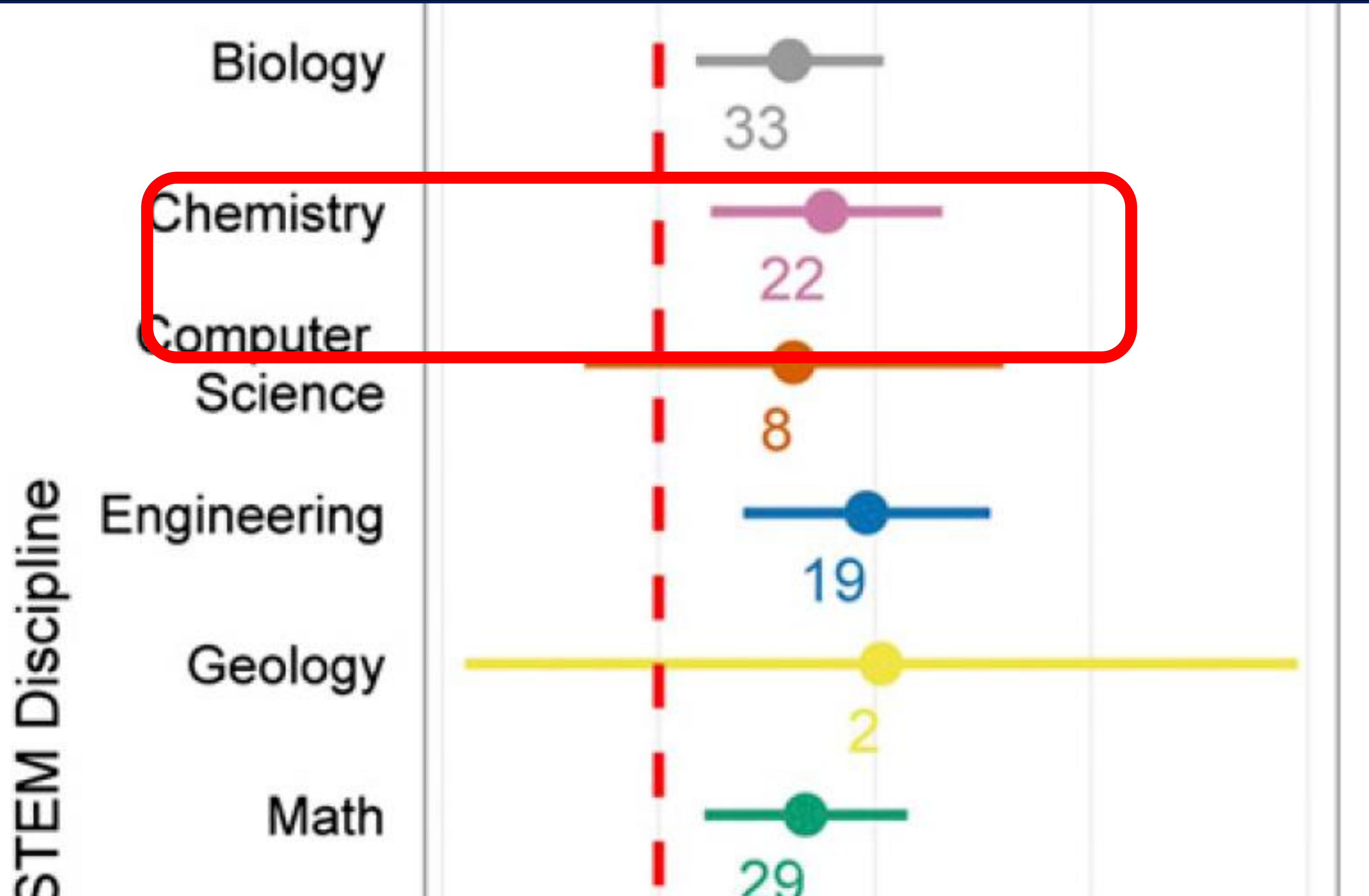
Freeman, Scott, et al. "Active learning increases student performance in science, engineering, and mathematics." *Proceedings of the National Academy of Sciences* (2014): 201319030.

Active Learning Reduces Failures

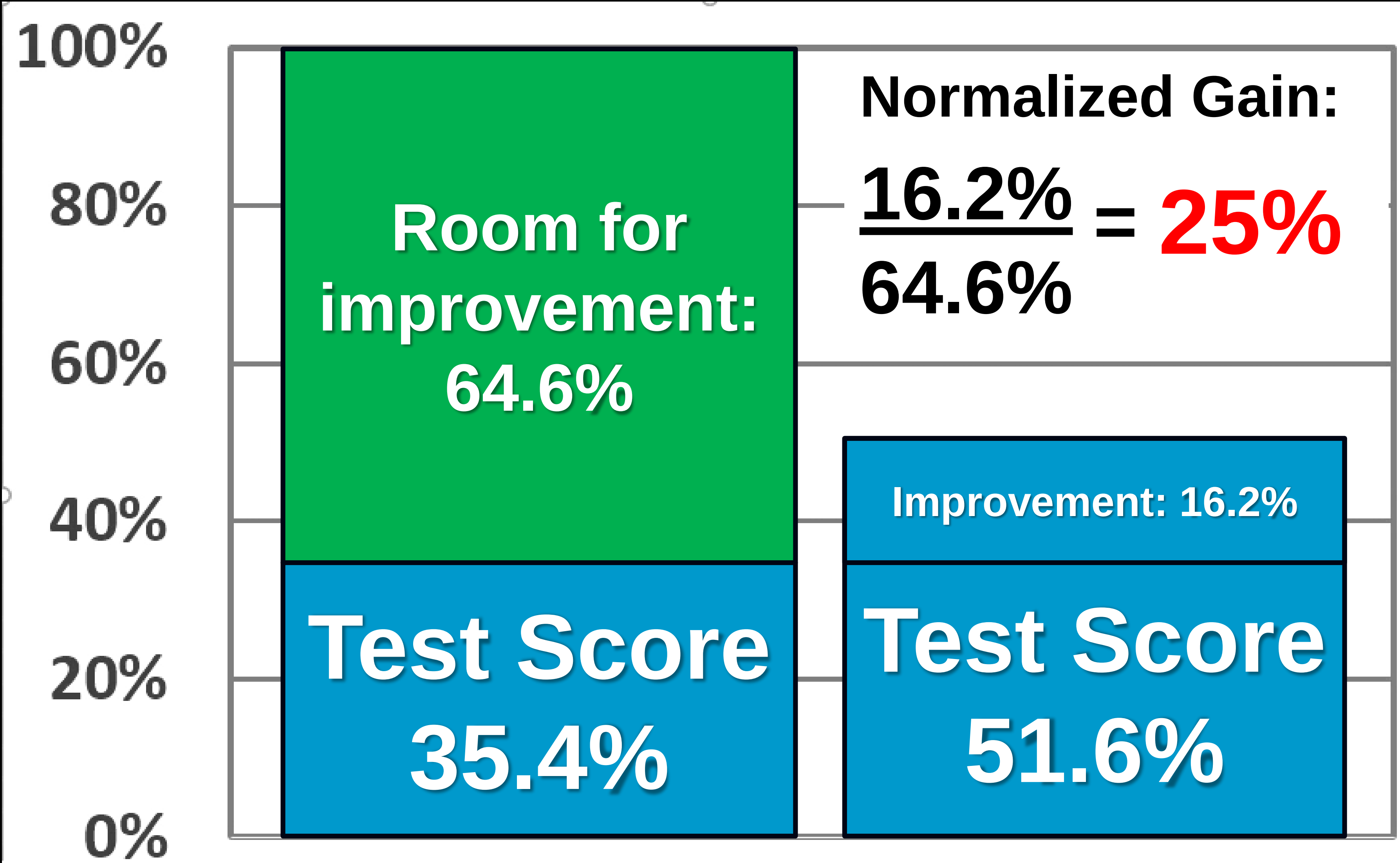


Freeman, Scott, et al. "Active learning increases student performance in science, engineering, and mathematics." *Proceedings of the National Academy of Sciences* (2014): 201319030.

Improves Course Performance

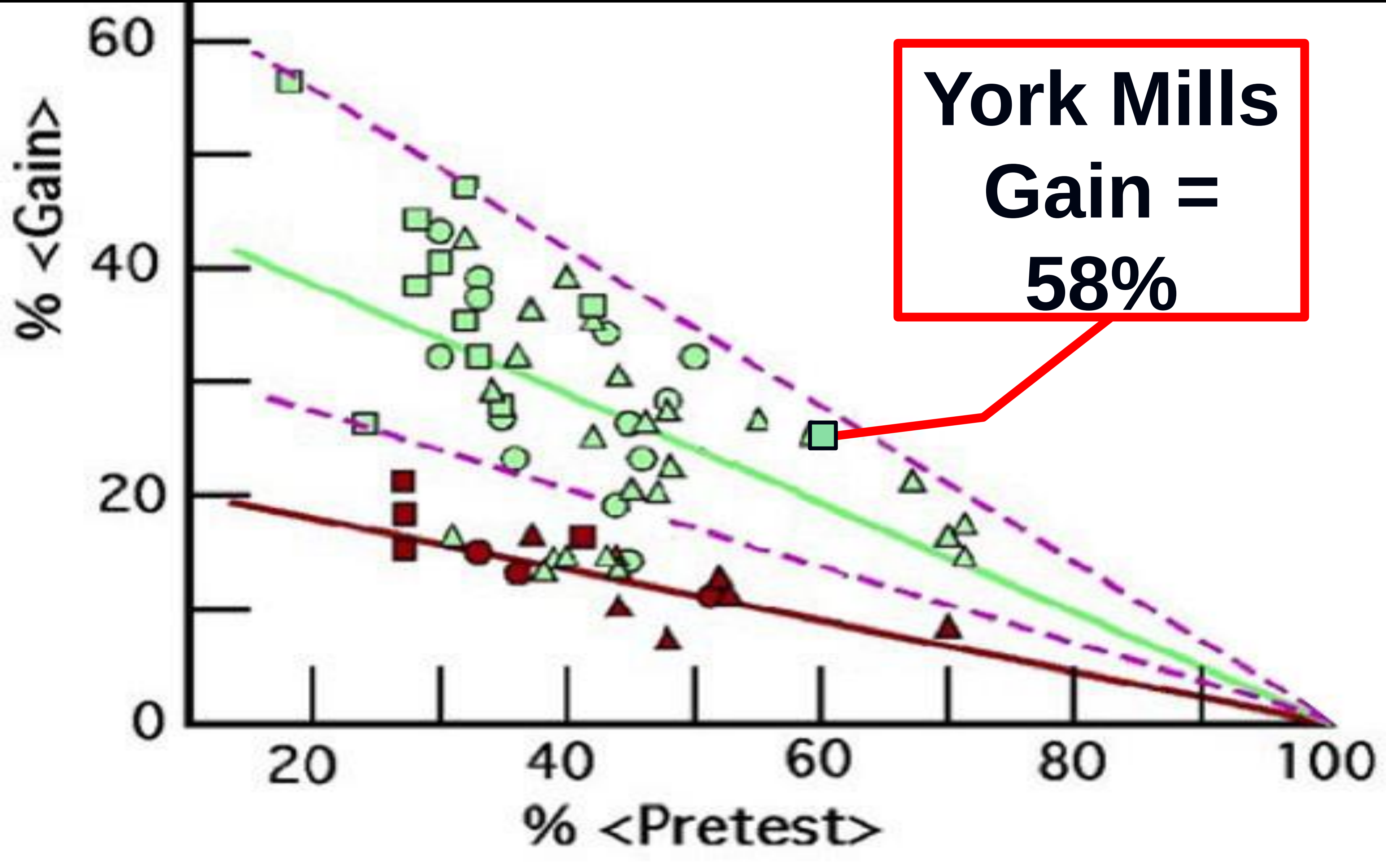


Force Concept Inventory Scores

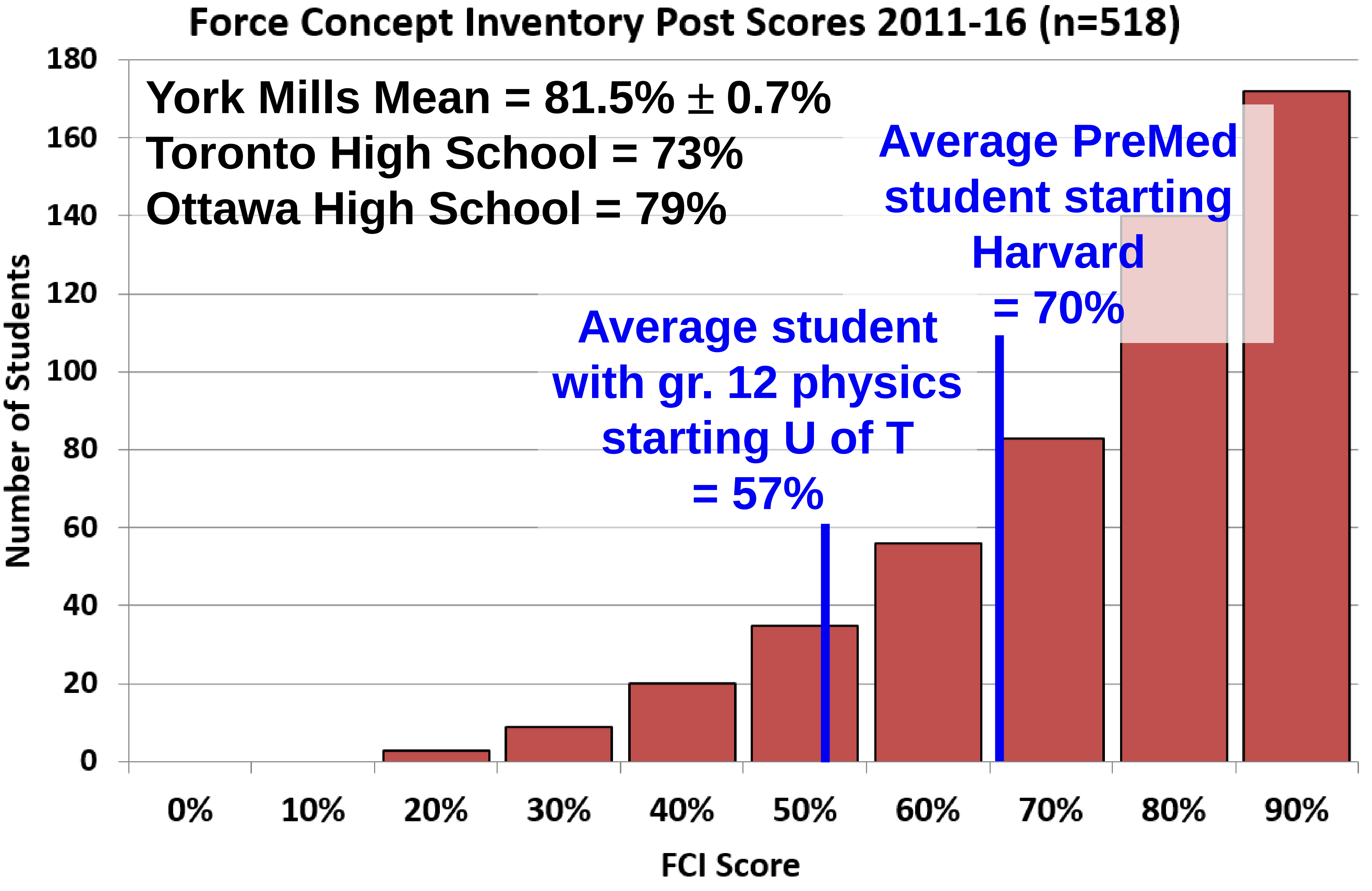


Milner-Bolotin, Marina, et al. "Attitudes about science and conceptual physics learning in university introductory physics courses." *Physical Review Special Topics-Physics Education Research* 7.2 (2011): 020107.

Active Learning Works!



Active Learning Works!



Change is necessary and possible

A 100% Satire-Free Modest Proposal

PCS 450/550

Directed Projects

Promote education as a research topic

Win-Win Deal

You need help and time

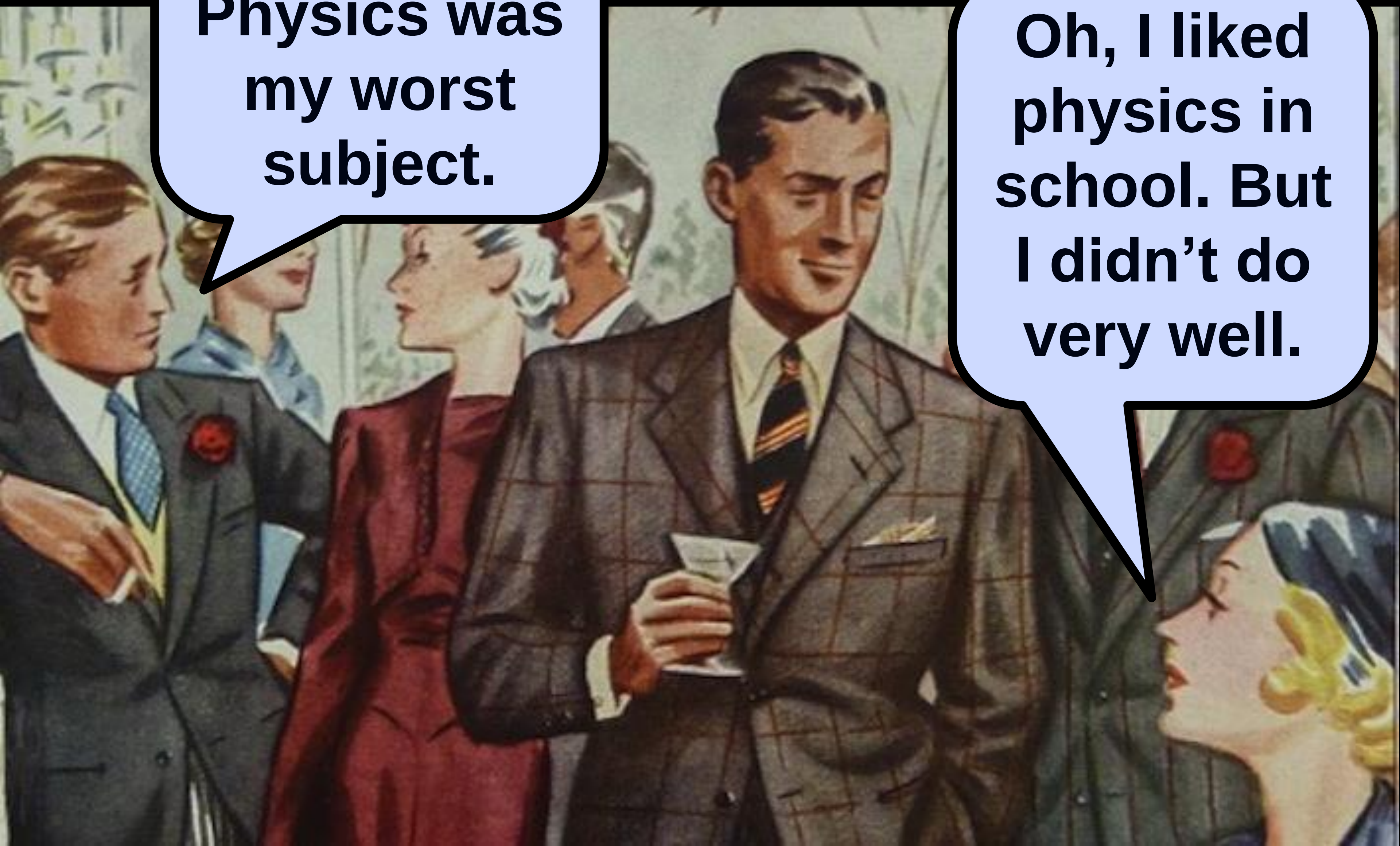
Senior students need apprenticeship in teaching and learning

Win-Win Deal

Use PCS 450/550 to:

- Summarize relevant literature
- Observe classes / interview students
- Study problem set / exam results
- Design lesson ideas to try

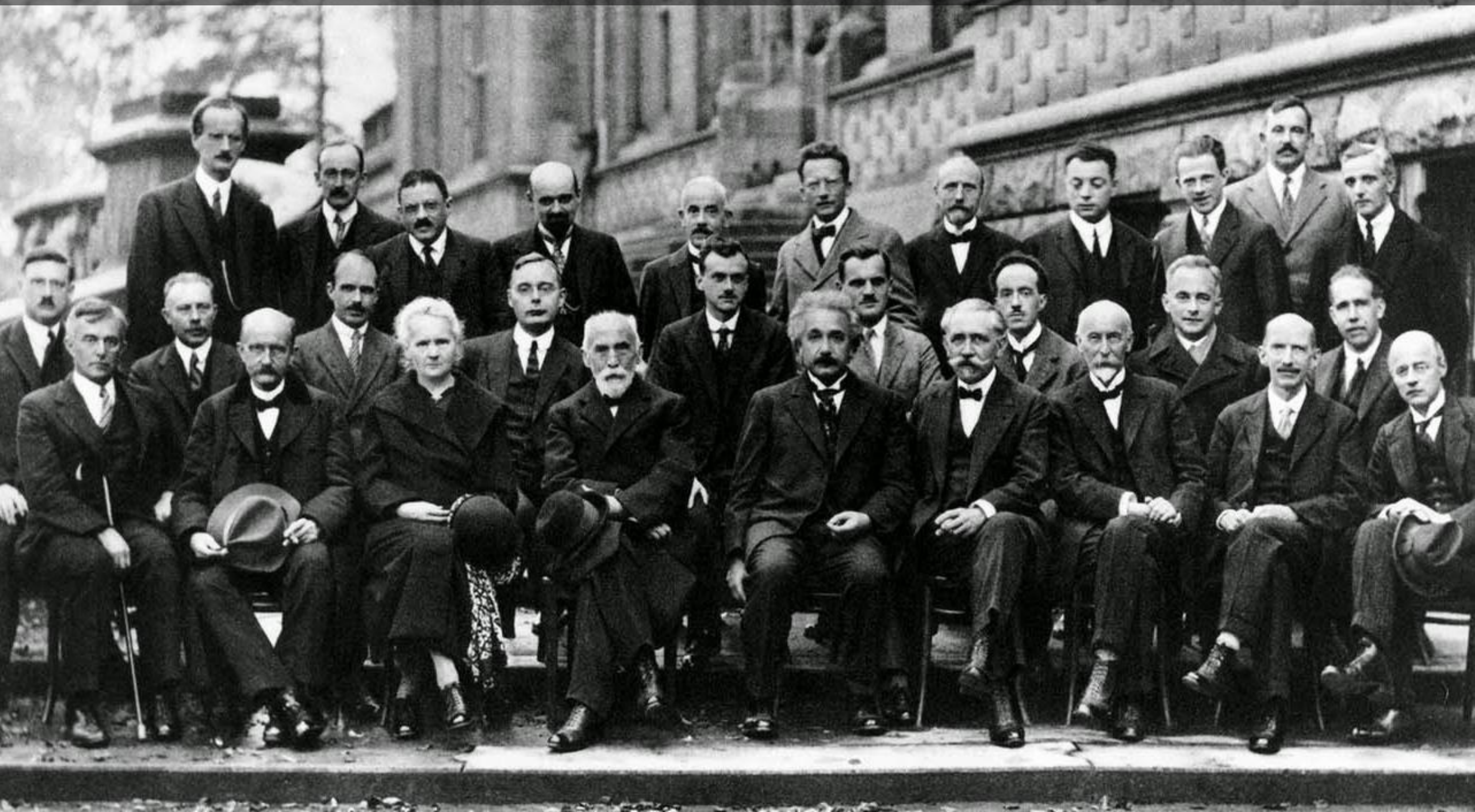
cktail Party



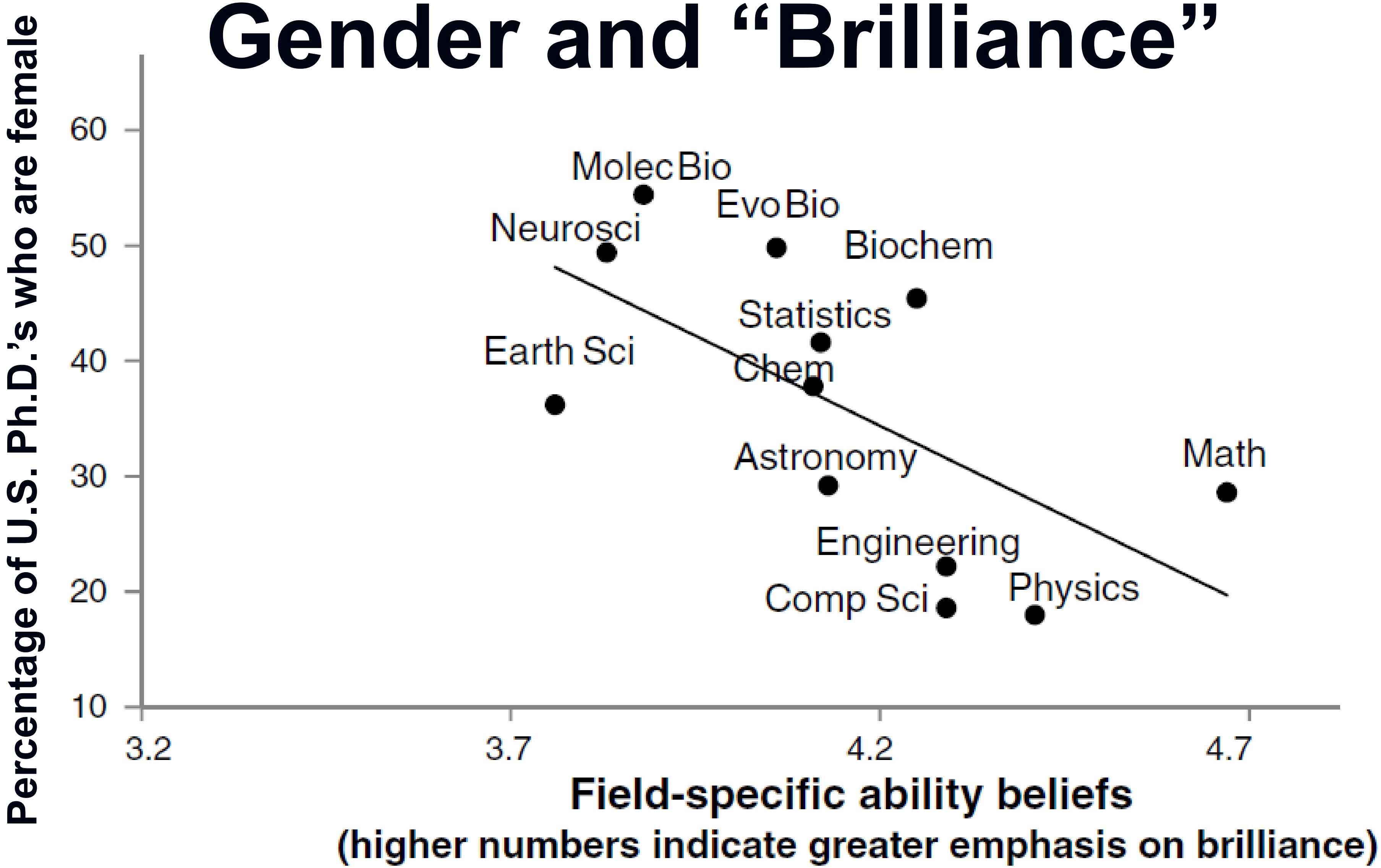
Physics is Hard

The Physics Community in 1927

What kind of people can do physics?



Gender and "Brilliance"



Leslie, Sarah-Jane, et al. "Expectations of brilliance underlie gender distributions across academic disciplines." *Science* 347.6219 (2015): 262-265.

The Social Contract of Teaching

Teach Our Kids Well ...

An Allegory of the Revolution **(1794),**
Nicolas Henri Jeaurat de Bertry

… Do Your Crazy Science Stuff

The Enlightenment Can Be Reversed

Break the Spell of Experts

High level of training

Anders Ericsson, K., Roring, R. W., & Nandagopal, K. (2007). Giftedness and evidence for reproducibly superior performance: An account based on the expert performance framework. *High Ability Studies*, *18*(1), 3-56.

My Prediction

Physics education will improve to the point that any adult of average intelligence can be trained to become a well-regarded, expert physicist.

Arabic Astronomers, 1513

A New Paradigm

What matters most in education

is what goes on in a student's head.


Join the Scientific Revolution for Teaching
Thanks!
www.meyercreations.com/physics