Why Students Hate Statistics and Why it Matters to the Reproducibility of Medical Research

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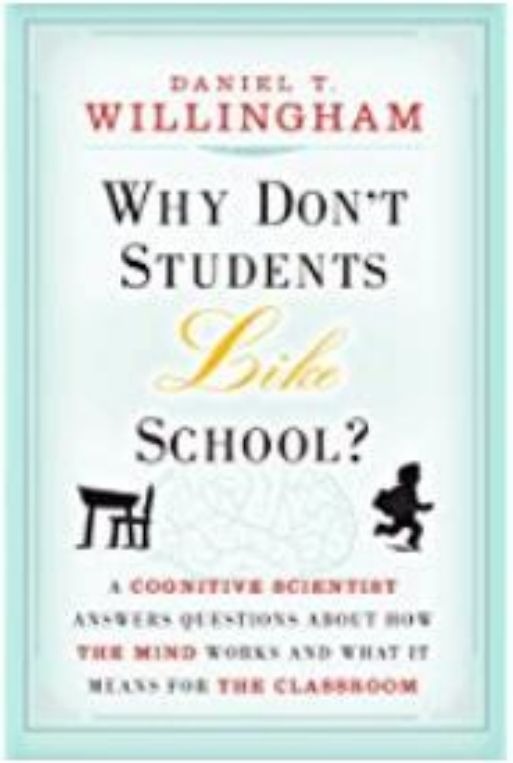
Abstract

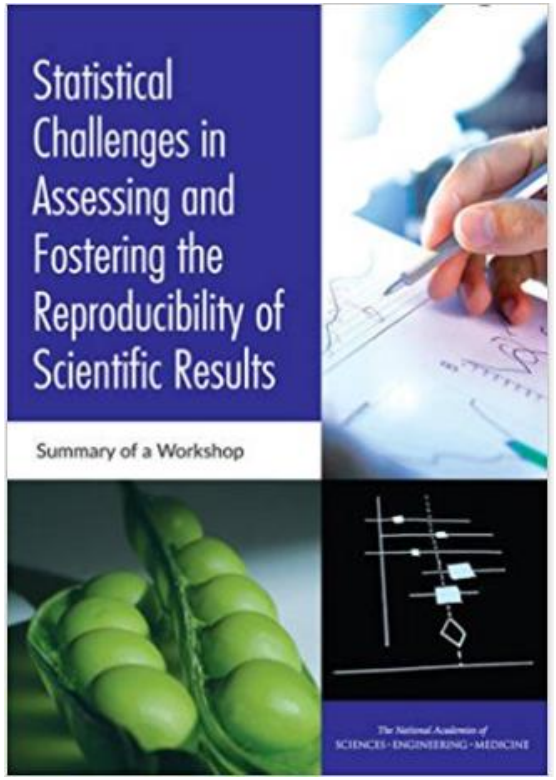
Among his numerous achievements, Jon Borwein promulgated the need to institute a culture of reproducibility. From *Statistics Done Wrong* (Reinhart, 2015) to findings from a recent National Academies of Sciences, Engineering, and Medicine workshop convened to address questions about the reproducibility of scientific research, lack of statistics education has been identified as a major culprit in the generation of poor science. In this talk, we give an overview of the statistical fields required to conduct medical research, explore barriers to learning statistics, and share successful teaching strategies developed at the University of Florida to engage clinicians in medical research.

Cyndi background (some highlights)

1) Completed BS and MA in pure mathematics
2) Completed PhD in theoretical statistics
3) 21 year career as a biostat professor AND statistics educator
4) Developed undergraduate course in statistics for students with learning disabilities (taught over 350 students with LD)
5) Statistical reviewer for medical journal PM&R (Physical Medicine and Rehabilitation)
6) Panel reviewer for Institute for Educational Sciences (IES)
7) Developed *Quantitative Literacy for Translational Research* course for physicians and other clinicians

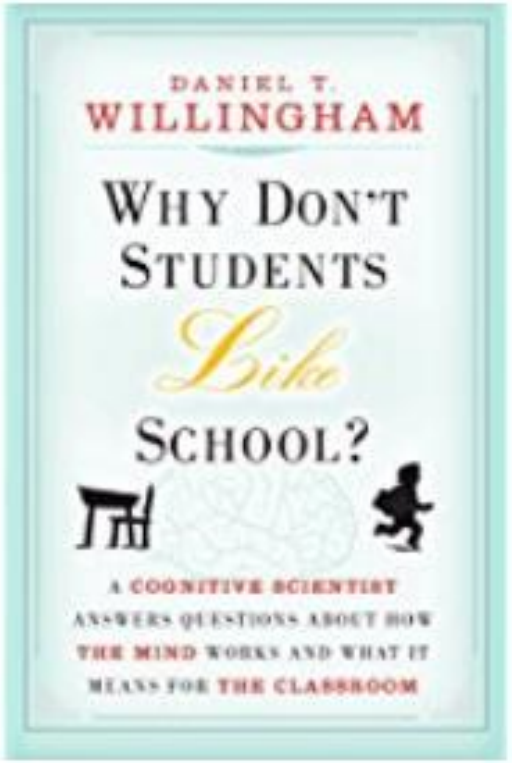
Genesis of this talk





Cyndi's talk

Why don't students like school?



Daniel T. Willingham is a cognitive scientist (PhD Cognitive Psychology, Harvard).

His book is about how the mind works and what it means for the classroom.

Audience interaction, fill in the blank:

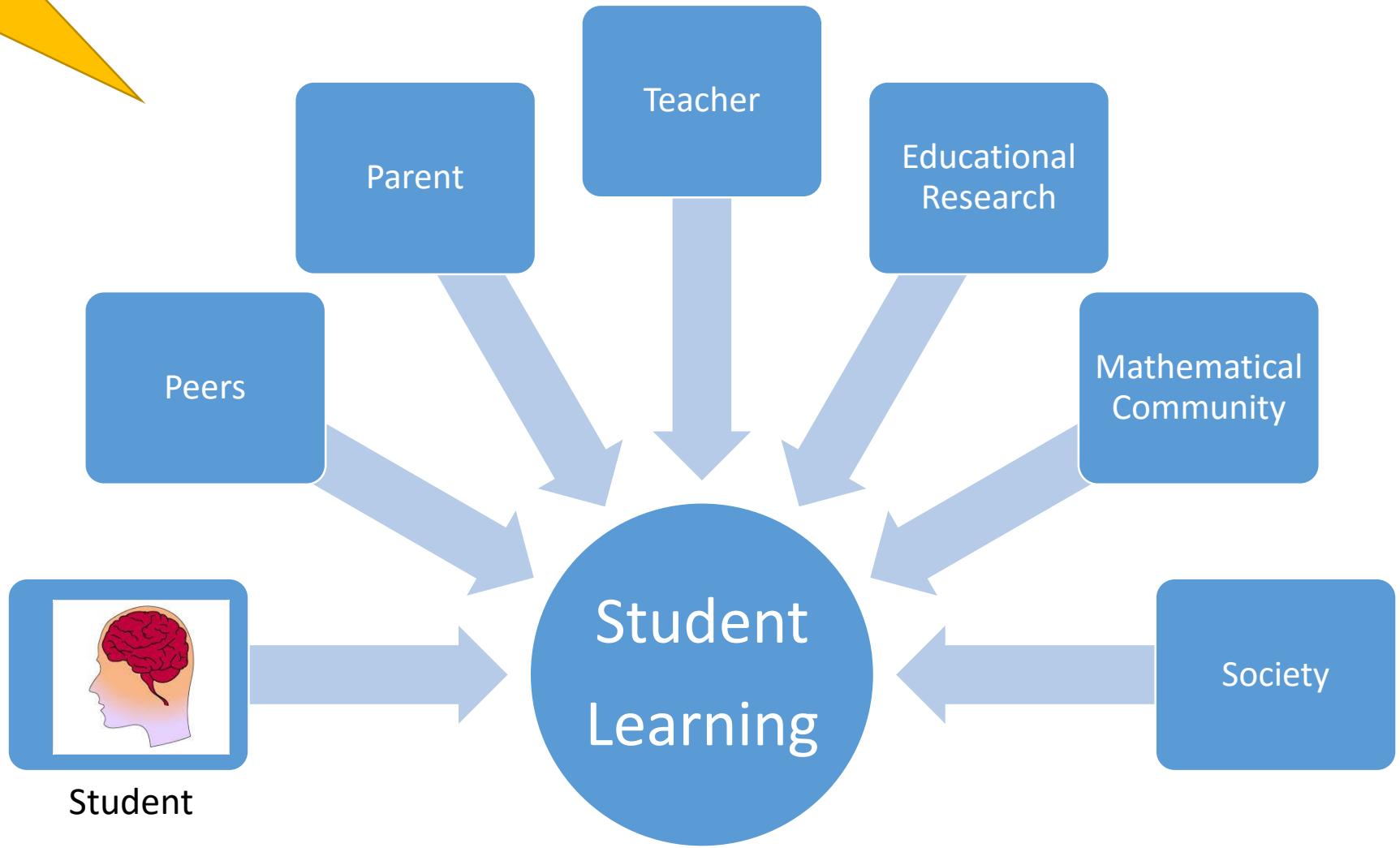
The education system in the United States, Canada and Australia can be described as _____.

“I don’t know what’s happening, but I do know it’s getting worse.”

- Frank Garvan

So, why don’t students like school?

Opportunities for Conflict Galore!



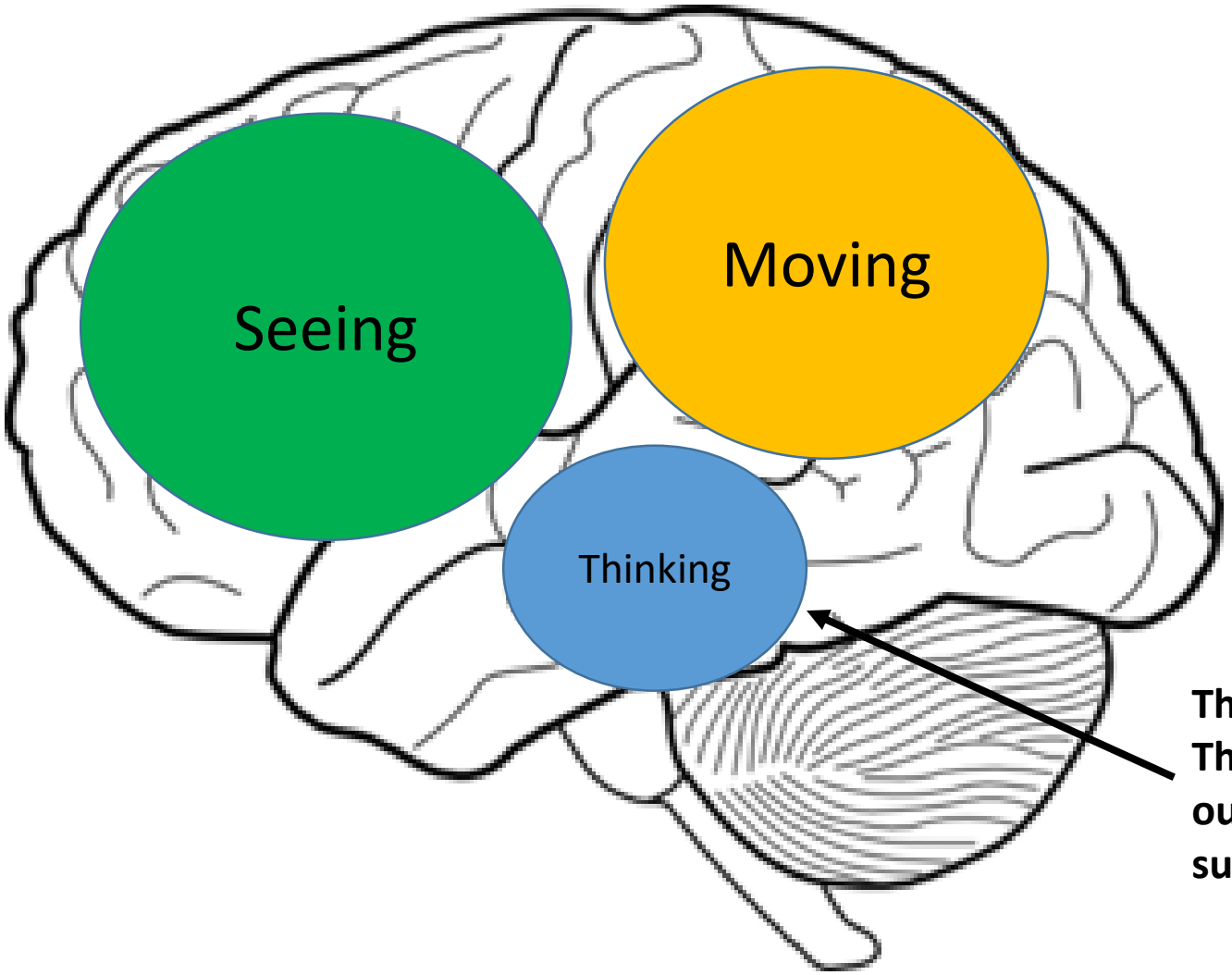
The mind is not designed for thinking.

People are naturally curious, but we are not naturally good thinkers; unless the cognitive conditions are right, we will avoid thinking.

Thinking is slow and unreliable.

People do enjoy mental work…if it is successful!

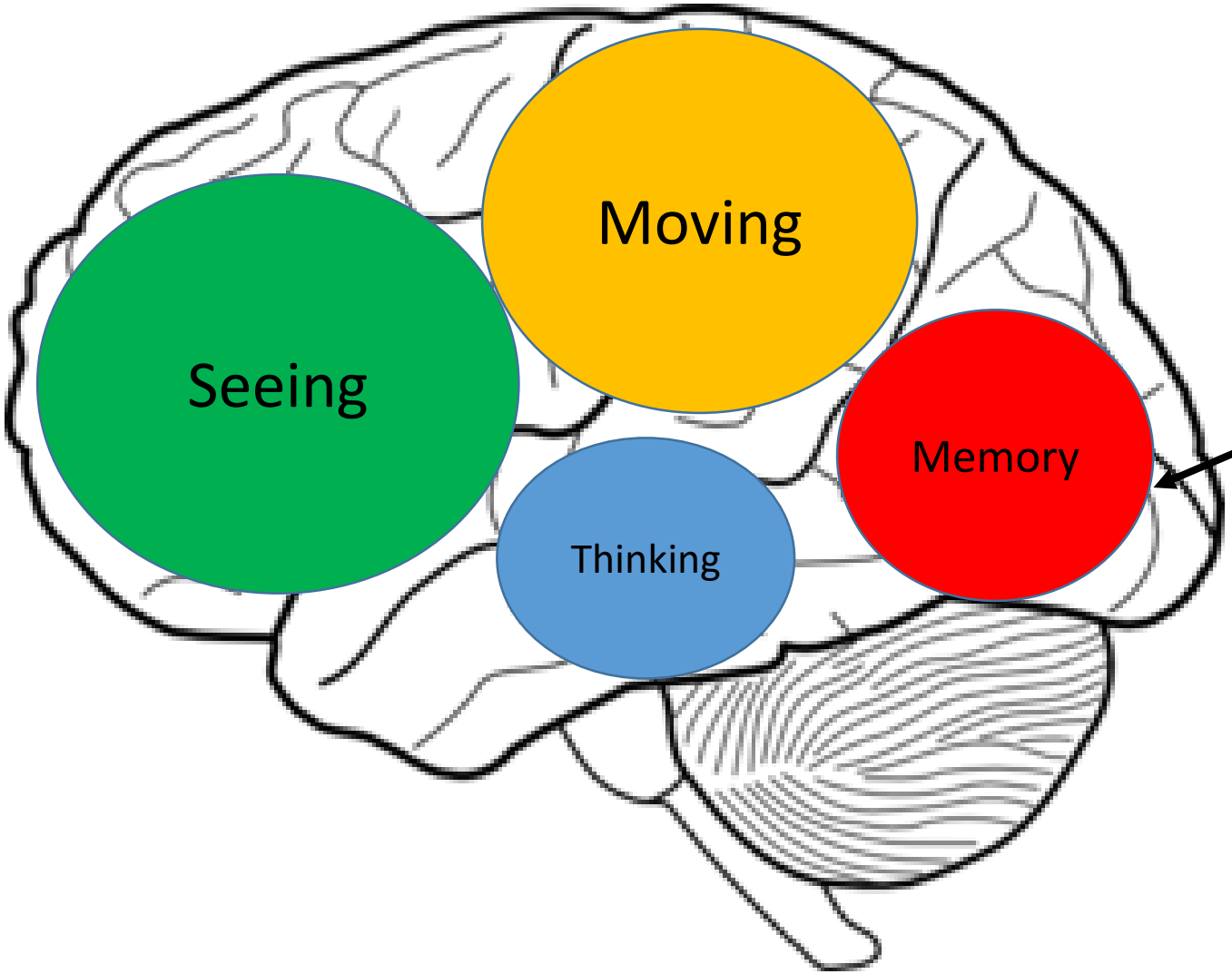
How thinking works



Thinking needs concentration. There is no guarantee that our thinking effort will be successful.

Q. If we are all so bad at thinking, how does anyone get through the day?

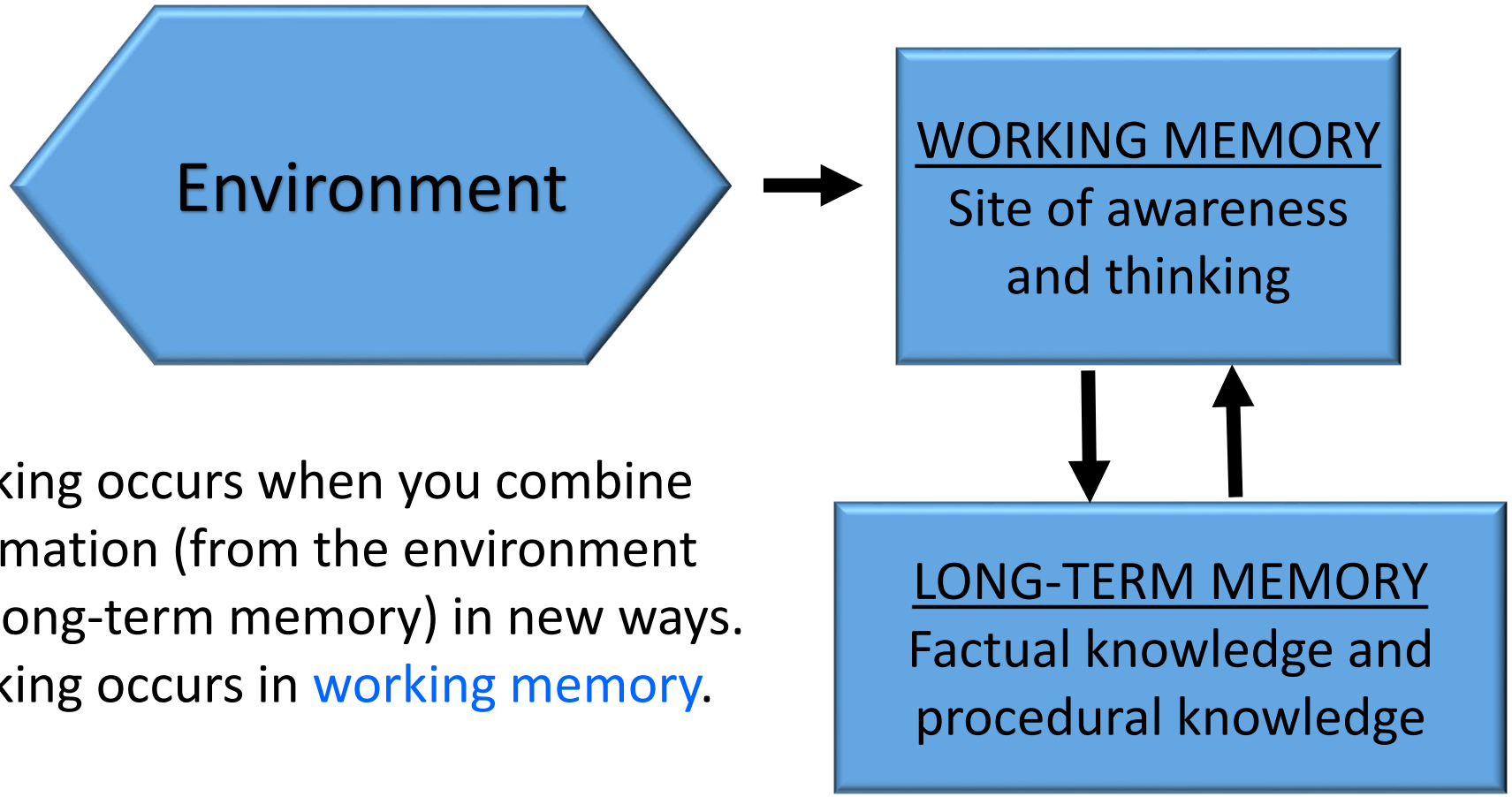
A. Most of the problems we encounter we have solved before. We have memory!



Memory is a more reliable system than thinking system.

Simple model of the mind

Understanding how thinking works helps you understand what makes thinking hard.



Thinking occurs when you combine information (from the environment and long-term memory) in new ways. Thinking occurs in working memory.

How to combine is the hard part!

The controversy of fact learning

Learning Facts

Commit facts to memory (*rote learning*).

1x1 = 1 1x2 = 2 1x3 = 3 1x4 = 4 1x5 = 5 1x6 = 6 1x7 = 7 1x8 = 8 1x9 = 9 1x10 = 10	2x1 = 2 2x2 = 4 2x3 = 6 2x4 = 8 2x5 = 10 2x6 = 12 2x7 = 14 2x8 = 16 2x9 = 18 2x10 = 20	3x1 = 3 3x2 = 6 3x3 = 9 3x4 = 12 3x5 = 15 3x6 = 18 3x7 = 21 3x8 = 24 3x9 = 27 3x10 = 30	4x1 = 4 4x2 = 8 4x3 = 12 4x4 = 16 4x5 = 20 4x6 = 24 4x7 = 28 4x8 = 32 4x9 = 36 4x10 = 40	5x1 = 5 5x2 = 10 5x3 = 15 5x4 = 20 5x5 = 25 5x6 = 30 5x7 = 35 5x8 = 40 5x9 = 45 5x10 = 50
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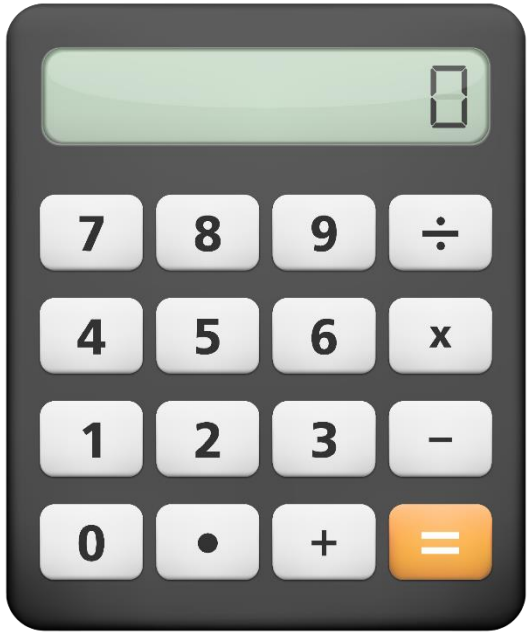
Critical Thinking

Students *evaluate* information instead of memorizing it.



Two types of knowledge

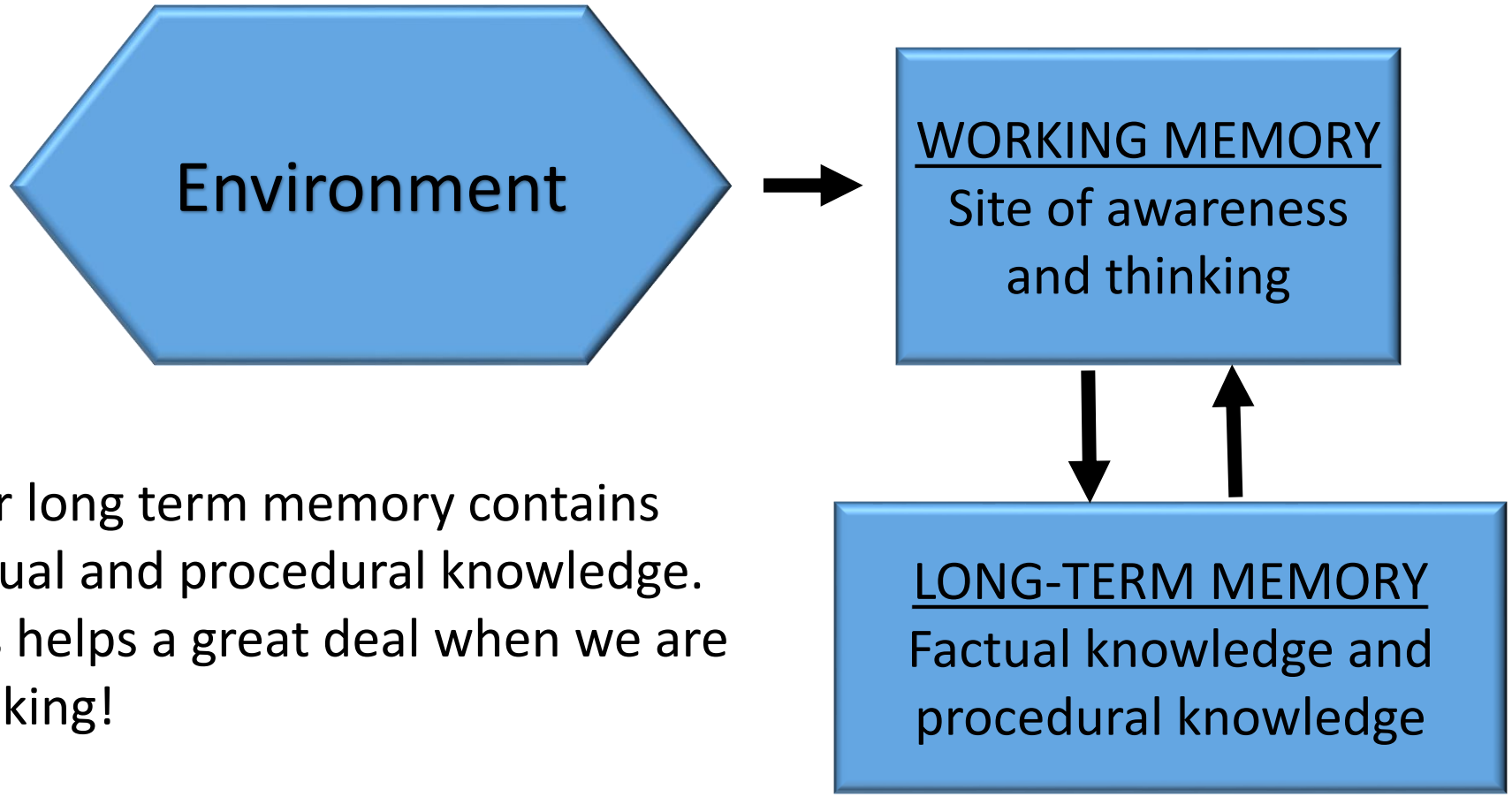
Procedural Knowledge

- Knowledge of formal language or symbolic representations
- Knowledge of rules, algorithms, and procedures
- Knowledge of the mental processes necessary to execute tasks

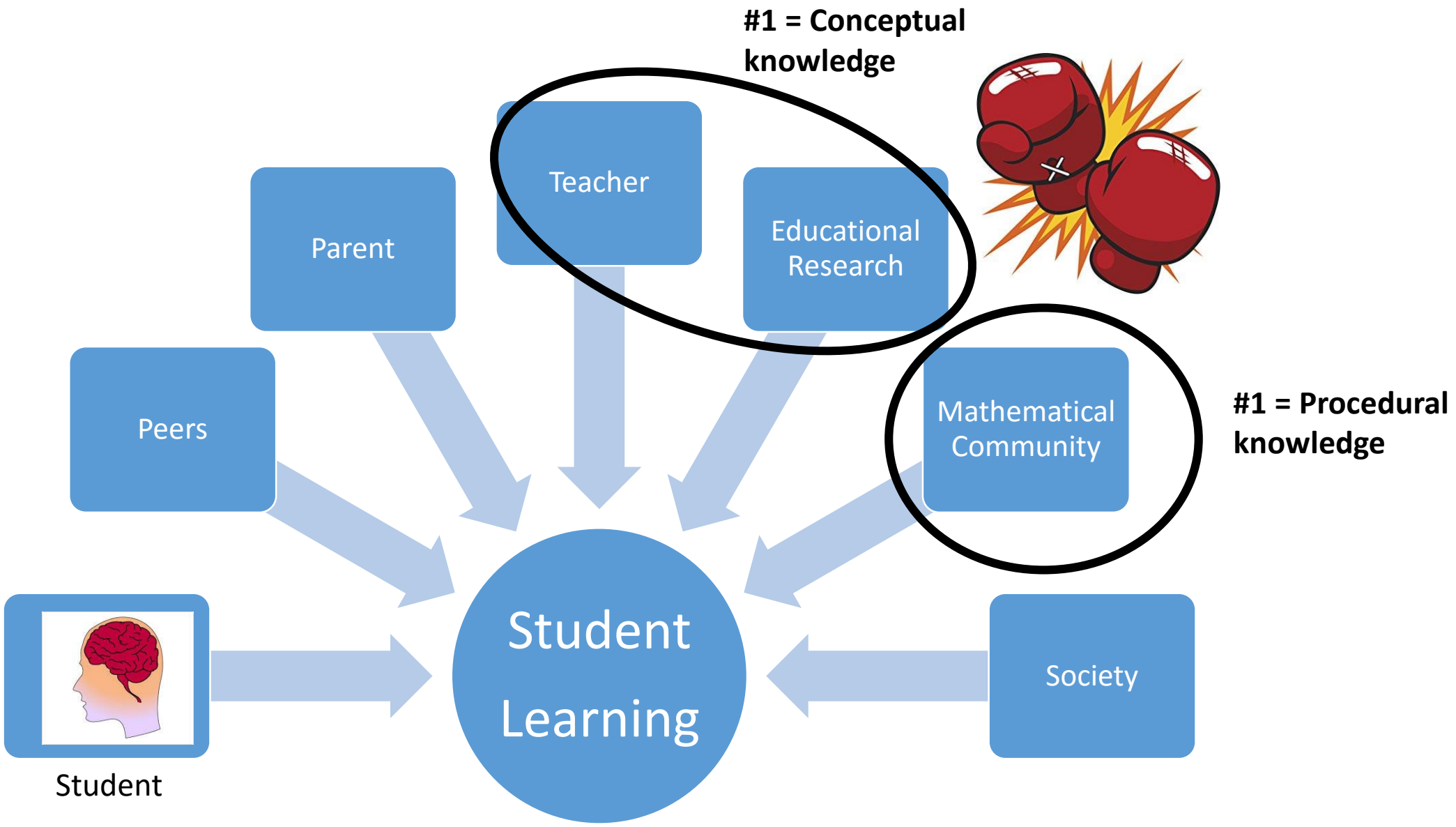
Conceptual Knowledge

- Knowledge rich in relationships and understanding
- By definition, conceptual knowledge cannot be learned by rote. It must be learned by thoughtful, reflective learning.
- Understanding why we do something

Simple model of the mind



Your long term memory contains factual and procedural knowledge. This helps a great deal when we are thinking!


#1 = Conceptual knowledge
Teacher
Parent
Educational Research
Peers
Mathematical Community
#1 = Procedural knowledge
Student Learning
Society
Student

What does cognitive science say?

Factual knowledge must precede skill.

- Background knowledge helps you understand what someone is talking about.
- If a vocabulary word or concept is missing from long term memory, you will be confused.

Building Cognitive Schema

Vocabulary

Idea A

Idea B

Connection between Ideas A and Idea B

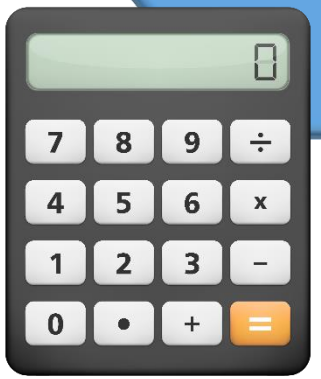
Idea C

Connections among Ideas A, B, and C

KNOWLEDGE IS

Simple model of the mind

Environment



WORKING MEMORY
Site of awareness and thinking

LONG-TERM MEMORY
Factual knowledge and procedural knowledge

1x1 = 1 1x2 = 2 1x3 = 3 1x4 = 4 1x5 = 5 1x6 = 6 1x7 = 7 1x8 = 8 1x9 = 9 1x10 = 10	2x1 = 2 2x2 = 4 2x3 = 6 2x4 = 8 2x5 = 10 2x6 = 12 2x7 = 14 2x8 = 16 2x9 = 18 2x10 = 20	3x1 = 3 3x2 = 6 3x3 = 9 3x4 = 12 3x5 = 15 3x6 = 18 3x7 = 21 3x8 = 24 3x9 = 27 3x10 = 30	4x1 = 4 4x2 = 8 4x3 = 12 4x4 = 16 4x5 = 20 4x6 = 24 4x7 = 28 4x8 = 32 4x9 = 36 4x10 = 40	5x1 = 5 5x2 = 10 5x3 = 15 5x4 = 20 5x5 = 25 5x6 = 30 5x7 = 35 5x8 = 40 5x9 = 45 5x10 = 50
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Why is it so hard for students to understand abstract ideas?

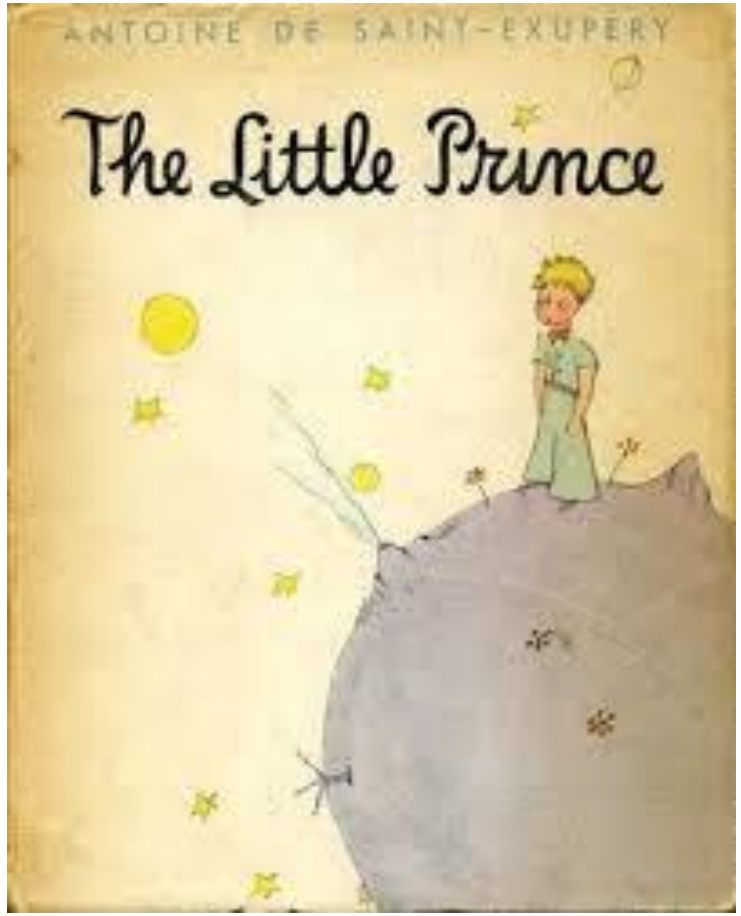
Answer: Abstraction is the goal of schooling. The teacher wants students to be able to apply learning in new contexts. The challenge is that the mind does not care for abstractions. The mind prefers the concrete.

$$\lim_{x \to 0} \frac{\sin(x)}{x} = 1$$

Drilling has been given a bad name, however, it is virtually impossible to become proficient at a mental task without extended practice. Practice enables learning.

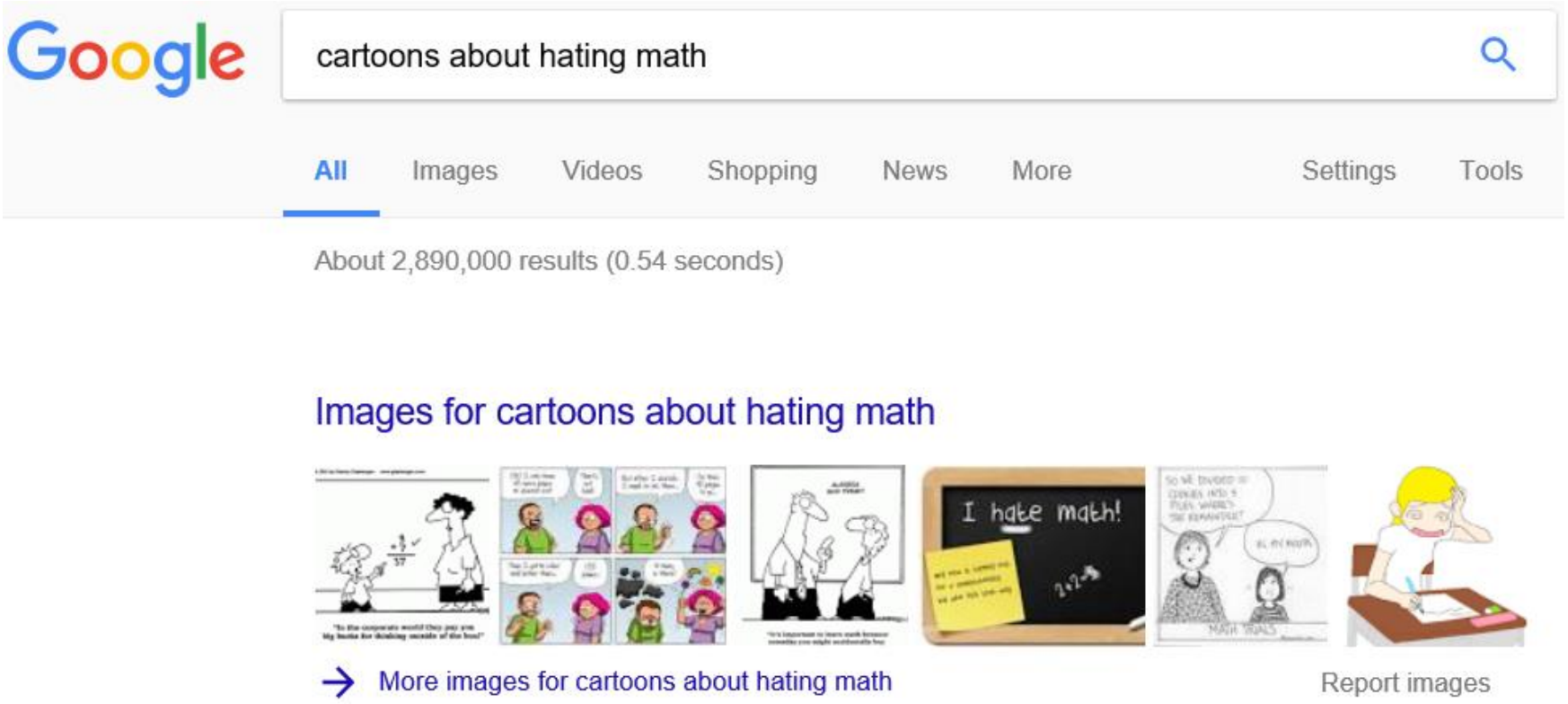
How do you get to Carnegie Hall?
Practice!

Motivation is, of course, of key importance!

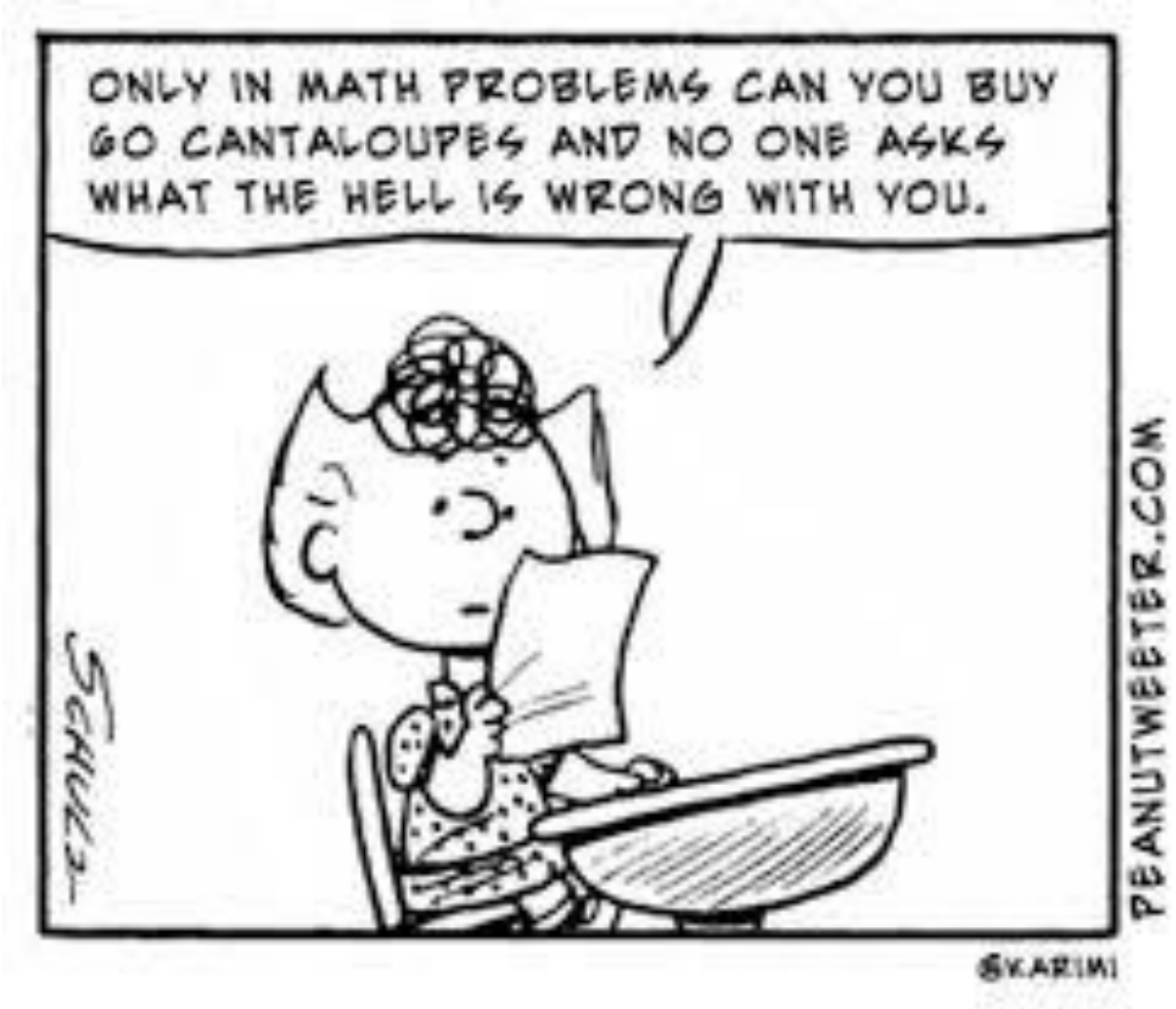


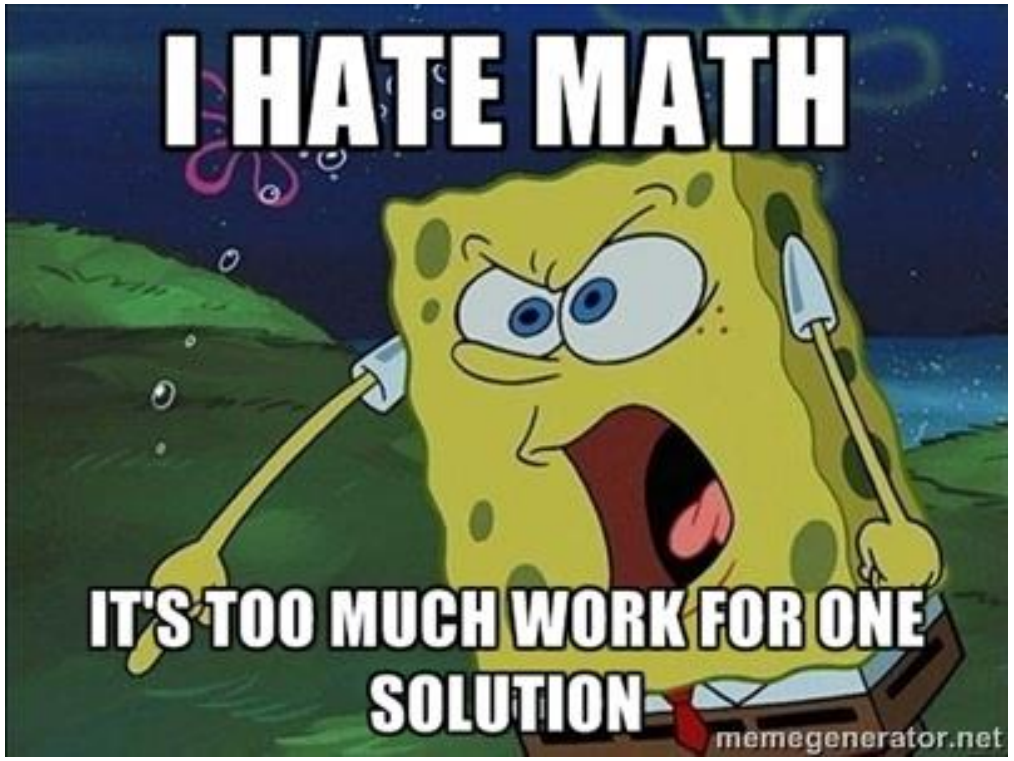
> If you want to build a ship, don't drum up people to collect wood and don't assign them tasks and work, but rather teach them to long for the endless immensity of the sea.
>
> **Antoine de Saint-Exupery**

Society's contribution to the problem



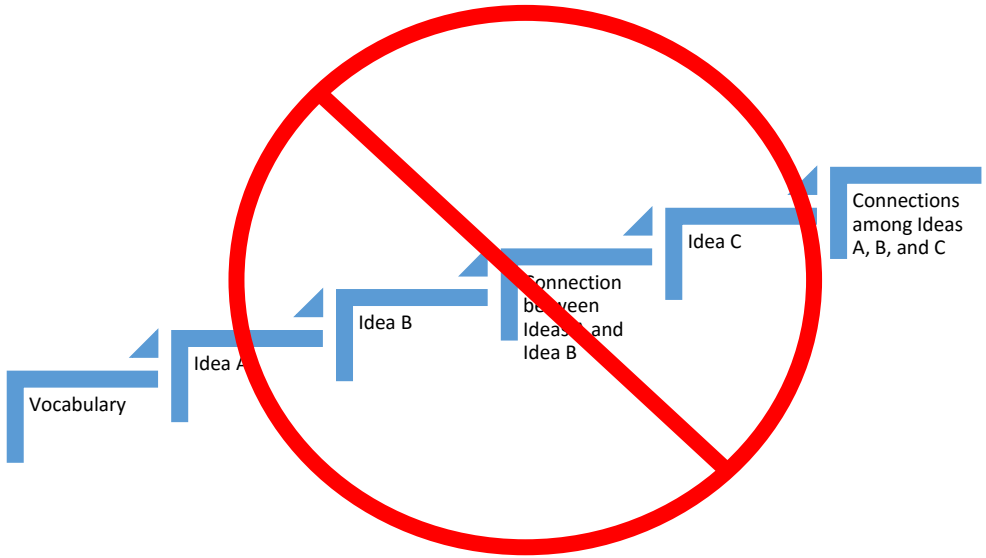
Mathematical illiteracy is A-OKAY!

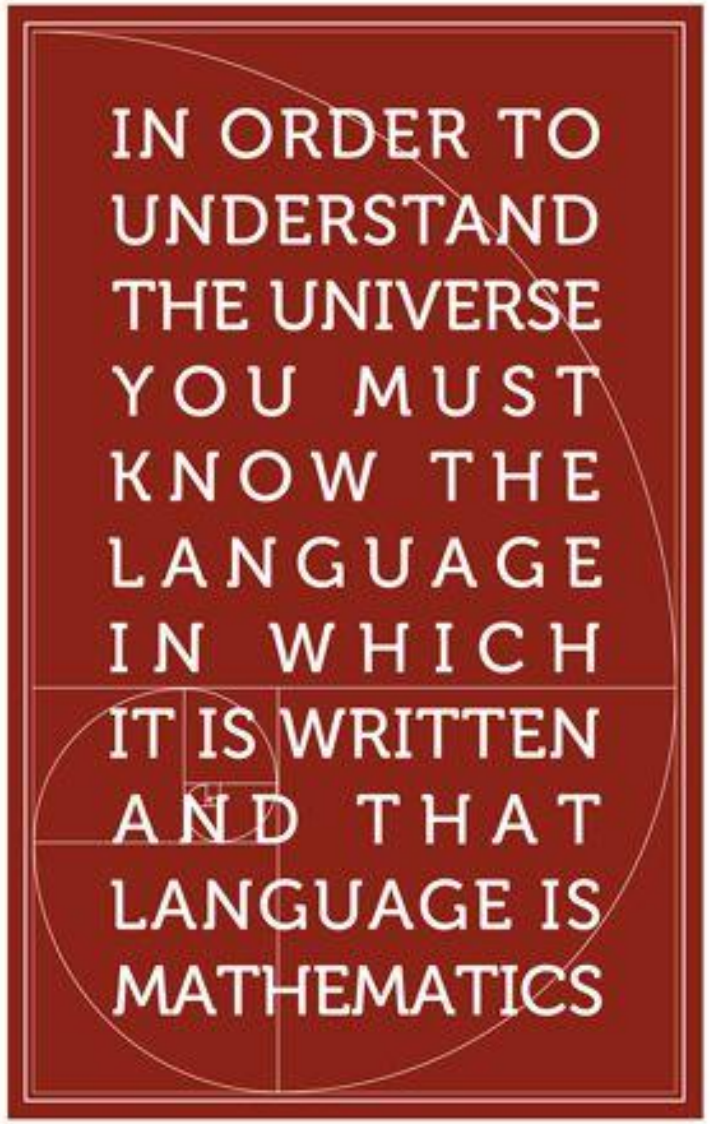


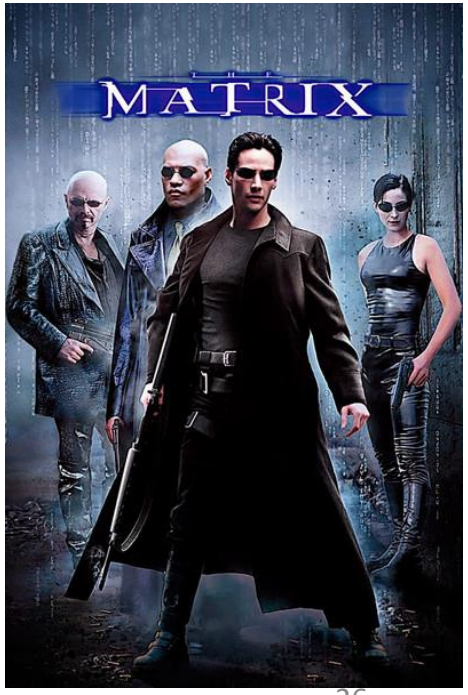


People differ in intelligence, but intelligence can be changed through sustained hard work.

And why do students especially hate statistics?







Why does it matter to the reproducibility of medical research?

NIH, we have a problem…

https://www.youtube.com/watch?v=OPrGEcxijJE

RIGOR AND REPRODUCIBILITY

Cornerstones of science advancement:

1) Rigor in designing and performing scientific research

Rigor ensures robust and unbiased experimental design, methodology, analysis, interpretation, and reporting of results.

2) Ability to reproduce biomedical research findings

When a result can be reproduced by multiple scientists, it validates the original results and readiness to progress to the next phase of research.

Most scientists 'can't replicate studies by their peers'

By Tom Feilden
Science correspondent, Today programme

22 February 2017 | Science & Environment

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Scientists attempting to repeat findings reported in five landmark cancer studies confirmed only two

According to a survey published in the journal Nature last summer, more than **70%** of researchers have tried and failed to reproduce another scientist's experiments.

Science is facing a "reproducibility crisis" where more than two-thirds of researchers have tried and failed to reproduce another scientist's experiments, research suggests.

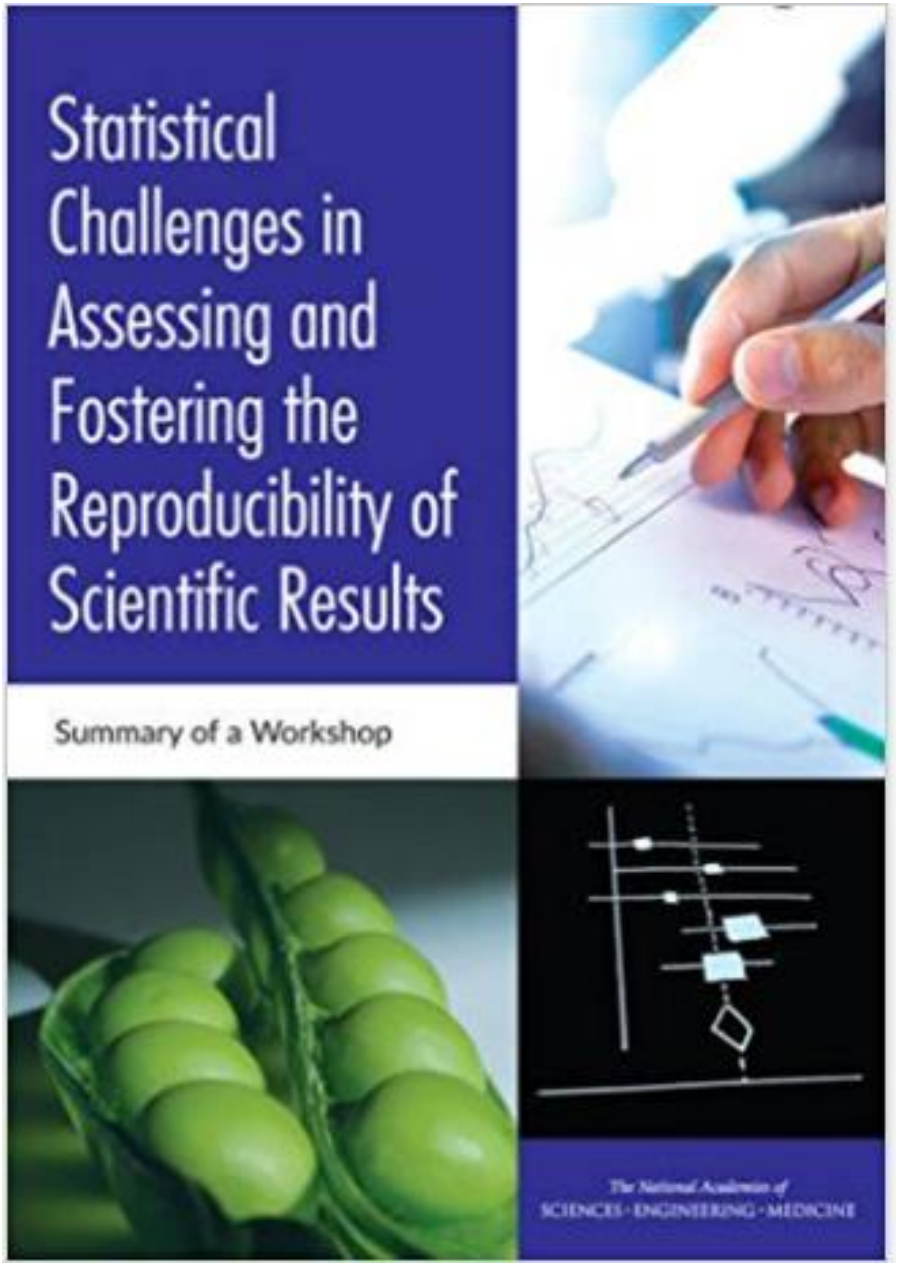
The Reproducibility Project attempted to repeat the findings reported in five landmark cancer studies. After meticulous research involving painstaking attention to detail over several years (the project was launched in 2011), the team was able to confirm only two of the original studies' findings.

Ideally, the authors should have done it themselves before publication and all anyone needs to do is read the methods section in the paper and follow the instructions.

Sadly nothing, it seems, could be further from the truth.

- Marcus Munafo, professor of biological psychology at Bristol University, almost gave up on a career in science when, as a PhD student, he failed to reproduce a textbook study on anxiety.
- "I had a crisis of confidence. I thought maybe it's me, maybe I didn't run my study well, maybe I'm not cut out to be a scientist."
- The problem, it turned out, was not with Marcus Munafo's science, but with the way the scientific literature had been "tidied up" to present a much clearer, more robust outcome.
- "What we see in the published literature is a highly curated version of what's actually happened," he says.
- "The trouble is that gives you a rose-tinted view of the evidence because the results that get published tend to be the most interesting, the most exciting, novel, eye-catching, unexpected results.

The reproducibility difficulties are not about fraud, according to Dame Ottoline Leyser, director of the Sainsbury Laboratory at the University of Cambridge. "It's about a culture that promotes impact over substance, flashy findings over the dull, confirmatory work that most of science is about."



Questions about the reproducibility of scientific research have been raised in numerous settings and have gained visibility through several high-profile journal and popular press articles.

Quantitative issues contributing to reproducibility challenges have been considered (including improper data measurement and analysis, inadequate statistical expertise, and incomplete data, among others), but there is no clear consensus on how best to approach or to minimize these problems.

2016 National Academies of Science

Victoria Stodden: Three aspects of reproducibility

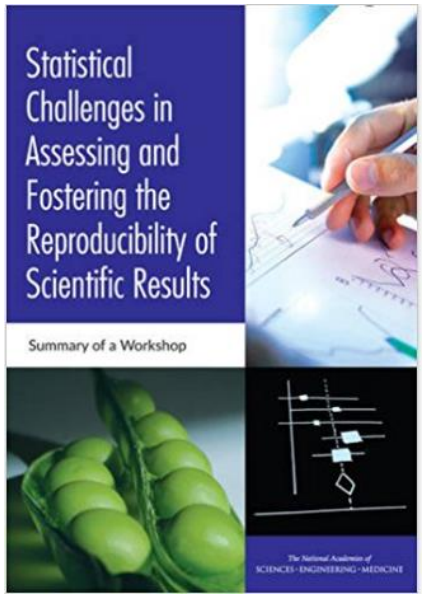
1) Empirical – traditional sense of following specific physical steps, protocols, and designs as described by a publication.

2) Computational – any issue arising from having a computer involved someplace in the work process.

3) Statistical – the ways in which statistics and statistical methods influence the degree to which science is reproducible.

Factors Affecting Reproducibility

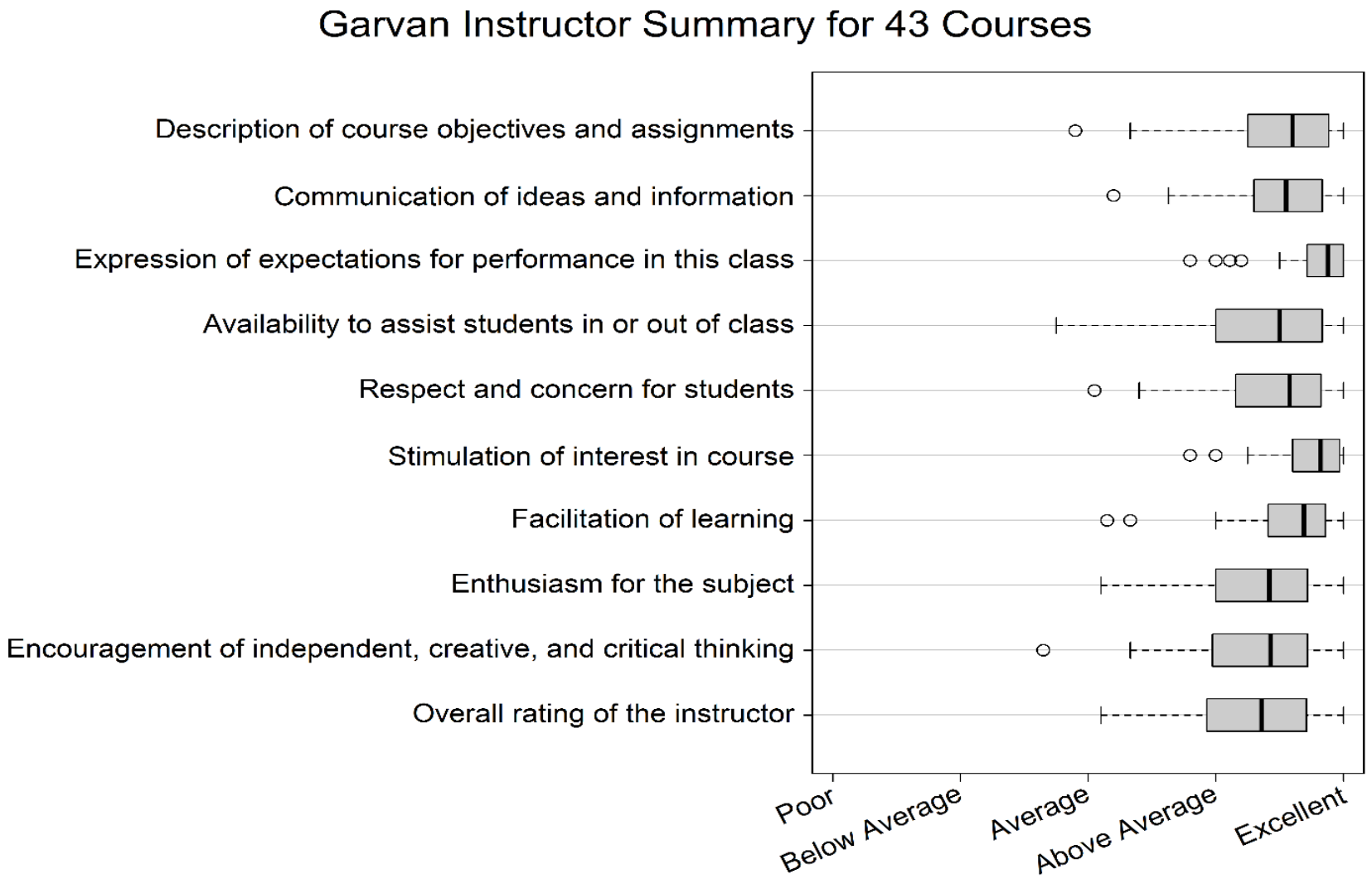
1) Incentives to publish
   - Positive results only!
   - Novelty/Innovation
   - Rush to publish - Career advancement, Competition
2) Funding biases
3) Lack of training (Biostatistics, Basic science, Experimental design)
4) Discordant (dysfunctional?) biomedical ecosystem
5) Empirical factors
6) Computational factors
7) Statistical factors



Recommendations from National Academies of Science Workshop

- Enhance and Clarify Protocols
- Unite the Community in Reproducibility Efforts
- Change Research Incentives
- Increase Sharing of Research Material
- Enhance Education and Training

We need to do a better job teaching math and statistics.



What does the research say about which professors get good ratings and why?

Of all the survey evaluation questions examined, the information in contained in only two items:

1) Does the professor seem like a nice person?
2) Is the class well organized?

Effective teachers are able to connect personally with students, and they organize the material in a way that makes it interesting and easy to understand.

“It is not only for what we do that we are held responsible, but also for what we do not do.”

—Moliere (1622-1673)
French Playwright, Actor

Thank you Jon.

Even the death of Friends will inspire us as much as their lives. They will leave consolation to the mourners, as the rich leave money to defray the expenses of their funerals, and their memories will be incrusted over with sublime and pleasing thoughts, as monuments of other men are overgrown with moss; for our Friends have no place in the graveyard. - Henry David Thoreau