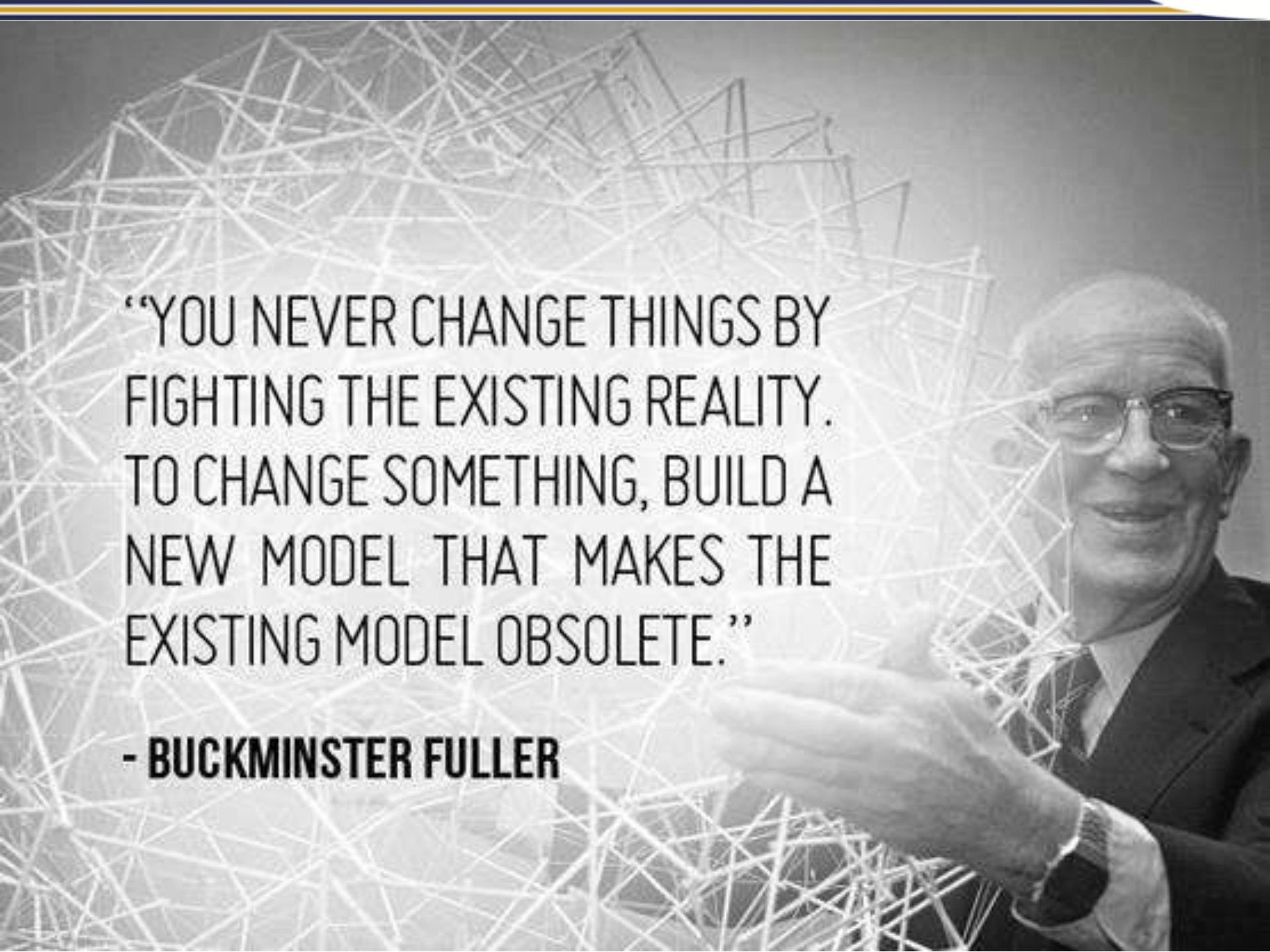


Mathematics for the 21st Century



Geneva May 2018

Charles@CurriculumRedesign.org



“YOU NEVER CHANGE THINGS BY FIGHTING THE EXISTING REALITY. TO CHANGE SOMETHING, BUILD A NEW MODEL THAT MAKES THE EXISTING MODEL OBSOLETE.”

- BUCKMINSTER FULLER

1 Conference + 2 Colloquia with OECD



Many thanks to

Sanjoy Mahajan



Massachusetts
Institute of
Technology



Olin College
of Engineering

Zbigniew Marciniak



Bill Schmidt

MICHIGAN STATE
UNIVERSITY

Ralph Abraham – UC Santa Cruz



UNIVERSITY OF CALIFORNIA
SANTA CRUZ

Michele Bruniges – New South Wales dept of education



NSW
GOVERNMENT

Education &
Communities



Education Team - Alberta Education

Alberta Education



Conrad Wolfram – Wolfram Research

WOLFRAM
RESEARCH

Report to download

PISA Mathematics in 2021

An analysis of the [CENTER FOR CURRICULUM REDESIGN \(CCR\)](#)

Authored by:

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Massachusetts
Institute of
Technology



Olin College
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Zbigniew Marciniak



Bill Schmidt

MICHIGAN STATE
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And Charles Fadel



With many thanks to reviewers/contributors:

Ralph Abraham – UC Santa Cruz



Michele Bruniges – New South Wales dept of education



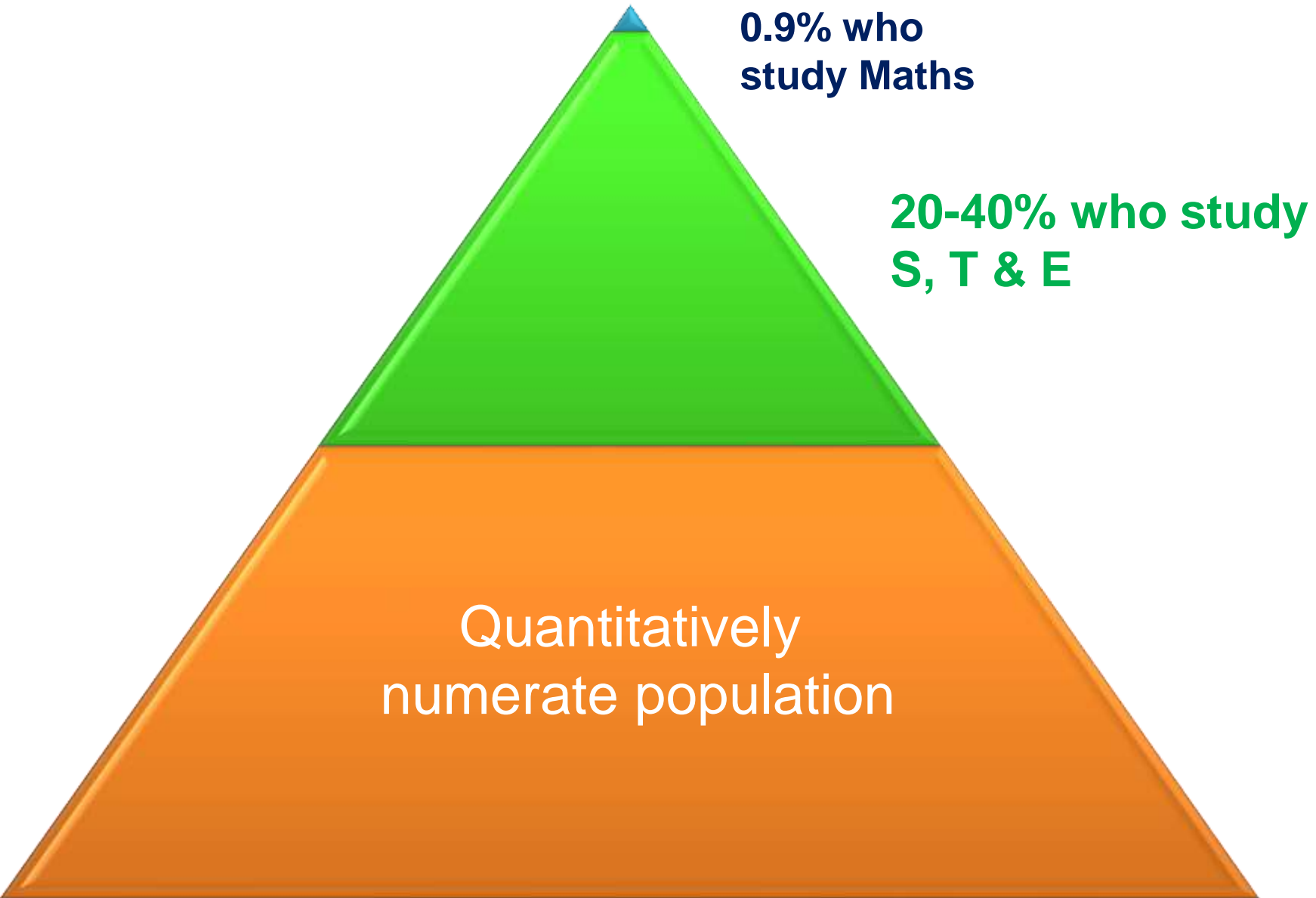
Education Team - Alberta Education



Conrad Wolfram – Wolfram Research

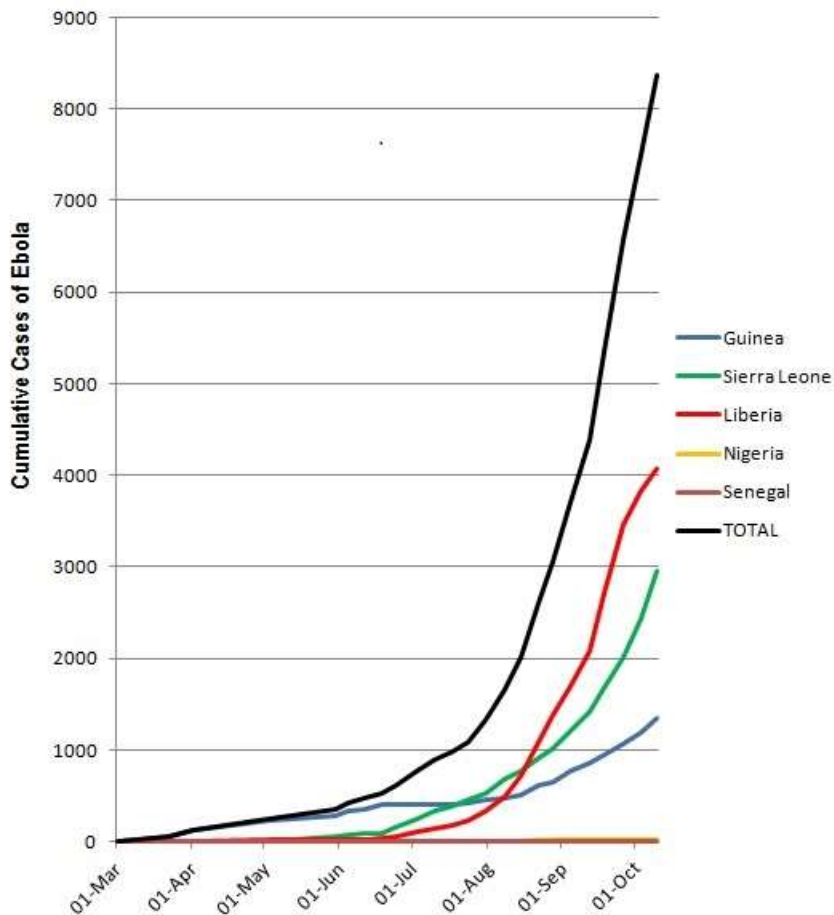


Maths for *All Three Groups*



Life needs deeper understanding of even *basic* Maths

Ebola in West Africa since March 2014

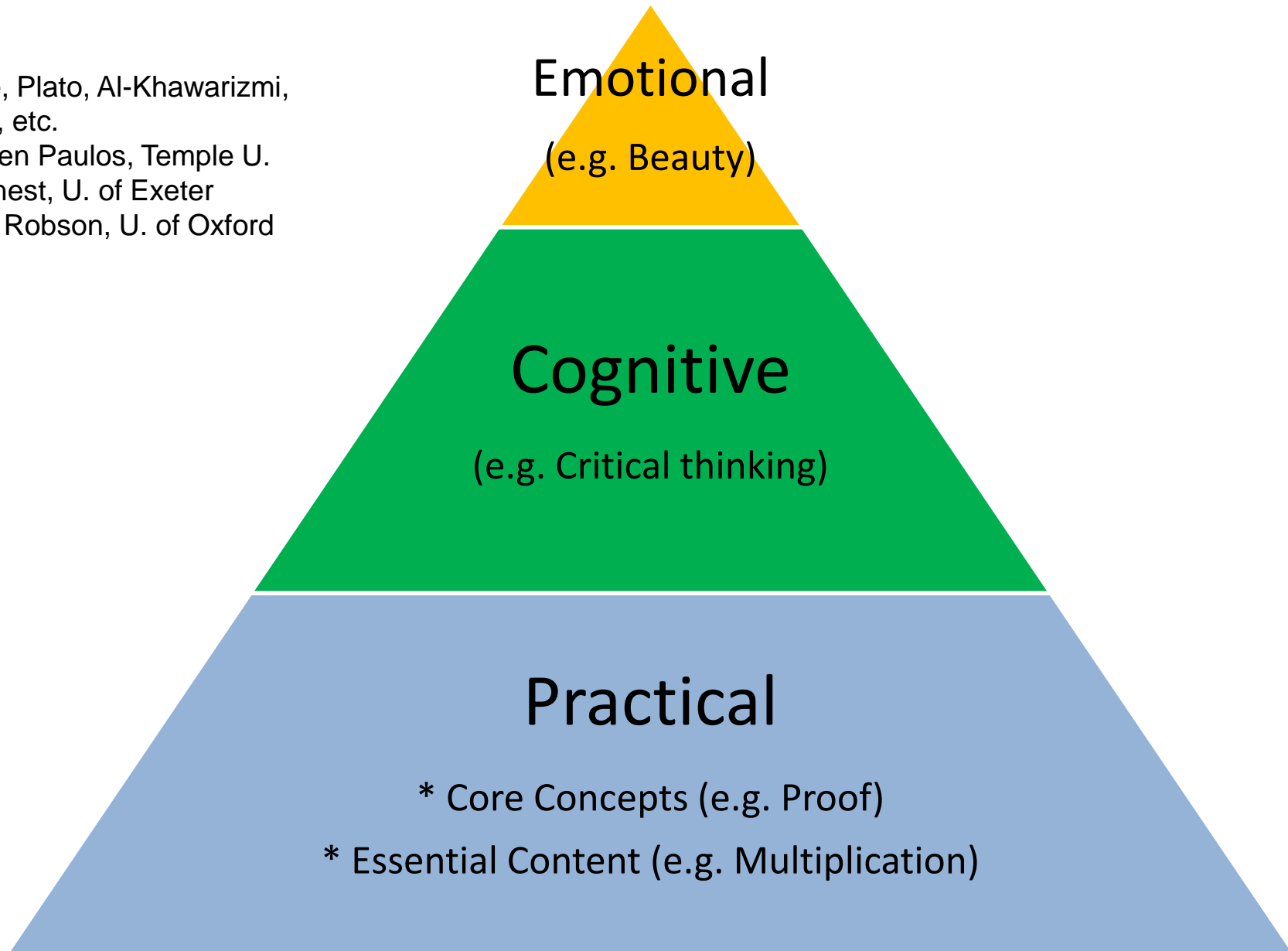


Principle of Proportionality

What are the goals of learning Mathematics?

Sources:

- Aristotle, Plato, Al-Khwarizmi, Al-Kindi, etc.
- John Allen Paulos, Temple U.
- Paul Ernest, U. of Exeter
- Eleanor Robson, U. of Oxford



Emotional

(e.g. Beauty)

Cognitive

(e.g. Critical thinking)

Practical

* Core Concepts (e.g. Proof)

* Essential Content (e.g. Multiplication)

Modern industry needs different Maths

Themes	Responses
	Knowledge
Complexity	Complex systems
Uncertainty	Statistics & probabilities
Multiple scales	Complex systems
Simulations & Modeling	Computational Maths (algorithms)
Data & Information	Statistics & probabilities
	Skills
Multidisciplinarity	Collaboration
Transfer of knowledge	Communication

Source: OECD Global Science Forum Report on Mathematics in Industry

Some observations

Most important in many occupations are

- Number, quantity, measure
- *Data handling and uncertainty*

Followed by

- Space and shape
- Relations, change, formulas

Workplace Mathematics

- Mathematical modeling:
 - e.g. energy requirement of a water company; cost of sandwich; ...
- Use of Software, and coping with problems:
 - e.g. oil extraction; dispersion of sewage; ...
- Costing (allocation, dispute management):
 - e.g. Contract cleaning of hospital; management of railway; ...
- Performance and ratios:
 - e.g. Insurance ratios; glycemic index; ...
- Risk:
 - e.g. clinical governance; insurance; ...
- Quality/SPC control:
 - E.g. Furniture; machine downtime; deviation of rails; ...

Relevance is a choice

© Charles Fadel Occupation (below)	Algebra	Applied Maths	Calculus	Discrete Mathematics	Foundations	Geometry	Numbers & Operations	Statistics & Probability	Topology & Recreational
Taxonomy & Ontology: Wolfram Research →	Matrices, Operations, Vectors etc	Complex systems, Control, Game theory, etc	Analysis, Transforms, Polynomials, etc	Automata, Graphs, Computational maths etc	Sets, Logic etc	Curves, Dimensions, Transformations, Trigonometry, etc	Arithmetic operations, Fractions, Sequences, etc	Distributions, Analysis, Estimation, etc	Knots, Figures, Folding, Spaces, etc
Agriculture						X	X	X	
Architecture		X				X	X	X	X
Astronomy/Cosmology	X	X	X	X		X	X	X	X
Biology, Botany, Zoology		X		X			X	X	
Biotechnology, Genetics	X	X	X	X		X	X	X	X
Business		X					X	X	
Cinematography/Photography						X	X		X
Civil engineering	X	X	X	X		X	X	X	X
Communication		X					X	X	
Computer science	X	X	X	X	X	X	X	X	X
Craftsmanship						X	X		X
Dance						X	X		X
Design						X	X		X
Drawing						X	X		X
Economics & Finance	X	X	X	X		X	X	X	
Education	X	X	X			X	X	X	
Electrical engineering	X	X	X	X		X	X	X	
Environmental science	X	X	X	X		X	X	X	
Ethics							X		
Geography/Geology	X	X	X	X		X	X	X	X
Health							X	X	
History/Archeology	X	X		X			X	X	
Journalism	X	X					X	X	
Languages/Linguistics	X	X		X			X	X	
Law		X					X	X	
Materials Science/Nanotechnology	X	X	X	X		X	X	X	X
Mechanical engineering, Robotics	X	X	X	X		X	X	X	X
Medicine/Pharmacy/Veterinary		X					X	X	
Music	X						X	X	
Painting						X	X		
Philosophy		X			X		X	X	
Physics	X	X	X	X	X	X	X	X	X
Poetry/Prose							X		
Psychology/Sociology/Anthropology	X	X		X			X	X	
Sculpture						X	X		X
Sewing/Knitting/Tapestry						X	X		X
Spirituality/Religions							X		
Theater/Acting							X		

Change is Hard

From NSF report:

- “more emphasis on estimation, mental maths...
- “less emphasis on paper/pencil execution...”
- “content in... algebra, geometry, pre-calculus and trigonometry need to be... streamlined to make room for important new topics.”
- “discrete Mathematics, statistics/probabilities and computer science must be introduced”.

Date of report: 1982 (!)

Why did we add Trigonometry in the 1800's?

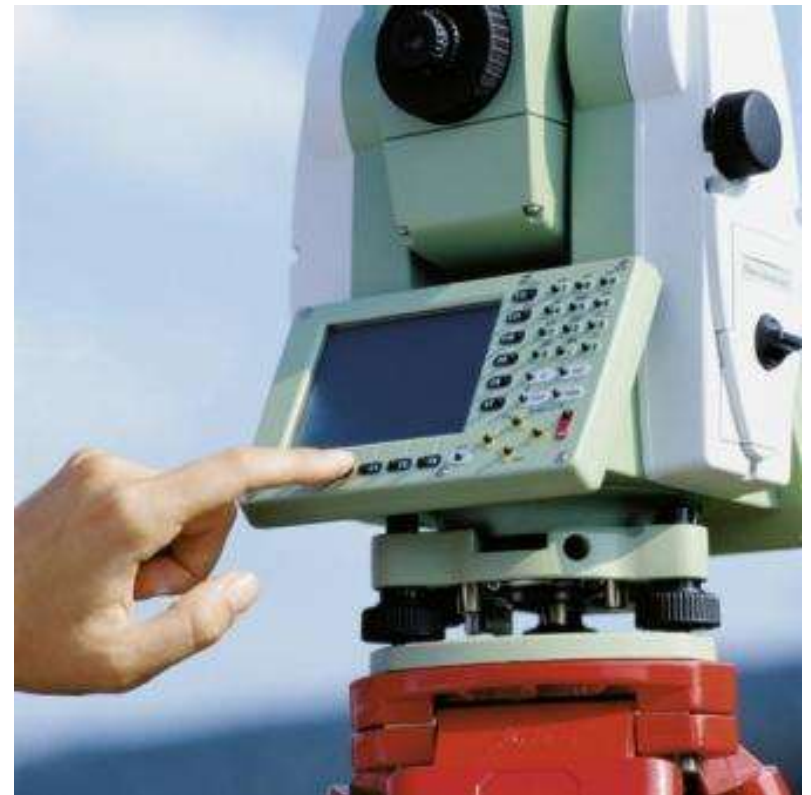
- a) Because it is pure
- b) Because the times required more land surveyors and woodworkers
- c) Because it was a predictor of college success

A: b) of course !

Surveyor at Stanford U.

Me: “How do you use ArcSecant ?”

Him: “I don’t – it’s computerized”



Wisdom from a Mathematician

“Numbers and probability provide the basis for statistics, which, together with Logic, constitute the foundation of the Scientific Method”

John Allen Paulos

Author, “A mathematician reads the newspaper”

Wisdom from a Corporation

“I keep saying the sexy job in the next ten years will be statisticians. People think I’m joking but who would’ve guessed that computer engineers would’ve been the sexy job of the 1990s.”



Hal Varian, Google Chief Economist
McKinsey Quarterly, Jan 2009

**Bloomberg
Businessweek**

America’s Hottest Job – data scientist

May 18, 2018

Cognitive Domain and Algorithms

CREATING Synthesizing
EVALUATING
ANALYZING
APPLYING
UNDERSTANDING
REMEMBERING



Invention Machine



Lex Machina
IP litigation data and analytics



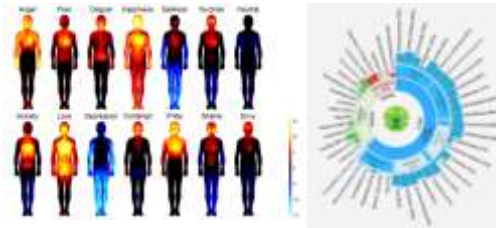
DRAGON
NATURALLY SPEAKING



IBM Watson

Affective Domain and Algorithms

INTERNALIZING
ORGANIZING
VALUING
RESPONDING
RECEIVING



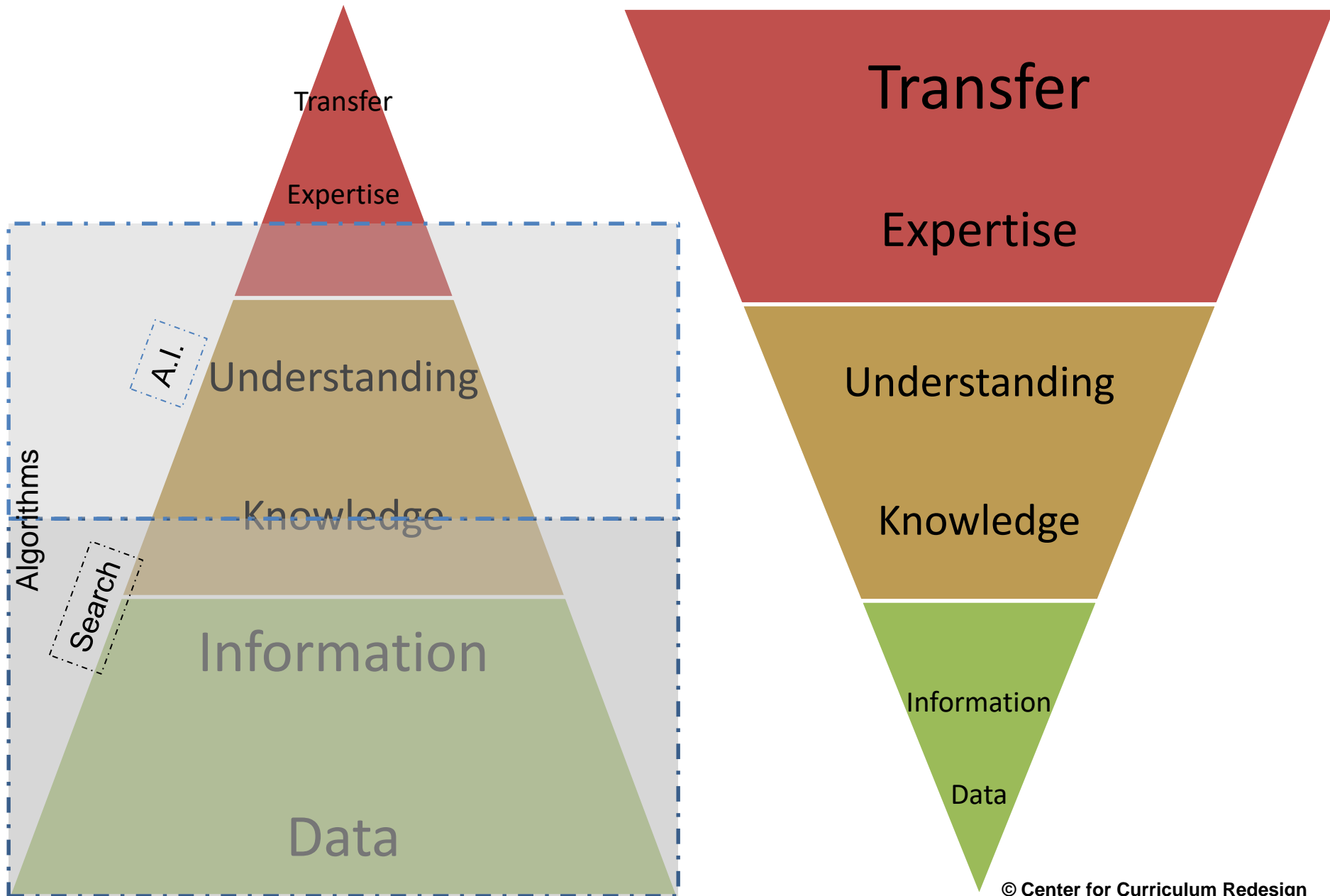
Source: Krathwohl, Bloom, Masia

Psychomotor Domain and Algorithms

ORIGINATION
ADAPTATION
COMPLEX OVERT RESPONSE
MECHANISM
GUIDED RESPONSE
SET
PERCEPTION



Flipping the Curriculum



The Challenge – Expertise & Transfer

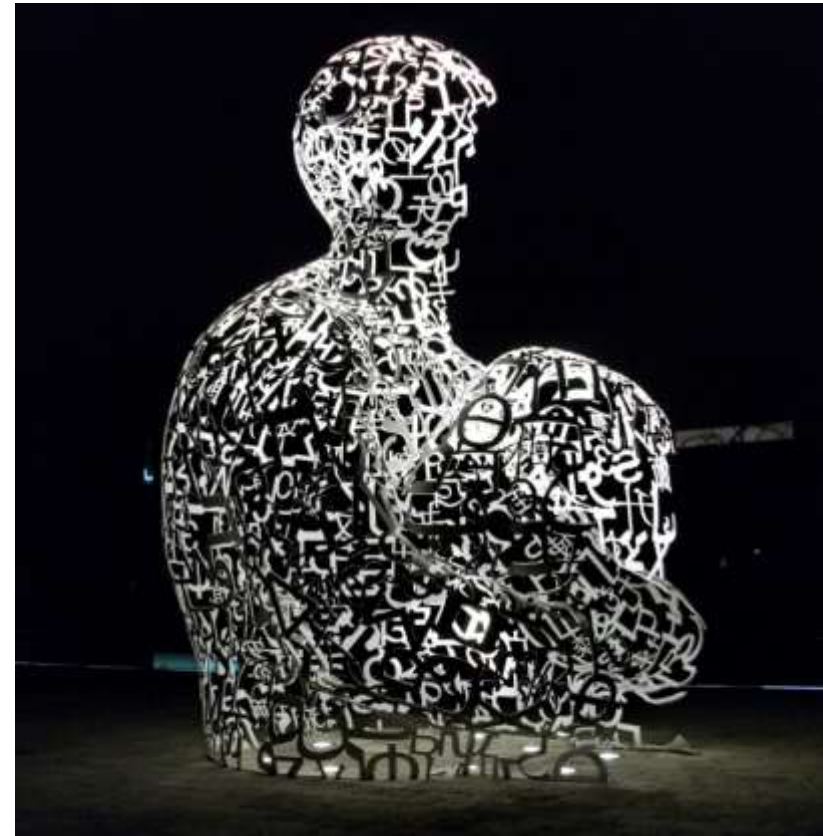
Save time and space for:

- More emphasis on *important* traditional areas
- Adding new, more *relevant* areas
- Deeper learning of core concepts
- Interdisciplinarity, for real-world relevance
- Developing Skills, Character, Meta-Learning

→ De-emphasize less relevant areas

What should be Emphasized?

- Number sense & estimation
- Proportionality
- Exponentials
- Etc.



What should be *added* ?

Branches/topics:

- Recreational Maths
- Statistics & probabilities
- Discrete Maths
- Applied Maths

Tools/Methods:

- Logic and argumentation
- Progression from concrete to abstract
- *Use of computer-based computation*
- *Linkages to the real-world*

What should be *emphasized or added* ? (3)

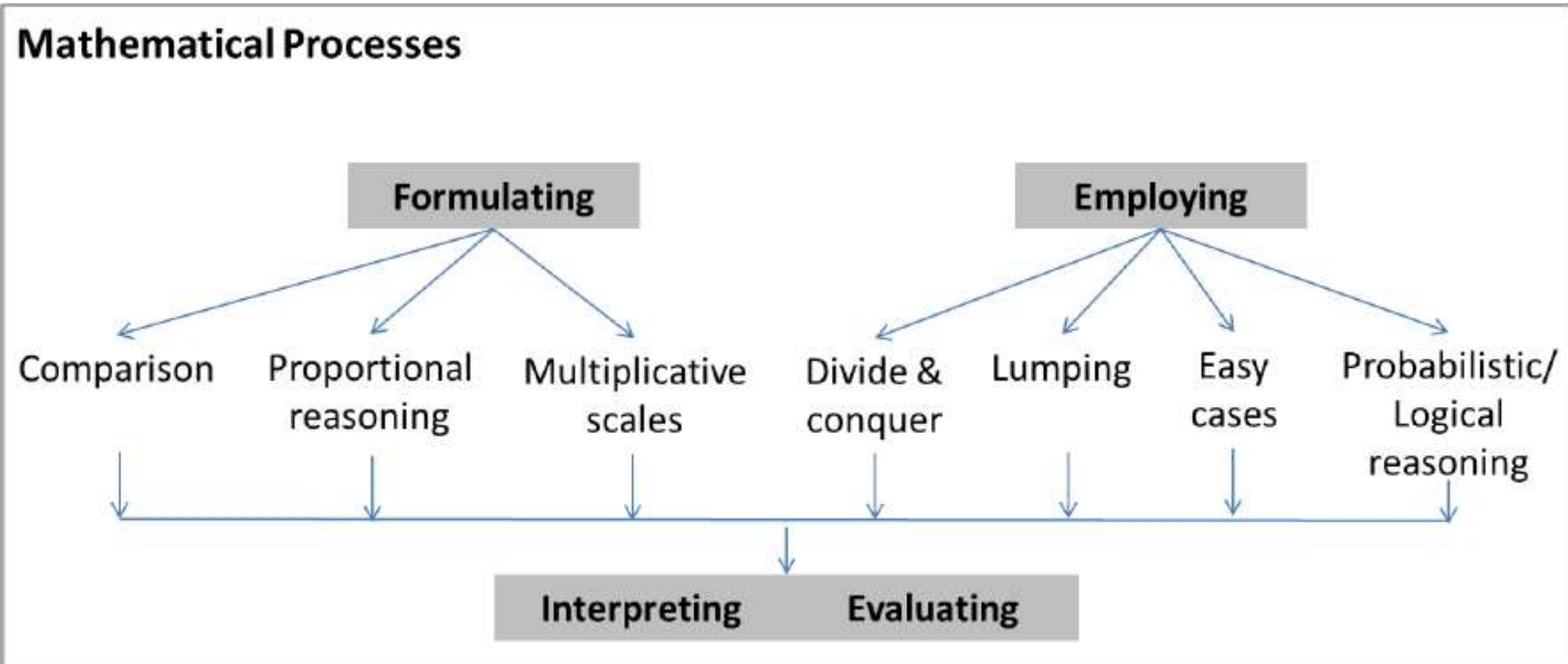
Core Concepts/Processes:

- Variable, rate, dimension, etc.
- Proving, representing, modelling etc.

Other Dimensions of Education:

- Skills: Creativity, Critical thinking
- Character: Resilience
- Meta-Learning: Metacognition; Growth Mindset

Critical Thinking: Explicit Reasoning



So...

What do we remove ?



→ Deep re-examination of every single branch, subject, topic, item...

...while fighting biases, groupthink, politics, etc.

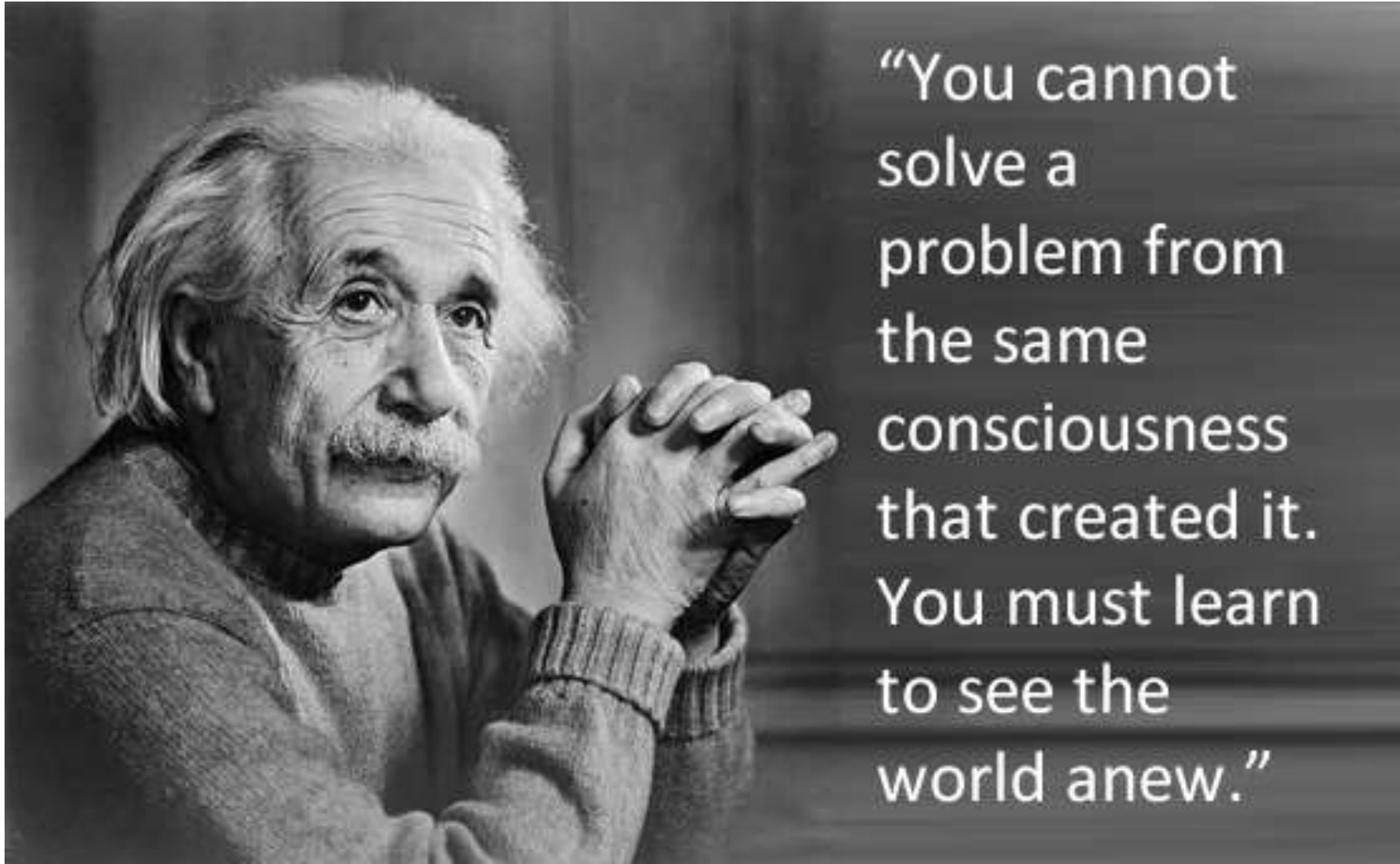
Online Poll

Login: ISG-Visitor

Password: math21

<http://bit.ly/gvamaths>

We agree



“You cannot solve a problem from the same consciousness that created it. You must learn to see the world anew.”

What should be *de-emphasized* ?

Branches/topics to carefully *curate*:

- Algebra
- Calculus
- Geometry/Trigonometry

Tools/Methods:

By-hand algebraic computation

Sobering Reality

“...there is nothing... more dangerous to manage than a new system. For the initiator has the enmity of all who would profit by the preservation of the old institution and merely lukewarm defenders in those who gain by the new ones.”

Niccolo Machiavelli
“The Prince”



Thank You !

“***What*** should students learn for the 21st century?”



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#4DEdu