

# Fixing Human Education...

## ...For the AI age

Conrad Wolfram

The real world changed...  
How should education react?

Changed how?

## Ubiquitous Computation

Deployed for taking decisions...

Enabling revolution for AI

## Entering the AI age

The fastest changing,  
...most quintessentially human  
...of industrial revolutions

## Entering the AI age

What is it to be human?

What do we need to learn?

What's cheating?

How can education adapt effectively?

Day job:  
build all-in-one  
math/computation tech/consulting »

(...maths, data science, modelling, AI...)



**WOLFRAM**



**MATHEMATICA**



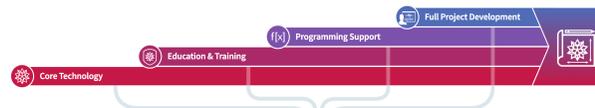
**WolframAlpha**

# Wolfram $\leftrightarrow$ Computation | 37 years

- Mathematica since 1988 (Steve Jobs named it!)
- Enterprise consulting since 2007
- Wolfram|Alpha since 2009
- Wolfram Language since 2014
- Enterprise AI since 2015
- Enterprise Cloud since 2016



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- Inventors of symbolic computing
  - Inventors of computational notebooks
  - Supplying LLM knowledge to ChatGPT, Anthropic and Google Gemini
  - Pioneers of enterprise AI
  - First round ChatGPT plug-in
  - First hybrid AI including notebook assistant
  - Instant supercompute services



Unique **Technology**  $\leftrightarrow$  **Consulting** continuum

## → 2022: high-level computation everywhere

Always	Newly conceived	New to computation
(Maths)	Programming	Biosciences
Physics	Data Science	History and archeology
Accounting	Social Media	Medicine (including pandemic response)
	Finance	Sports
	AI	Agriculture
		Marketing and business

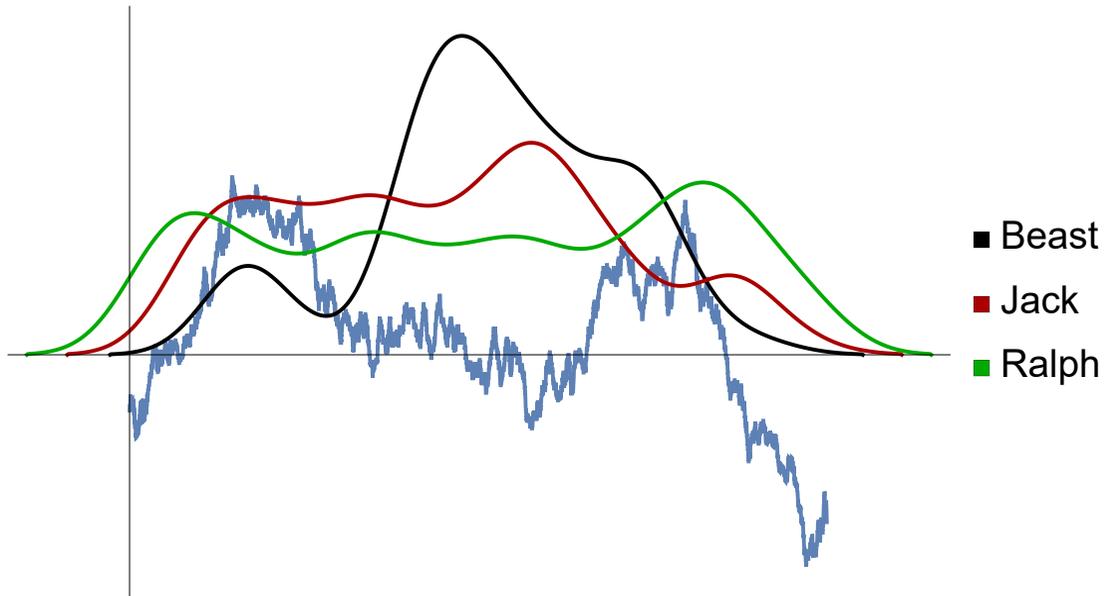
Today's decisions depend on computation

## Example: Biology

**GenomeLookup**["CACTCCTCCCTCAAAT"]

```
{{{Chromosome4, -1}, {165 569 926, 165 569 941}}, {{Chromosome11, 1}, {114 918 572, 114 918 587}},  
{{Chromosome11, -1}, {119 440 945, 119 440 960}}, {{Chromosome13, -1}, {26 470 804, 26 470 819}},  
{{Chromosome15, -1}, {16 404 621, 16 404 636}}, {{ChromosomeX, -1}, {13 783 127, 13 783 142}}}
```

## Example: Sentiment analysis



→ 2023: high-level computation everywhere  
+ accessible to everyone, in all fields ?

LLMs: major new bridge between  
computational and human world

Itself achievement of:

~50 years of mechanised computation,  
~3000 years of computational ideas

# Example: AI written code that you can read...

Make me a program to show EU countries each marked with their GDP/person

To display EU countries marked with their GDP per person, you can use the `GeoRegionValuePlot` function along with `CountryData` to fetch the GDP per capita for each country. Here's a program that does this:

(\* Get a list of EU countries \*)

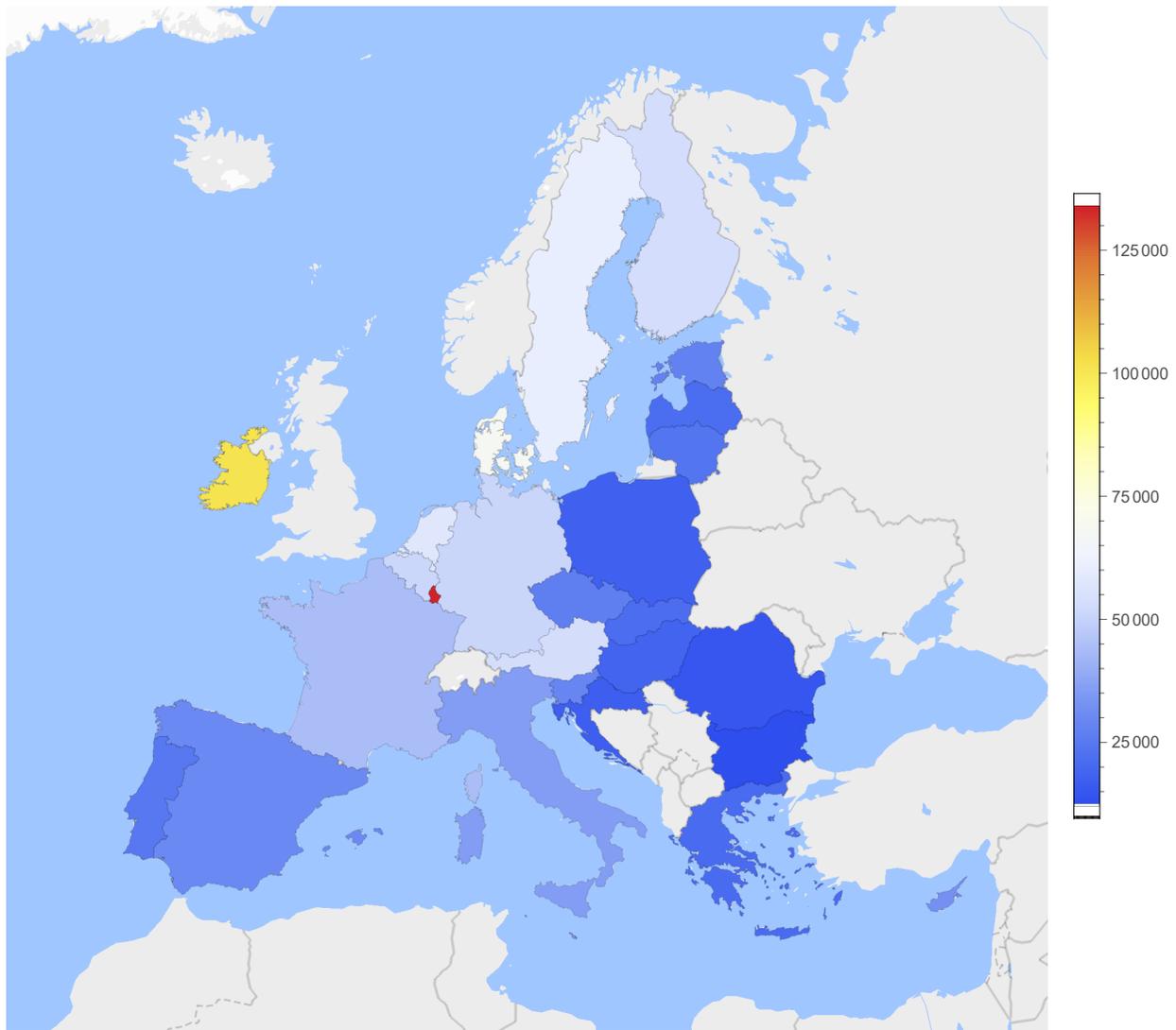
```
euCountries = EntityList[ European Union COUNTRIES];
```

(\* Get GDP per capita for each EU country \*)

```
gdpPerCapita = Association[  
  # -> CountryData[#, "GDPPerCapita"] & /@ euCountries  
];
```

(\* Create a geo plot showing GDP per capita for each EU country \*)

```
GeoRegionValuePlot[  
  gdpPerCapita,  
  ColorFunction -> "TemperatureMap",  
  PlotLegends -> Automatic,  
  GeoLabels -> Placed["Name", Above],  
  ImageSize -> Large  
]
```



This code will generate a geographical plot with EU countries colored according to their GDP per capita. The plot will include a legend for reference. The `GeoLabels` option is used to display the name of each country on the map. You can adjust the `ColorFunction` to change the color scheme if desired.



Can you add tooltips on each with the value?



Certainly! You can add tooltips to the plot by using the `Tooltip` function to display the GDP per capita when hovering over each country. Here's how you can modify the code to include tooltips:

(\* Get a list of EU countries \*)

```
euCountries = EntityList[ European Union COUNTRIES];
```

(\* Get GDP per capita for each EU country with tooltips \*)

```
gdpPerCapitaTooltips = Association[  
  # → Tooltip[CountryData[#, "GDPPerCapita"],  
    CountryData[#, {"Name", "GDPPerCapita"}]] & /@ euCountries  
];
```

(\* Create a geo plot showing GDP per capita for each EU country with tooltips \*)

```
GeoRegionValuePlot[  
  gdpPerCapitaTooltips,  
  ColorFunction → "TemperatureMap",  
  PlotLegends → Automatic,  
  GeoLabels → None,  
  ImageSize → Large  
]
```

Education must reflect  
this *changed* real world:

Real subjects

Today's machinery

Optimise human involvement...

...including modernised “Thinking”

Don't confuse

What we need to learn [Subject]

How we optimise learning it [Pedagogy]

NB. AI drives need for subject change, changes pedagogical toolset

Emblematic of the challenges facing education  
(+ critical in its own right):

(Mainstream)

Math(s)

## Maths at the epicentre. Why?

More “Important” for AI age  
More quantitatively assessable  
More learning hours  
More students  
Subject more divergent from real world

Terrible job adapting to changed real-world

## Steve Jobs (1988):

“Mathematica **will** revolutionize the teaching and learning of math by focusing on the prose of mathematics without getting lost in the grammar.”

## Mainstream need for AI age:

Better decisions (life, work, society)  
using the power of computation (maths)

### **Computational Thinking**

Value-add  
Subsistence  
Survival

### **Computational Literacy**

Mainstream need for AI age:

Modern Framework for Reasoning  
cf. philosophy

Education crisis:  
No core CT/CL subject

Math: 80% off base...

What's wrong?

No computers for computation/calculating...

“In real-world math, computers do almost all the calculating;  
in educational math, people do almost all the calculating”

80% subject mismatch

# CT/maths process?

1. **DEFINE** QUESTIONS

2. **ABSTRACT** TO COMPUTABLE FORM (real world  $\rightarrow$  abstract)

3. **COMPUTE** ANSWERS

4. **INTERPRET** RESULTS (abstract  $\rightarrow$  real world)



# Use computers for...

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## Use humans for...

1. **DEFINE** QUESTIONS

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## 2023+: Use humans for...

1. **DEFINE** QUESTIONS

2. **ABSTRACT** TO COMPUTABLE FORM (real world → abstract)

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# CT/Maths: problem-solving process



Remove the computer...

⇒ remove the context

⇒ wrong subject

## Remove the computer...

⇒ different computational toolset

⇒ wrong subject and approach

Result: Wrong algorithms, wrong capabilities being emphasised, wrong style of mathematical thinking, poor handling of complexity, management of automation.

(4-steps' cost-benefit analysis)



## Reorder for conceptual not computational complexity

Eg. 3D geometry first  
Machine-Learning for Elementary  
Calculus for 10-year-olds



# Summary: maths education mistakes

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**Basics = By hand**

**Succeeding in education = Improving assessment results**

**Fair = Assessable (reproducibly )**

**Essence = Mechanics of past moment**

**How to work the machine = How the machine works**

**Driving = Building**

**Conceptual = By hand**

**Trustworthy = By hand**

**Innovation –led evidence = Evidence –led innovation**

**Lower risk = No change**

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Avoid when AI affects every subject!

## Real consequences now:

Education: needless rejection of students

Work: increasingly bad decisions

Life: societal dislocation

# Major societal problems:

Simplistic quantification, *but* Complex issues

Quantifiable primary effect...blanks out all others

“Quantification beyond its ability to judge”

“Marketing panache of the number”

Claiming you can compute...when in practice you can't

# Where is this x 1000s in the curriculum?

Describing trends  
Understanding bias  
Processing messy data  
Spotting anomalies in data  
Understanding reliable sources  
Making assumptions to simplify problems  
Constructing and testing a model  
Using machine learning  
Summarising a huge dataset  
Forecasting from models  
Presenting convincing visuals  
Conducting a fair test  
Optimising systems  
Assessing risk  
Etc...

Need far broader “outcomes”

Not just ones easy to assess...

...with a simple number!

# Including experience of current technologies

“A bad workman blames his tools” →  
“A bad workperson uses the wrong tools for the job”

## MANAGING COMPUTATIONS

The computation phase begins with students choosing the manifestation of the tool(s) to produce a result. This may be a trivial step for one tool with a simple input but could also be organisationally complex for combinations of a number of tools. Once the computation reaches a certain size, the process of performing the computation becomes a significant consideration.

### C COMPUTE ANSWERS: STEP 3 OF THE COMPUTATIONAL THINKING PROCESS

#### MC1 Choosing an appropriate technology

Choosing between various forms of technology (hardware/software), physical machine or brain power.

#### MC2 Being able to interpret documentation

- Accessing documentation and using it to inform the use of the tool in the context that is required.

cf. DIY toolsets

## Quick briefing on Computational Tools

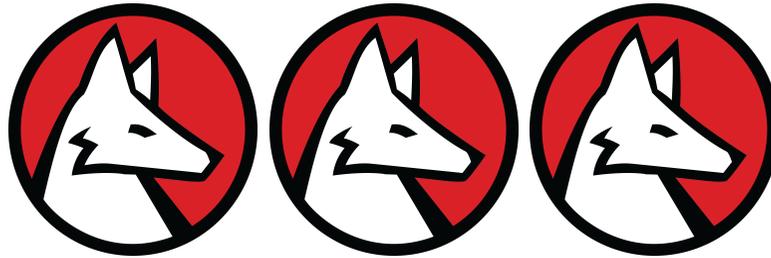
Language

Scope

Interface (including linguistic)

# Wolfram Language

## Unifying Computation



Programming language AND  
Superset computation representation AND  
Human technical communication language

cf. Faraday's and Maxwell's unification of electricity

# Key concept: Symbolic Expressions

The screenshot displays a software interface with a left pane containing mathematical expressions and a right pane showing their internal representation as nested lists. A vertical toolbar on the far right contains buttons for various features.

**Left Pane (Mathematical Expressions):**

$$\frac{1}{20} \left( -2\sqrt{10} - 2\sqrt{5} \operatorname{ArcTan}\left[\frac{1+\sqrt{5}-4x}{\sqrt{10}-2\sqrt{5}}\right] + \right.$$
$$\left. 2\sqrt{2}\sqrt{5+\sqrt{5}} \operatorname{ArcTan}\left[\frac{-1+\sqrt{5}+4x}{\sqrt{2}\sqrt{5+\sqrt{5}}}\right] + 4\operatorname{Log}[1+x] + \right.$$
$$\left. (-1+\sqrt{5})\operatorname{Log}\left[1+\frac{1}{2}(-1+\sqrt{5})x+x^2\right] - (1+\sqrt{5})\operatorname{Log}\left[1-\frac{1}{2}(1+\sqrt{5})x+x^2\right] \right)$$

**Right Pane (Internal Representation):**

```
Times[Rational[1, 20], Plus[Times[-2, Power[Plus[10, Times[-2, Power[5, Rational[1, 2]]]], Rational[1, 2]], ArcTan[Times[Power[Plus[10, Times[-2, Power[5, Rational[1, 2]]]], Rational[-1, 2]], Plus[1, Power[5, Rational[1, 2]], Times[-4, x]]]], Times[2, Power[Times[2, Plus[5, Power[5, Rational[1, 2]]]], Rational[1, 2]], ArcTan[Times[Power[Times[2, Plus[5, Power[5, Rational[1, 2]]]], Rational[-1, 2]], Plus[-1, Power[5, Rational[1, 2]], Times[4, x]]]]], Times[2, Plus[5, Power[5, Rational[1, 2]]]], Rational[1, 2]], Plus[4, Log[1 + x]], Times[-1 + Sqrt[5], Log[1 + 1/2 (-1 + Sqrt[5]) x + x^2]], Times[-1 + Sqrt[5], Log[1 - 1/2 (1 + Sqrt[5]) x + x^2]]]
```

**Right Toolbar (Buttons):**

- Maths
- Data
- Graphs
- Images
- Documents
- Graphics
- 3D Graphics
- Sound
- Neural net
- Programs
- Interface

Major power of unification

For computation itself

For curriculum delivery

Pedagogy

How to deliver CT/CL  
...in the AI age?

# New Computational Curriculum

## What to deliver?

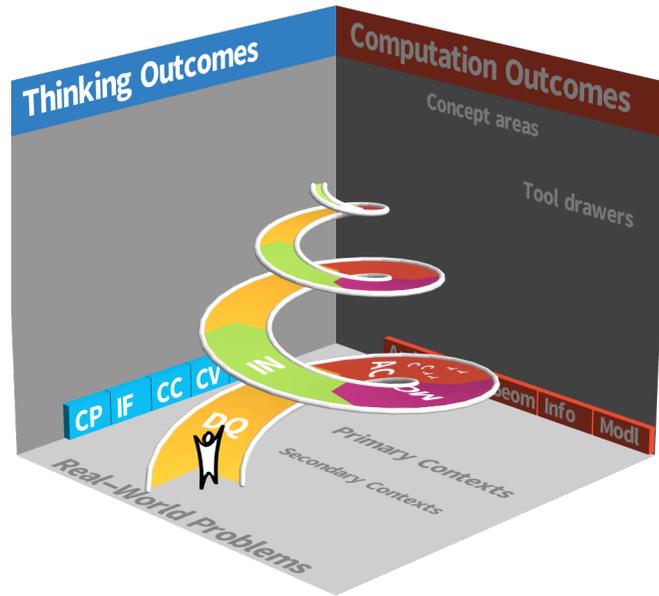
Actual student learning materials (via personas, teachers)  
...to map the curriculum

Directed to modern outcomes

Tethered to representative (open-ended) assessments

Curriculum specing process (for humans and AI personas )

AI tutoring and assessment



Show dimensions

Room	Problems	Step outcomes	Computation outcomes	Thinking outcomes
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Grade

Student

## Outcomes»: must engender AI-age “Thinking”

Abstraction of thinking techniques  
Hybrid human-AI management (right team for job)  
Intertwining creativity and process

# Build a Computational Curriculum ...that assumes computers exist...



[computerbasedmath.org](http://computerbasedmath.org) • [computationalthinking.org](http://computationalthinking.org)

Elements include: **modules**», projects, primers, symbolic curriculum

Example module:  
Can I spot a cheat? »

Unified Education  
Curriculum, Materials, Pedagogy  
*Symbolically Represented*

Easy to AI!

# AI tutoring and assessment?

Is it a reality? Will it be?

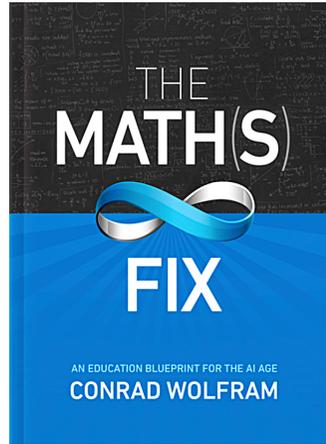
Cost effective mass personalised learning?



CAIT – your Computational AI assistant T »

*Live example from coin toss before! »*

# First detailed proposal for fundamental change



## Part I: The Problem

- 1 | Maths v. Maths
- 2 | Why Should Everyone Learn Maths?
- 3 | Maths and Computation in Today's World
- 4 | The 4-Step Maths/Computational Thinking Process
- 5 | Hand Calculating: Not the Essence of Maths

## Part II: The Fix

- 6 | 'Thinking' Outcomes
- 7 | Defining the Core Computational Subject
- 8 | New Subject, New Pedagogy?
- 9 | What to Deliver? How to Build It?

## Part III: Achieving Change

- 10 | Objections to Computer-Based Core Computational Education
- 11 | Roadmap for Change
- 12 | Is Computation for Everything?
- 13 | What's Surprised Me on This Journey so Far
- 14 | Call to Action

Key question:

## What's for the AI What's the for human?

Rough start at answer:

AI: practice with humans

AI/human: constructing arguments

Human: handling other humans

AI: easy to procedurise

Human: how to manage

AI/human: abstraction

# Abstract representation: still for the human?

Do we still need (explicit) Code?

“Now Computers Talk ‘Human’, Do Humans Need to Talk ‘Computer’?”



Precision of abstraction: Still critical for humans

Key message:

**Don't cleanse the reality!**

Messy problems, machinery not working, hunches,  
competition, human emotion

**Bad educational trend:  
more Formulaic → less Usable**

Bigger picture: **Job of Education?**

Simple answer: **Enrich Life**

Key process: **Accelerating Experience**

Making change:

## Employers

Key to fix: *CT/CL non-technical*  
employee, management training

**Uptick core:** Decision-taking with computation  
(Even a 2-day course could improve outcomes)

Making change:

## Universities

Key to fix: Core CT subject,  
Computational X for all subjects

Implementation rethink: AI v. human tutoring

Conceptual is practical: more real mess, hair

Making change:

## Policymakers

Key to fix: Stuck Ecosystem of Education  
for **subject change**

**Incentives wrong:** real risk not aligned with individuals'

**Iteration slow:** crazy process for curriculum production

**Funding siloed:** materials, curricula, exams, teaching

cf. Startups, 1960s-

Lynchpin for system change:  
University Admissions, math requirement

Which universities first?

Other lynchpins?

New Maths/Computational Curriculum

*Achieve what?*

Achieve:

First rate human problem solvers,  
not third-rate human computers

ie. working a level up from the machines,  
not competing with what they do best...

Optimising human-computer  
hybrid decision-making

Achieve:

Computational Literacy for all (2020s)

cf. Literacy for all (1800s)

Early States, Countries, Organisations

Leapfrog others

Achieve:

## Better enfranchisement across society

Avoiding “Computational” divide  
Achieving “Computational Knowledge Economy”

## Rebuild TRUST

Achieve:

# Education reformed for AI age

## Math reform as the forerunner



[conradwolfram.com](http://conradwolfram.com)  
[wolfram.com](http://wolfram.com)