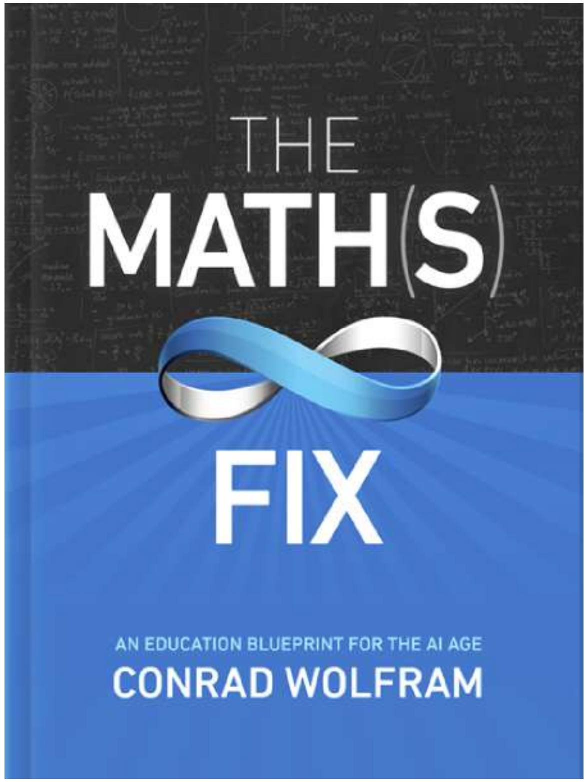
Building tomorrow's
Core Computational Curriculum



Integrating coding,
maths and STEM ...
for the AI age

Day job:

build the best maths/computation tech »

WOLFRAM MATHEMATICA WolframAlpha

Wolfram ⟷ Computation | 33 years

- Mathematica since 1987 (Steve Jobs named it!)
- Enterprise consulting since 2007
- Wolfram|Alpha since 2008
- Wolfram Language since 2014
- Enterprise AI since 2015
- Enterprise Cloud since 2016

- Inventors of symbolic computing
- Inventors of computational notebooks
- Supplying knowledge to Siri, Alexa and Microsoft 365
- Pioneers of enterprise AI

Day job: Computation for Everyone

$\Longrightarrow$ smart automation

Extra job: Everyone for Computation

$\Longrightarrow$ computational thinking

The real world changed.

How should education react?

Changed how?

Ubiquitous Computation

High-level computation now applicable everywhere, eg:

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

Example: Agriculture

sheep in new zealand v. people in UK

Example: Linguistic Programming

World War 2 battles

Example: Biology

```
GenomeLookup["
```

Example: Image detection

Stop | Image contents | FacialGender | FacialAge | FacialExpression

Key technology: Wolfram Language

Programming language AND

Superset computation representation AND

Human technical communication language

```
Dynamic[CurrentImage[ImageSize → 700]]
```

Key Computational subfields...

Coding

Data Science

...but not whole picture

Core human skill:
Computational Thinking

Manifested by maths education...?

Maths/coding education

Achieving data literacy, data science?

Promoting logical thought?

Optimising economic results/jobs?

...Developing computational thinking?

Maths education crisis:

80% wrong subject?

Key difference:
Computers

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

Everyone for “maths”/CT?

Key reasons for the “right maths”:

1. Technical jobs
2. Everyday living
3. Logical mind training

Value-add

Subsistence

Survival

CT/maths process?

1. **DEFINE** QUESTIONS
2. **ABSTRACT** TO COMPUTABLE FORM (real world → abstract)
3. **COMPUTE** ANSWERS
4. **INTERPRET** RESULTS (abstract → real world)

Use computers for...

1. **DEFINE** QUESTIONS
2. **ABSTRACT** TO COMPUTABLE FORM (real world → abstract)
3. **COMPUTE** ANSWERS
4. **INTERPRET** RESULTS (abstract → real world)

Use humans for...

1. **DEFINE** QUESTIONS
2. **ABSTRACT** TO COMPUTABLE FORM (real world → abstract)
3. **COMPUTE** ANSWERS
4. **INTERPRET** RESULTS (abstract → real world)

CT/Maths:problem-solvingprocess

```
Solve[{x + 2 == 2 y, y - x == 5}, {x, y}]
```

Today’s maths education headings

[About hand-calculating]

Similar triangles
Calculate this long division
Completing the square
Inverting matrices
Simplifying Surds and Recurring Decimals
Solving simultaneous equations
The chain rule

Tomorrow’s CT/math headings

[Contextual problems needing whole process]

What's the perfect password for your login?
Am I normal?
Should I insure?
How do I design controls for my game?
Are our incentives working?
How do we evaluate our social media effectiveness?
Is a fraud occurring?
How much can you compress photos, video or music before you notice?
By how many levels of friends are we separated on Facebook?
What's a beautiful shape?

Remove the computer...

⇒ remove the context

Remove the computer...

⇒ different computational toolset

⇒ different subject

(4-steps' cost-benefit analysis)

Reorder for conceptual not computational complexity

Eg. 3D geometry first

Machine-Learning for Elementary

Calculus for 10-year-olds

Example problem: can I spot a cheat?

Enter 200 coin flips | Computer's test results

ththththththththththththththhthththhht-
htttthhhttthhhttththththhththththththt-
hththththththththththhhthhhthttthtttthtthth-
thththtthththhththhththththhththththt-
hthhthththhththhhththhthhthththhht-
hththth

Count: 196 data points

Modern algorithmic thinking / data science ideas; only possible if computer-based

New Computational Curriculum
What to deliver?

Actual learning materials for teacher and student...
...to map the curriculum

Directed to modern outcomes

Tethered to representative assessments

New Computational Curriculum Deliverables:

Directed learning (Modules)

Guided learning (Projects)

"Documentation" (Primers)

New Outcomes

Curriculum specing process

New assessments types

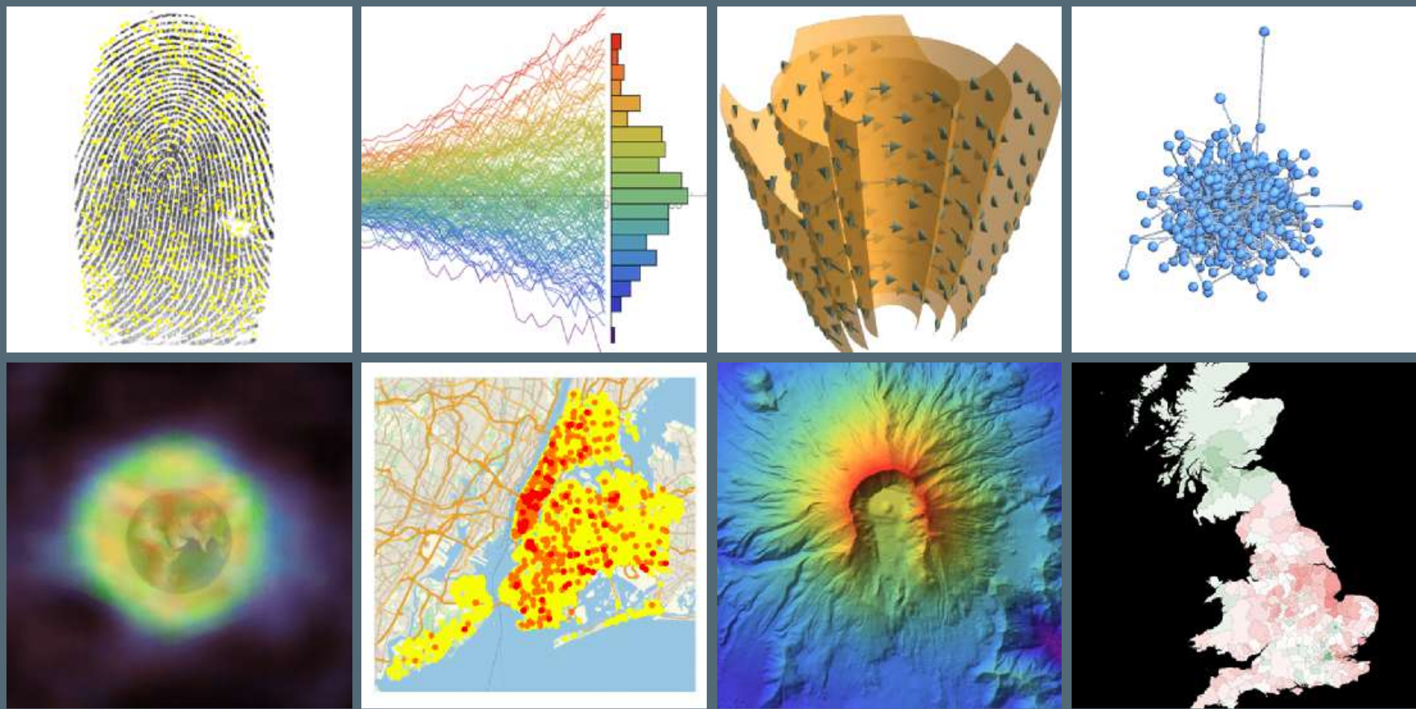
Since 2010:

“Build a core computational curriculum that assumes computers exist”

Example module:

How fast can I cycle...?

Example projects:
(Independent problem solving)



New Computational Curriculum

Right Outcomes »

Right assessments

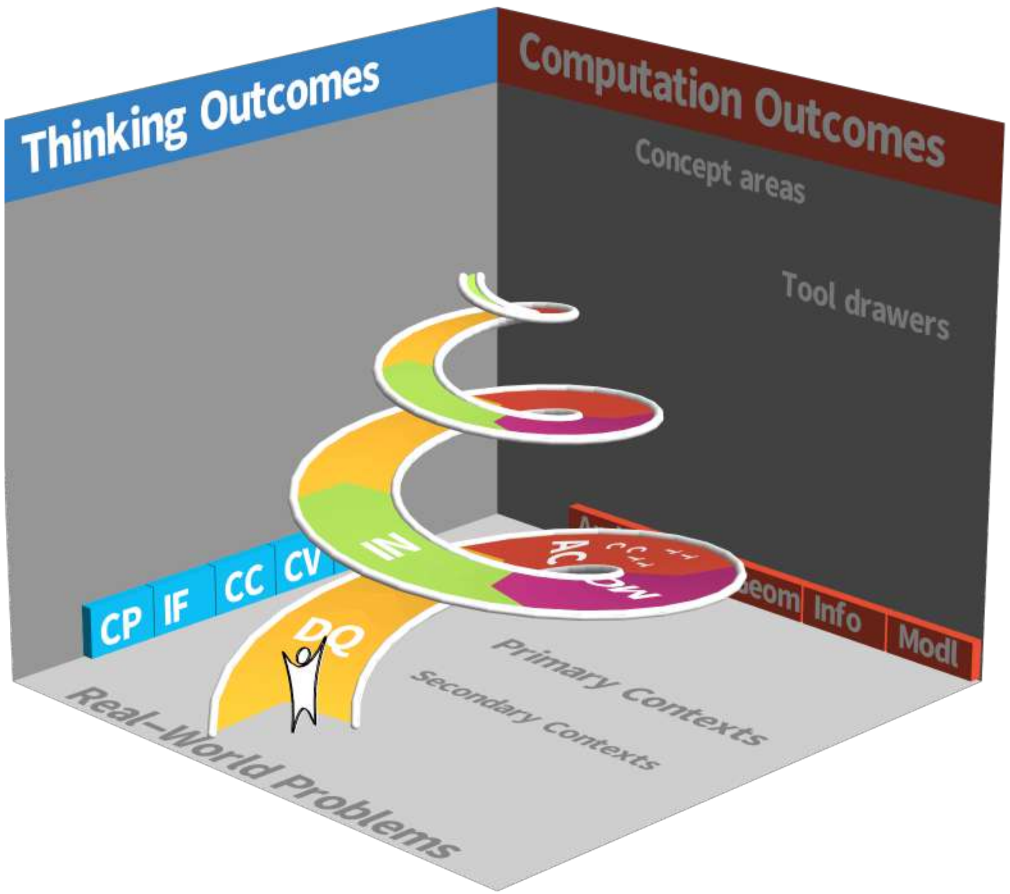
Outcomes: must engender AI-age “Thinking”

Abstraction of thinking techniques

Hybrid human-AI management

Intertwining creativity and process

Outcomes, contexts, process, grades



Show dimensions | Room | Problems | Step outcomes | Computation outcomes | Thinking outcomes

Grade **0**

Student

Specification:dimensionsof outcomes

			Grades	1	2	3	4	5	6	7	8
Thinking Outcomes	CP		CONFIDENCE TO TACKLE NEW PROBLEMS								
		CPr	Recalling the four-step process	Desc	→	Desc	→	Desc	Desc	→	→
		CPa	Applying the four-step process	Desc	Desc	→	Desc	→	Desc	→	Desc
		CPm	Managing the process of breaking large problems into small problems	Desc	Desc	→	→	Desc	→	Desc	Desc
		CPt	Applying existing tools in new contexts	Desc	→		Desc	→	Desc	→	Desc
		CPk	Knowing how to teach yourself new tools	Desc	→	Desc	→	→	Desc	Desc	→
		CPi	Interpreting others' work		Desc	→	→	→	Desc	Desc	→
	IF		INSTINCTIVE FEEL FOR COMPUTATIONAL THINKING								
		IFu	Identify the usefulness of computational thinking for a given real-world problem	Desc	Desc	→	Desc	→	Desc	→	Desc
		IFp	Assessing the plausibility of computational thinking being useful		Desc	→	→	Desc	→	Desc	Desc
		IFf	Identifying fallacies and misuse of computation	Desc	→	→	Desc	→	Desc	→	Desc
		IFr	Having a feel for how reliable a model will be	Desc	→	Desc	→	→	Desc	Desc	→
		IFe	Estimating a solution of the defined problem		Desc	→	→	→	Desc	Desc	→
	CV		CRITIQUING AND VERIFYING								
		CVa	Quantifying the validity and impact of the assumptions made		Desc	→	Desc	→	Desc	→	→
		CVl	Quantifying the validity and impact of tools and concepts chosen	Desc	→	Desc	Desc	→	→	Desc	Desc
		CVc	Listing possible sources of error from computation failures or limitations		Desc	→	Desc		Desc	→	→
		CVm	Listing possible sources of error from concepts' limitations		Desc	Desc	→	Desc	→	→	→
		CVe	Identifying systematic and random errors		Desc	Desc	→	→	Desc	→	→
		CVt	Being able to corroborate your results	Desc	→	→	Desc	→	Desc	Desc	→
		CVr	Qualifying reliability of sources		Desc	Desc	→	→	Desc	→	→
		CVd	Deciding if the results are sufficient to move to the next step, including whether to abandon	Desc	→	→	Desc	→	Desc	Desc	→
	GM		GENERALISING A MODEL/THEORY/APPROACH								
		GMi	Identify similarities and differences between different situations for the purposes of abstraction	Desc	Desc	→	→	Desc	→	→	Desc
		GMv	Taking constants from initial model and making them variable parameters			Desc	→	Desc	Desc	→	Desc
		GMw	Being able to draw wider conclusions about the behaviours of a type of problem		Desc	Desc	→	→	Desc	→	Desc
		GMg	Implementing a generalised model as a robust program	Desc	→	→	Desc	→	Desc	Desc	→
	CC		COMMUNICATING AND COLLABORATING								
		CCv	Distilling or explaining ideas visually		Desc	Desc	→	→	Desc	→	→
		CCp	Distilling or explaining ideas verbally	Desc	→	→	Desc	→	Desc	Desc	→
		CCd	Distilling or explaining ideas through written description		Desc	Desc	→	Desc	→	→	→
		CCc	Using vocabulary, symbols, diagrams, code accurately and appropriately for your		Desc	Desc	→	→	Desc	→	→
		CCb	Choosing the best form of communication for a given purpose	Desc	→	Desc	→	→	→	→	→
		CCr	Structuring and producing a presentation or report	Desc	→	→	Desc	Desc	Desc	→	Desc
		CCg	Being able to work effectively in a group to solve a problem	Desc	→	Desc	→	→	Desc	→	Desc
		CCf	Deciding which facts support or hinder an argument		Desc	→	→	→	Desc	→	Desc
		CCi	Understanding and critiquing ideas presented to you		Desc	→	→	→	Desc	Desc	→
		CCq	Using techniques for questioning, interrogation, cross-examining	Desc	→	Desc	Desc	→	Desc	Desc	→
	DQ		DEFINING THE QUESTION								
		DQf	Filtering the relevant information from available information		Desc	Desc	→	Desc	→	→	→
		DQm	Identifying missing information to be found or calculated		Desc	Desc	→	→	Desc	→	→
		DQq	Stating precise questions to tackle	Desc	→	→	Desc	Desc	Desc	→	Desc
		DQa	Identifying, stating and explaining assumptions being made	Desc	→	Desc	→	→	Desc	→	Desc
	AC		ABSTRACTING TO COMPUTABLE FORM								
		ACp	Identifying the purpose of the abstraction		Desc	Desc	→	Desc	→	→	→
		ACd	Creating diagrams to structure knowledge		Desc	Desc	→	→	Desc	→	→
		ACc	Identifying relevant concepts and their relationship	Desc	→	Desc	→	→	Desc	→	Desc
		ACr	Understanding the relative merits of the concepts available	Desc	→	→	Desc	Desc	Desc	→	Desc
		ACa	Being able to present alternative abstractions	Desc	→	Desc	→	→	Desc	→	→

Process Outcomes	C	CONCEPT - C1 C2 C3 C4								
	C1	Being able to describe the concept								
	C2	Recognising whether the concept applies								
	C3	Knowing which tools are relevant to the concept								
	C4	Having intuition for the relative merits of the concept								
	Examples									
		2D and 3D shapes	C1 C2	C3 C4	→	→	→	→	→	→
		Charts and information visualisation		C1	C2 C3	→	→	C4	→	→
		Equation solving	C1	C2	C3	→	C4	→	→	→
		Colours	C1	C2	C3 C4	→	→	→	→	→
	T	TOOLS - Tb Ti Ta Tc Tr								
	Tb	Having intuition about the tool's behaviour								
	Ti	Composing appropriate and accurate input for the tool								
	Ta	Applying the tool or demonstrating experience of its application								
	Tc	Being aware of comparable tools								
	Tr	Understanding the relative merits of different tools for use in the context								
	Examples									
		Plus	Ti Ta	Tb Tc	→	→	→	→	→	→
		Polygon		Ti Ta	Tb Tc	Tr	→	→	→	→
		PieChart3D			Ti Ta	Tb Tc	Tr	→	→	→
		GeometricTransformation				Ti	Ta	Tb	→	→
	MC	MANAGING COMPUTATIONS								
	MC1	Choosing an appropriate technology	Desc	→	Desc	→	→	→	→	→
	MC2	Being able to interpret documentation	Desc	→	→	Desc	Desc	Desc	→	Desc
	MC3	Assessing the feasibility of getting a useful answer	Desc	→	Desc	→	→	Desc	→	Desc
	MC4	Having intuition about whether the output is appropriate for the context		Desc	→	→	→	Desc	→	Desc
	MC5	Combining tools to produce results required	Desc	Desc	→	→	Desc	→	→	Desc
	MC6	Isolating the cause(s) of operational problems	Desc	Desc	→	→	Desc	→	→	Desc
	MC7	Resolving operational problems			Desc	→	Desc	Desc	→	Desc
	MC8	Optimising both speed of obtaining results and reusability of computation		Desc	Desc	→	→	Desc	→	Desc
	IN	INTERPRETING								
	IN1	Reading common and relevant representations and notations		Desc	Desc	→	→	Desc	→	→
	IN2	Making statements about the output in the context of the original problem	Desc	→	Desc	→	→	→	→	→
	IN3	Identifying and relating features of the output to real-world meaning	Desc	→	→	Desc	Desc	Desc	→	Desc
	IN4	Identifying interesting features in results	Desc	→	Desc	→	→	Desc	→	Desc
	IN5	Inferring a hypothesis beyond the current investigation		Desc	→	→	→	Desc	→	Desc
Contexts	Category	Primary contexts								
		Biotechnology and Healthcare: Medicine	Desc	Desc	Desc	→	Desc	Desc	→	Desc
		Biotechnology and Healthcare: Fitness	Desc	→	Desc	Desc	→	→	Desc	Desc
		Finance and Economics: Banking		Desc	→	Desc		Desc	→	→
		Finance and Economics: Insurance		Desc	Desc	→	Desc	→	→	→
		Data Science and Business: Statistics		Desc	Desc	→	→	Desc	→	→
		Secondary contexts								
		Engineering: Architecture		Desc	Desc	→	→	Desc	→	→
		Biotechnology and Healthcare: Bioinformatics	Desc	→	→	Desc	→	Desc	Desc	→
		Finance and Economics: Investing		Desc	Desc	→	Desc	→	→	→
		Finance and Economics: Economics		Desc	Desc	→	→	Desc	→	→
		Science: Astronomy	Desc	→	Desc	→	→	→	→	→

Today's maths trains your mind

We're already doing a new computer science subject

Get the basics first

You need to know how the computer works first

Today's maths helps with real–world computation

We're already doing maths with computers

Objections

Children have too much screen time

Hand–calculating teaches understanding

It's too risky to make this change

Computers dumb maths down

You need evidence before you make this change

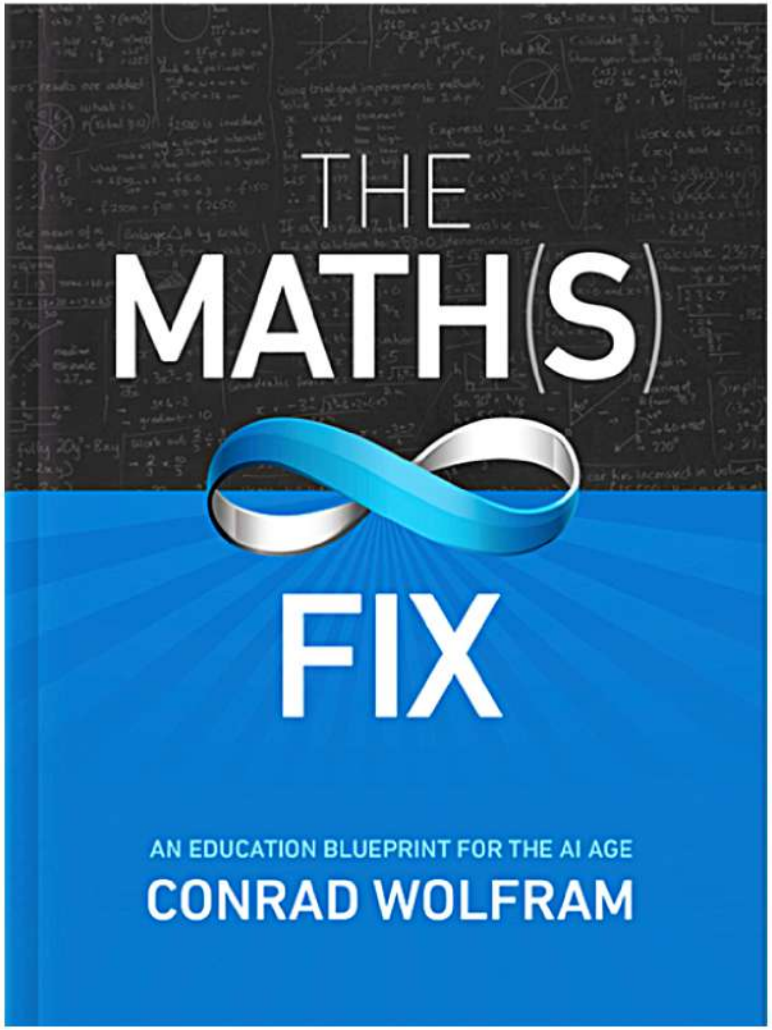
Don’t confuse major effects of AI:

What we need to learn [Subject]

How we optimise learning it [Pedagogy]

ie. AI drives need for change, also provides tools

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

New 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:

Better enfranchisement across society

Avoiding “Computational” divide

Achieving “Computational Knowledge Economy”

Needs Revolution
not just Evolution

(80% not 10% problem)

Join the C^5

Campaign for Core Computational Curriculum Change

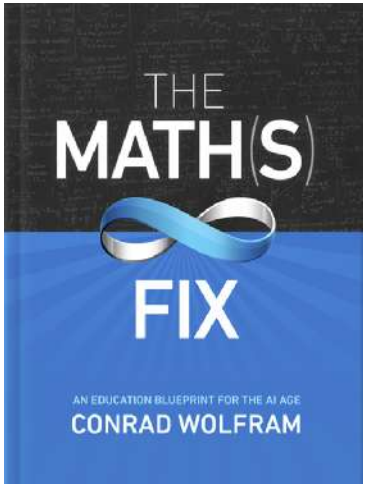
Human role	Stand on the power of computers, don't compete with them. *(Make first-rate human problem-solvers, not third-rate human calculators.)*
Mainstream	Establish a mainstream, core computational thinking curriculum for all. *(Not for its own sake but to power problem-solving across all subjects.)*
Realistic	Use the real world as your guide for what to learn: concepts, strategies and toolsets. *(Computers opened up real life to computation; education should too.)*
Toolset	Prioritise breadth of computational applications over the details of their implementation. *(Don't exclude what you can't hand calculate or can't explain about the computer's calculations.)*
Urgency	Implement Computational Thinking education—society's key preparation for the AI age. *(The cost of delay is mounting year on year.)*

Compare:

Mass Literacy (from 1800s)

Mass Computational Literacy (2020s -)

Enter a New Era of
Computational Enfranchisement



conradwolfram.com
mathsfix.org
wolfram.com
wolframalpha.com

UK: can we lead?

Topic 1:

Tweak existing curricula and qualifications?

Add something new as an option?

Start over and do it properly?

Topic 2:

What age/stage to start?

Topic 3:

Overcoming inertia of the system:

assessment, training, hardware, time: what to loose to make room?

Topic 4:

Where are the teachers currently?

Science? Maths? Computing? Technology? Business? Humanities?