COMPUTER-BASED-MATHS.ORG

Let's get on with fixing maths together

> *Computers liberated real-world maths from hand-calculating to go far further and faster than anyone could have imagined. Now it's vital that educational maths stands on this automation too.*

Conrad Wolfram
FOUNDER, COMPUTERBASEDMATH.ORG

computerbasedmath.org

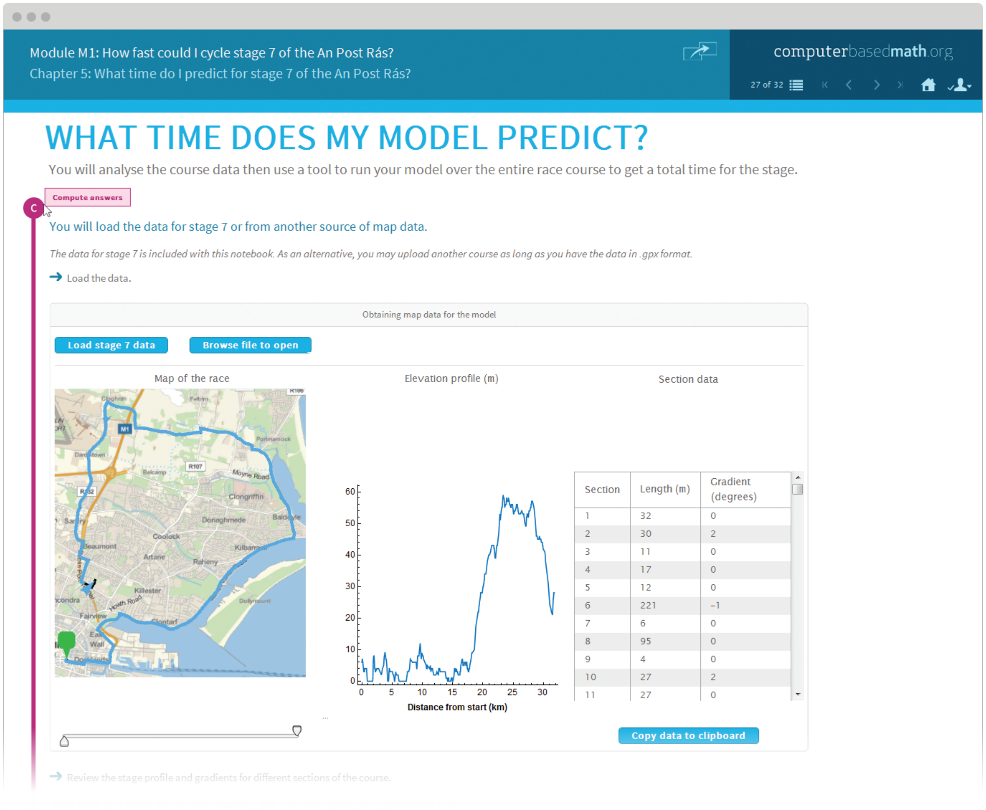
What is Computer-Based Maths?

It's a new subject that starts from maths in the real world and works back to redefine the educational subject to match. A crucial change is to have computer-based (rather than human-powered) computation at its heart—redefining maths as the anchor subject for computational thinking across all subjects, centred on real-life problem solving, not historical hand-calculating techniques. Maths is so vital to today's students because computers mechanised calculating in the real world and enabled its application to so many aspects of life. Yet traditional maths education ignores this fundamental change, cutting out the computer, and with it the context, complexity, objective and often, fun.

The subject's new curriculum is also problem centred versus the traditional mechanics-centric, so students learn to find solutions using the best tools available, rather than being taught isolated, out-of-context processes like completing a long division problem or calculating standard deviation. CBM teaches problem-solving skills such as the identification of relevant concepts, the planning and managing of computations, interpretation, verification and communication.

How is a CBM lesson different?

First, lessons are focussed around answering a question that the student can understand, questions like ‘How long does a password need to be?’ or ‘How many people will live in my town in 50 years?’ Second, to solve those questions, students are encouraged to apply maths concepts using the best technology—just like they would outside the classroom. There are many other differences too. Students work with 10,000s of data points, decide whether one effect causes another, and write programs to work out answers. They work individually, in groups, persuade one another with maths arguments, and automatically send group findings to the teacher, for example, to aggregate results.



Comparison of today’s curriculum to CBM in data science

Traditional curriculum: Mechanics-centric topic	CBM curriculum: Problem-centric similar module
Mean, mode, median	‘Am I normal?’
Probability	‘Do I know what I do not know?’
Averages, ranges and percentiles	‘Are girls better at maths?’
Representing data	‘How can I convince you?’
Distribution fitting	‘How tall is the tallest woman in Estonia?’
Hypothesis testing	‘Can I spot a cheat?’

What is maths for anyway...
...and how does it work?

The main reason for everyone to study maths is to learn one of humankind's most successful systems of problem solving, which involves creatively applying this four-step process:

D DEFINE QUESTIONS
Think through the scope and details of the problem; define manageable questions to tackle.

T TRANSLATE TO MATHS
Prepare the questions as maths models ready for computing the answer. Select from standard techniques or formulate algorithms.

C COMPUTE ANSWERS
Transform the maths models into maths answers with the power of computers, or by hand calculating. Identify and resolve operational issues during the computation.

I INTERPRET RESULTS
Did the maths answers solve the original problem? Fix mistakes or refine by taking another turn around the Solution Helix.

THE CBM SOLUTION HELIX OF MATHS
Available as a classroom poster at:
computerbasedmath.org/helix

What's wrong with today's maths education?

Mainly that 80% of the time is spent learning hand-calculating techniques on simpler problems, rather than getting the computation done by the computer, and having students concentrate far more on the other three steps, applied to complex problems.

Why is CBM better?

Because it prepares students for real maths: with real context, real-world complexity, real outcomes—even answers like 'we can't predict this'. To achieve this, CBM lessons involve many opportunities for students to engage with dynamic demonstrations, test their understanding, discuss a strategy, and listen to other students present their opinions. Many activities feed back instantly to the students, whilst others use the teacher's knowledge to assess the level of the responses. The teachers are trained in the new approach and able to draw upon the opinions of the class regularly throughout the lesson to move everybody on at a fast pace of learning together.

Tethering to outcomes

What are the outcomes we want from school maths? At CBM, we couldn't find a list that reflected real-world requirements sufficiently, so we set about redefining them ourselves. The result is 11 key dimensions, each a critical competence, that when brought together enable this vital subject to empower a student's life.

CT CONFIDENCE TO TACKLE NEW PROBLEMS

Students show confidence to attempt solutions to new problems by application of the four-step process. They use the problem-solving process as a mechanism to overcome hard-to-handle or unknown scenarios and can adapt previously learnt methods, concepts and tools to new contexts. They are able to overcome sticking points in the process and teach themselves new tools as the need arises.

IF INSTINCTIVE FEEL FOR MATHS

Students are able to use their experience to know when something just 'smells' wrong. They are aware of common errors made and have a working mental knowledge of the use of maths concepts.

DQ DEFINING THE QUESTION

Students begin the problem-solving process by organising the information needed to solve the problem and identifying suitable smaller tasks that can be solved. They understand assumptions and use them effectively to aid progress on the solution.

AM ABSTRACTING TO MATHEMATICAL CONCEPTS

Students begin the translation to maths phase by taking their precise questions and working out strategies or mathematical concepts to explore. They organise their information and identify the relevant concepts and their suitability for the purpose.

CM CONCEPTS OF MATHS

Concepts are what you want to get done (hang a picture, solve an equation, describe an event's probability…). Tools are what you want to use to do it (glue, nail, screw, graph, formula, normal distribution…). Most concepts begin life with one tool; you invent the concept for a given problem and a tool to fix that. Though retrospectively, people might collect a number of tools and create an umbrella concept to cover them.

TM TOOLS OF MATHS

Tools take the form of functions, methods or processes that enable a conversion from the abstracted form of the defined question into a form that is useful in answering the question. The tool may not necessarily be computer based. The most efficient manifestation of the tool for the purpose should be chosen.

MC MANAGING COMPUTATIONS

The computation phase begins with students choosing the manifestation of the mathematical 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.

IN INTERPRETING

Students take the output of the computation stage and translate this back to the original real-world problem by relating the output to their precise question. They consider further areas of investigation as a result.

CV CRITIQUING AND VERIFYING

Critiquing is a consideration of what could possibly be wrong with your process or solution. Asking the questions: Where? When? Why? What? Who? It is a constant process of scepticism towards results, from unexpected results to expected results. Verifying is comparing against a hypothesis to confirm an answer and being able to justify the result.

GM GENERALISING A MODEL/THEORY/APPROACH

Once a model has been built for a specific purpose, looking further afield for instances where the model may apply or providing sufficient documentation for others to adapt the model for their purpose.

CC COMMUNICATING AND COLLABORATING

Communicating and collaborating is a continual process that happens throughout all stages. Students use media fit for the purpose and combine multiple representations effectively for the intended audience to be able to follow the ideas presented.

Details at: computerbasedmath.org/outcomes

Questions and answers about CBM

Q: Don't you have to learn the basics first?

A: Yes, but the key question is, basics of what—hand calculating or the broader subject of maths? Analogies may be helpful. The basics of driving a car are not the same as the basics of car mechanics. Today's basics of photography do not involve film processing; indeed, nor does today's advanced photography. In each case, the essence of the subject and today's mechanics are important basics, but not historical mechanics or human replication of today's mechanisation. The essence of maths is the four steps of problem solving, and today's mechanics are calculating with a computer. It's understandable how this was confused with today's basics being hand calculating because for centuries those mechanics were the main stumbling block to applying maths to problems. Now they're not, and it's critical that this misunderstanding is corrected in education.

Q: Doesn't using computers 'dumb down' the understanding?

A: Quite the contrary, having a computer allows far more complex scenarios to be manipulated and deeper concepts to be studied without being held back by the need to perfect hand-calculation techniques. If the computer is used to create processes, investigate parameters and solve problems, then this demands a skill set far more advanced than is currently being taught.

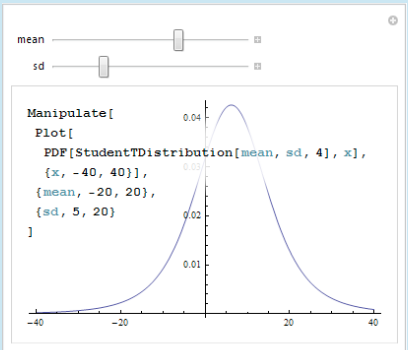
Q: Can CBM help with groups traditionally disadvantaged for maths?

A: Often, yes. CBM starts with problems that students can relate to and uses abstraction as a tool for solving them. Traditional maths starts with abstract concepts and only sometimes follows up by applying them, and then seldom to realistic problems (which need a computer).

Those traditionally classed as low attainers often fare worst because they have the least experience and motivation to push through abstract ideas upfront—scaring them off traditional maths at the outset. By contrast, with CBM, the problem is always at the forefront of any activity, providing motivation and meaning for all abilities.

Is coding part of CBM?

Yes, because coding is the way that technical ideas are written down in practice in today's real world. If you want to apply maths, fairly soon you have to write code. That's the case for CBM curriculum problems too, though it is carefully phased in through the modules, so as not to preclude those not yet knowledgeable about coding.



Is CBM a Computational Thinking curriculum?

CBM is the start of today's best structured program for engendering Computational Thinking—one that's principally around maths but applied to problems and projects from all subjects. Ultimately our aim is to build the anchor Computational Thinking school subject as we broaden CBM beyond being solely based in maths.

Q: Not all students learn in the same way. How does CBM cater for diversity?

A: In CBM, we include a range of teaching and learning styles in the lessons, from data gathering to presentations, from individual work to group tasks, from typed answers to diagrams, posters and videos. Many CBM problems can be answered at a wide variety of levels (unlike most calculating-only maths)—giving stimulation for a wide variety of abilities.

CBM intentionally delivers problem sets that appeal to all genders by applying maths to a multitude of engaging topics—for example, complex social issues—the analysis of which requires powerful computation. This enables all students to address interesting problems that have traditionally been locked out of the curriculum.

Q: The current exam doesn't use computers. How will CBM help?

A: In several ways. For a start, by engaging students better. Having real problems to solve closer to a student's real-life experiences makes maths more exciting for many. Secondly, by understanding the concept as maths for problem-solving, that calculating is only a part of the process, then even if calculating has to be learnt by hand for today's exams, the context will make it easier to understand. So CBM complements the standard curriculum whilst traditional exams are in place. But we are campaigning on many levels to change the curriculum and assessments to include the skills we believe are necessary in later life.

Q: Who started computerbasedmath.org, why and when?

A: Conrad Wolfram started it in 2010. He is also an executive and European cofounder of Wolfram Research—renowned as a world leader in computation technologies for over 25 years. He had watched as Wolfram's and other computing technologies revolutionised the use of maths outside education but barely impacted the school subject.

By 2010, the extent of the real-world maths to educational maths chasm alongside the ease and availability of classroom technology made the time ripe for fundamental change. Wolfram's connection with millions of maths users, researchers and employers in every field and every country gives the group an unparalleled perspective over the real-world maths landscape—not to mention key technologies and skills to implement change.

See more at: computerbasedmath.org/about

What technology is implementing CBM?

Wolfram software such as the Wolfram Language™, Mathematica®, Computable Document Format™ documents and Wolfram|Alpha®! The CBM team did not make this choice because of familiarity but because only this technology delivers the best flexibility across a wide spectrum of activities, from preconfigured easy interactivity to powerful language for open-ended problem solving.

Moreover, these technologies are widely used in higher education, industry and government around the world, so by learning them students will gain an extra, marketable skill. But the CBM philosophy is not dependent on any one technology base—including Wolfram's.

See full reasons at: computerbasedmath.org/technology

CBM is keen to gain support for this fundamental maths education shift that's so vital to your community and others. If you can help, whether by lending support, contributing ideas or sponsoring, or you just want to find out more, go to computerbasedmaths.org or contact us at info@computerbasedmath.org.