Fundamentally fixing maths education: Applying CBM in your country

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You know, I've been watching as the real-world subject of maths and the educational subject of maths have diverged. Computer-Based Math has been founded to fix that problem, to move the educational maths to really represent what people are doing in the real world. You know, there's a very simple reason why this chasm has opened up. In the real world almost universally we use computers for calculating as part of the maths process. In education we almost universally use humans for doing the calculating. The subjects are different, and unless we fix the educational subject to be the mainstream subject we need for the real world, we can't fix maths education. So what we need to do is fix the content, not just the delivery. So our new Computer-Based Math curricula reflect this fundamental decision: assume computers by default for calculating and then move and build the curriculum out from that assumption. Now one of the things that you immediately come up with then is the curricula are problem-centric. What does that mean? Well you start with an actual problem you're interested in solving. You use maths and then the computer in a sense to drive the maths to solve that problem. Traditional curricula often do it totally the other way around. They start with, so to speak, the mechanics inside, and then if you're lucky after you've gone through by hand, calculating all of the results, the student might find out why on earth they're doing this.

Curriculum design

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The first challenge we had to face was what topics to include, and we chose to use the real world as our guide on this. So we prioritised the maths that is needed for everyday living and technical jobs above cultural and historical maths. And using the real world changes abstraction within the subject. It becomes a point later in the process to make the maths more powerful, rather than where you start.

Another key decision following the real world was to use computers by default. So we use them for all computation, unless either hand calculating is the most practical way of doing that type of computation, or the process of doing the hand calculation is conceptually empowering. One liberating consequence of using computers by default is that we can order the subject by conceptual difficulty instead of computational difficulty. Topics that at the moment are very late, because they are difficult to actually compute, can be introduced much earlier, because the concepts are actually quite straightforward.

The maths process

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If you look at the traditional curriculum,

the four steps of the problem-solving process, we spend the majority of the time on step 3: computation, learning how to do hand-calculation methods, pen and paper or pen and calculator or just mentally. We spend a huge amount of time and very rarely do we do anything else about the problem-solving cycle other than compute. If you look at the balance in the new CBM Solution Helix of Math,

we give equal weighting to all of the steps. It's all important.

The maths process: step 1

DEFINE QUESTIONS In CBM:

The first step is to define the question. We have to be really clear about what it is we're trying to work out. And part of that is to think through, what do we know and what don't we know? and importantly, what assumptions are we going to be making? One aspect of this is there's often more than one way to work out a problem, and particularly things like the assumptions are quite subjective. And so we've needed to think through some of the class collaboration tools to allow the discussion and decision making to be more efficient in a classroom environment.

DEFINE QUESTIONS Traditionally:

So traditionally, this step is rarely taught. The problems we teach in the traditional curriculum are broken up into little manageable pieces that are easy to test, but the good thing is that the best teachers know this and they are teaching problem solving, mainly in Primary at the earlier ages. They're teaching Frogs, they're teaching Pond Borders, teaching Painted Cube and other investigations, teaching the problem-solving process. But the problem is, they're restricted by the level of computation. They cannot do the real-world complex mathematics because of the restrictions of the hand-calculating curriculum.

The maths process: step 2

DEFINE QUESTIONS **TRANSLATE** TO MATHS In CBM:

The second step is to translate from our knowledge of the world and our question into a mathematical representation. So that could simply be a very clear mathematical statement such as: I want to do a hypothesis test of our data against a uniform discrete distribution. Or it might be developing a model or a formula, but in more complex cases it's going to be to develop an algorithm and then write a computer program to execute that automatically.

DEFINE QUESTIONS **TRANSLATE** TO MATHS Traditionally:

So in the real world, abstraction is how we solve large- and small-scale problems by defining the variables, realising their limits, finding tools, having an expectation of the result and confidence in the result. In the traditional curriculum this is rarely done: the problems are ready-made by the teacher or examiner or by the textbook. There is some attempt to start converting into maths in some of the examples, but the context is so trivial, there's no relation to the real world.

The maths process: step 3

DEFINE QUESTIONS **TRANSLATE** TO MATHS **COMPUTE** ANSWERS Traditionally:

So as we said, in the traditional curriculum this is where we spend over 80% of our time: having the challenge to solve problems by hand or mentally, spending time learning how to do the complex calculations by hand. In the real world you have to be able to estimate in your head and do simple calculations on paper, but the rest of the time, the vast majority of the time, all of the calculations are done on a computer.

DEFINE QUESTIONS **TRANSLATE** TO MATHS **COMPUTE** ANSWERS In CBM:

In Computer-Based Maths, computation is the easiest step and it's no harder for big and complex problems either. We are constrained only by the conceptual difficulty. And this means we can tackle real-world problems that are messy and big, not the toy problems you typically see in education. More importantly, it's a quick step, and that gives us more time for the other steps that are more important.

The maths process: step 4

In CBM:

The last step in our process is to interpret the results, to translate from our computed answer to a real-world answer. What does the answer mean? What decisions can I make off the basis of it? Now a key part of that is to critique our answer, to ask ourselves, do we believe it? Can we quantify how accurate it is? And it might be that the result of critiquing is to iterate and go another lap around the Solution Helix of Maths by asking new questions.

Traditionally:

In the real world, the output is interpreted in the context of the problem, the reliability of the results is assessed, the results are formally reported, and also other people have to interpret your results. But in the traditional curriculum at the moment, we stop after the calculation. Once we've got an answer and it's checked either by the teacher or the back of the book, that's the end. There isn't any interpretation. There isn't a context, so it's impossible to do the interpretation.

The deployment

While the key thing here is to rethink the curriculum for the modern age, we can't do that in isolation without thinking about the deployment of that curriculum. Now of course there's more than one way to do that. Our initial deployment is for class-based with teacher guidance. The students come into the room and they sit down at their own computer where they have all of the tools for exploration that they need and a programming language to develop their own ideas. We've also set up collaboration tools for them to share data and ideas with each and also to feed that back to the teacher.

So as with any curriculum change, the key to this will be the teachers. They're going to be the ones that implement it in the classroom day-to-day. So they need some training on how to do this, and they also need everything they require easily accessible in one place. They don't want to be shuffling papers or planning lessons using textbooks, using online materials, using clickers to get the voting done. They want everything in one place. So what we've designed is a system to do this. We've got everything in one place. We've got the lesson materials, the lesson plans, everything they need, everything the students will see, and the formative assessment instantly available on the screen at the same time. So we can do peer assessment, we can do collaboration, we can take the best of collaborative practice that's currently going on and we can use it in the CBM classroom. So we can do 'think-pair-share', we can do 'round table', we can do a new modality called 'manipulate to discover'. So we use this in a range of situations, either from simulating data or experiments or from changing parameters to see their effect on the underlying problem.

Why are we learning maths anyway?

I've struggled to find what I consider a very coherent list of outcomes from maths around the world. You'd think this was pretty well established in the sense that we spend billions of dollars around the world teaching maths in almost every country, so you'd think it would be obvious what outcomes we're looking for. Well, all I can say is, we've had trouble finding that list, so we decided to build our own and it's pretty complex. It's a 10-dimensional list. And it really covers a wide range of what we think is important. 'Confidence to tackle new problems', for example. It's crucial that when you're given a new piece of maths or a new problem, you know how to push through that. And that's an important outcome. Another thing that's really surprising to me is in so many of the outcomes lists I've seen, the idea of the maths concept and the actual tool of maths are not very separated. So for example, many people learn quadratic equations at school. The thing that perplexes me is that the concept of an equation isn't separated much more from the detailed way you might happen to solve a quadratic, or a cubic, or a quantic for that matter. So we need to separate the idea of equations from the detailed tools to do with how you would handle a quadratic equation or indeed leave that to a computer. Those are crucial separations that are often not reflected in traditional lists of maths outcomes.

Let’s get on with fixing maths

You know, I think it will take 25 years, but we need to fundamentally change maths education to the right subject all the way around the world, and that's what I hope CBM and Computer-Based Maths can really help with. You know, if we don't fix maths education in the way I'm talking about, I think there's a serious chance that it will go the way of classics. It will become an exciting sideshow for some people, and that's great for those people who are excited by it, but it won't become the mainstream driver of our economies and our livelihoods, both for wider society and for each individual.

So people often say to me, 'We agree with you about CBM; we just can’t see how to make it happen.' I say, we’re actually well down the path of working through the transformation, building curricula, specifying outcomes, and building materials with leaders in this change. We’re actually in great shape to help your country or region make it, wherever you are in PISA at the moment. This is a case where being early is best, a bit like it was for early adopters of universal education. There’s really no reason not to start today. Let’s get on with fixing maths together.