ISSUE #06

What’s Inside:

Anchoring Computational Thinking in today’s curriculum

Effective differentiation: where a growth mindset meets the ZPD
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Maths Matters: advancing maths education for the future

Horizon forum with Conrad Wolfram (left), Strategic Director and European Co-Founder/CEO of the Wolfram group of companies, in conversation with Educational Leaders Jodie Parsons (middle) and Yvonne Reilly (right)

What skills do young people need in the era of computers and automation?
Quantitative understanding is becoming increasingly important both in the workplace and in society. But the preparation for this computational thinking—mathematics education—is not keeping up.

Join us for a panel discussion on how we can ensure mathematics education is relevant and meaningful. The panel will explore:
- the skills young people need to make a valuable contribution in the era of computers and automation
- the role of people in a workplace with increasing artificial intelligence
- how to empower more students to engage in maths.

Conrad will be joined by Sunshine College Educational Leaders Jodie Parsons (Curriculum Design and Delivery) and Yvonne Reilly (Maths and Numeracy) in a discussion facilitated by Sonia Sharp, Principal at Nous Group.

Date: Wednesday 19 July 2017
Session: 5.00 pm to 7.00 pm
Nibbles and networking: to follow discussion
Venue: Bastow, 603–615 Queensberry St, North Melbourne
Cost: $35
Register to attend

Disrupting maths in our schools

A workshop with Conrad Wolfram for mathematics leaders and learning specialists

Start teaching computer-based maths.
Conrad Wolfram will challenge thinking about how we deliver mathematics in Victoria’s schools, with the aim of disrupting preconceived notions of maths content and delivery.

Conrad will explore what a future curriculum may look like in the context of the Victorian education system and how this can meet the expectations of the future job market. He will show how you can use technology as an aid to computational thinking and the problem-solving cycle in the classroom.

The workshop will explore:
- Wolfram’s computer based maths and scope
- how you can introduce computer based maths or curriculum change in your school
- how to support teachers and engage stakeholders in teaching less calculation and teaching more maths.

Date: Thursday 20 July 2017
Session: 9.00 am to 5.00 pm
Venue: Melbourne Convention and Exhibition Centre
Cost: $95
Register to attend

At Bastow
Via Video Conferencing
A message from the Director

Lifting student achievement in maths is one of the central challenges we face as we move forward in our commitment to improving student outcomes across Victoria. This challenge is not unique to Victoria, or even to Australia: school systems around the world are recognising the urgent need to engage students differently to drive consistent improvement in maths.

I am therefore delighted to present this latest Horizon publication, which features papers from leading thinkers in maths education—Conrad Wolfram of the Wolfram Group, and Educational Leaders Yvonne Reilly and Jodie Parsons from Sunshine College in Victoria. Both papers challenge us to consider how we might change our approach to maths education and reinvigorate the curriculum.

Conrad is known for his thought leadership in reforming education using modern technology. In his paper he builds the case for Computational Thinking as a fundamental approach not only to real-world maths, but across the curriculum more broadly.

Yvonne and Jodie’s paper outlines their model for lifting student achievement in maths through effective differentiation and fostering a growth mindset. This model has yielded impressive results in the classroom: in February 2014 the Grattan Institute recognised Sunshine College as a turnaround school.

Conrad, Yvonne and Jodie will be presenting a Horizon forum at Bastow on Wednesday 19 July. Please join us for what promises to be a lively discussion about why maths matters and how we can advance maths education for the future.

Many maths leaders will be familiar with Wolfram products. They are internationally recognised as powerful learning tools across STEM, and the Department holds a licence for their use across all Victorian secondary schools.

While Conrad is in Melbourne he will be conducting a workshop for maths leaders. I’d encourage anyone with an interest in exploring how we might disrupt maths education in our schools to register.

Lisa Black
Acting Director
Anchoring Computational Thinking in today’s curriculum

Author: Conrad Wolfram, Wolfram Group

There is a lot of talk of Computational Thinking as a new imperative of education, so I wanted to address a few questions that keep coming up about it. What is it? Is it important? How does it relate to today’s school subjects? Is Computer-Based Maths (CBM) a Computational Thinking curriculum?

Firstly, I’ve got to say, I really like the term. To my mind, the overriding purpose of education is to enrich life (yours, your society’s, not just in terms of ‘riches’ but in meaning)—and having different ways of thinking about how you look at ideas, challenges and opportunities seems crucial to achieving that. Therefore, using a term of the form ‘X Thinking’ that cuts across boundaries but can support traditional school subjects (e.g. history, English, maths) and that emphasises an approach to thinking is important to improving education.
Now, we’ve had widespread use of the term ‘Critical Thinking’ for some time, but to me it has much less power of actuality than ‘Computational Thinking’. Computation is a highly definitive set of methodologies—a system for getting answers from questions, and one rapidly gaining in power and applicability each year. There is no parallel, definitive ‘critic’ system; and even the related ‘critiquing’ is a rather vague skill bucket, not a systemic—and highly successful—roadmap. As a result, Critical Thinking often becomes more of an aspiration of student capability, not a definable, definite, life-enriching set of problem-solving abilities.

To be specific, I’d argue that Computational Thinking is a mode of thinking about life in which you creatively and cleverly apply a four-step problem-solving process to ideas, challenges and opportunities you encounter, to make progress with them.

Here’s how it works.

You start by defining the question that you really want to address—a step shared with most definitions of Critical Thinking.

But computational thinking follows this with a crucial transitional step 2 in which you take these questions and translate into abstract computational language—be that code, diagrams or algorithms. This has several purposes. It means that hundreds of years’ worth of figured-out concepts and tools can be brought to bear on the question (usually by computer), because you’ve turned the question into a form ready for this high fidelity machinery to do its work. Another purpose of step 2 is to force a more precise definition of the question. In many cases this abstraction step is the one that demands the most high conceptual understanding, creativity, experience and insight.

After abstraction comes step 3, the computation itself—where the question is transformed into an abstract answer, usually by computer.

In step 4 we take this abstract answer and interpret the results, re-contextualising them in the scope of our original questions and sceptically verifying them.

The process rarely stops at that point, because it can be applied over and over again with output informing the next input until you deem the answers sufficiently good. This might take just a minute for a simple estimation, or a whole lifetime for a scientific discovery.

I think it’s helpful to represent this iteration as ascending a helix made up of a roadway of the four steps, repeating in sequence until you can declare success.

While I’ve emphasised the process end of Computational Thinking, the power of its application comes from (what are today!) very human qualities of creativity and conceptual understanding. The magic is in optimising how process, computer and human can be put together to solve increasingly tough problems.
The Computational Thinking process

Modern technology has dramatically shifted the effective process because you don’t get stuck on your helix roadway at step 3, so you may as well zoom up more turns of the track faster.

Is this process of Computational Thinking that I describe connected with maths—are they even one and the same? And what about coding? There is very heavy overlap with the Computer-Based Maths approach, and much less with today’s traditional maths education; coding is an important element, particularly as the main way in which you manifest abstraction.

Real-world maths—defining it and its applications broadly, as I do—absolutely relies on Computational Thinking. There are also specific areas of knowledge that maths is considered to contain (e.g. particular concepts and algorithms), which are often important in applying Computational Thinking to different areas of life. Maths is a domain of factual knowledge as well as the skills knowledge of how to process it.

Even in the real world this broad definition of maths may be alien to engineers or scientists, who would consider what I’m describing simply as part of engineering or science respectively.

Even in the real world this broad definition of maths may be alien to engineers or scientists, who would consider what I’m describing simply as part of engineering or science respectively.

There’s another key difference, too, between a traditional maths way of thinking about a problem and a modern Computational Thinking approach, and it has to do with the cost–benefit analysis between the four steps of the helix.

Before modern computers, step 3—computation—was very expensive because it had to be done manually. Therefore in real life you’d try very hard to minimise the amount of computation at the expense of much more upfront deliberation in steps 1 (defining the question) and 2 (abstracting). It was a very deliberate process. Now you might have a much more scientific or experimental approach, with a looser initial question for step 1 (‘Can I find something interesting in this data?’), and an abstraction in step 2 leading to a multiplicity of computations (‘Let me try plotting correlation of all the pairs of data’) because computation (step 3) is so cheap and effective you can try it lots and not worry if there’s wastage at that step. Modern technology has dramatically shifted the effective process because you don’t get stuck on your helix roadway at step 3, so you may as well zoom up more turns of the track faster.

A useful analogy is the change that digital photography has brought. Taking photos on film was relatively costly (though cheap compared with the chemical-coated glass plates it replaced). You didn’t want to waste film, so you’d be more meticulous at setting the shot before you took it. Now you may as well take the photo; it’s cheap. That doesn’t mean you shouldn’t be careful to set up (abstract it) to get good results, but it does mean the cost of misfires, wrong light exposure and so forth is less. It also opens up new fields of ad-hoc photography to a far wider range of people. Both meticulous and ad-hoc modes can be useful; the latter has added a whole new toolset, though it doesn’t always replace the original approach.

Back to maths. What’s sadly all too clear is that today’s mainstream educational subject in this space of ‘maths’ isn’t meeting the real-world need of Computational Thinking that could be addressed by Computer-Based Maths. Its focus on teaching students how to do step 3 manually might have made sense when that was the sticking point in applying maths in life: because if you couldn’t do the calculating, you couldn’t use maths (or Computational Thinking). Conversely, providing experience primarily in a very deliberate, meticulous, uncontextualised, pre-computer application of the computational process—rather than in a faster-paced, computer-based, experimental, scientific-style application to real problems—cannot continue to be maths’ chief purpose if the subject is to remain mainstream. Instead its primary purpose ought to be Computational Thinking—as it is in our Computer-Based Maths manifestation.

Like real-world maths, coding relies on Computational Thinking but it isn’t the same subject or (by most definitions) anything like a complete route to it. You need Computational Thinking for figuring out how to extract

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problems to code and get the computer to do what you want, but coding is the art of instructing a computer what to do; it’s the expertise you need in order to be the sophisticated manager of your computing technology, and that includes speaking a sensible coding language, or several, to your computer.

What of other school subjects? Computational Thinking should be applicable to a very wide range. After all, it’s a way of thinking—not the only way of thinking, but an important perspective across life. Whether it’s design (‘How can I design a streamlined cycle helmet?’), or history (‘What was the key message each US president’s inaugural address delivered?’), or music (‘How did Bach’s use of motifs change over his career?’), every subject should envelop a Computational Thinking approach.

An important practical question is whether this wider application can happen without there being a core educational subject whose essence is Computational Thinking? I don’t think so. Not at school levels, anyway. That’s because the Computational Thinking approach needs knowledge of what’s possible, experience of how you can apply it, and knowledge of today’s machinery to perform it. You need to know which concepts and tools there are to translate and abstract to in step 2. I don’t think you can learn this only as part of other subjects; there needs to be an anchor where these modern-day basics (learnt in a contextualised way) can be fostered.

Politically, there are two primary ways to achieve this: introduce a new core subject, or transform an existing one. Either is a major undertaking. Maths and coding are the only existing school subject contenders for the transformational route. Maths of course is ubiquitous, well-resourced and occupies a big part of the curriculum—but today’s subject largely misses the mark. Coding is the new kid on the block, too narrow, not fully established; it has far less time or money but has a zeal to go to new places.

How does CBM relate? For the very short term, simply as the start of today’s best structured program for engendering Computational Thinking—one that’s principally around maths but is applied to problems and projects from all subjects.

Ultimately our aim is to build the anchor Computational Thinking school subject as we explicitly broaden CBM beyond being based in maths (and, just as importantly, beyond the perception of it being based only in maths). Look out for modules of CBM geography and CBM history!

Make no mistake: whatever the politics or how it’s labelled, whoever wins or loses—someday a core, ubiquitous school subject in the space I’m describing will emerge. The first countries, regions and schools that manage this new core and its cross-curricular application will win big time.

This was first published on 4 October 2016 as a blog post at www.conradwolfram.com/home/anchoring-computational-thinking-in-todays-curriculum and is reproduced here with the permission of the author.

Conrad Wolfram, physicist, mathematician and technologist, is Strategic Director and European Co-Founder/CEO of the Wolfram group of companies. Described as the ‘Computation Company’ and uniquely operating at the intersection of computation, data and knowledge, the Wolfram Group is driving innovation across data science, modelling and maths through technology and solutions. Conrad is also widely known for his thought leadership in reforming education using modern technology. He founded computerbasedmath.org to fundamentally rethink and rebuild the mainstream maths education curriculum, introduce computational thinking and combine with coding now computers can be assumed. The resulting major change is now a worldwide force in re-engineering STEM, with early projects in Estonia, Sweden and Africa.
Effective differentiation: where a growth mindset meets the ZPD

Authors: Yvonne Reilly and Jodie Parsons, Sunshine College

The challenge of practically providing each student in a class with the opportunity to work at their own Zone of Proximal Development (ZPD) (Vygotsky, 1978), is often insurmountable to many practitioners. Our model not only alleviates the practical aspects of this challenge, but in addition, creates an environment where students believe that they can improve and an environment where students are expected to identify and select the activity which is ‘just right’ for their learning requirements.
Introduction

Sunshine College is a multi-campus government secondary school located within the South Western Victorian Region. It is positioned across four sites and is made up of three junior campuses, including a deaf facility and one senior campus. It is a culturally diverse school with more than fifty language backgrounds. The population, in general, suffers a high degree of disadvantage and a low socio-economic position, with an average Student Family Occupation (SFO) index of 0.8, and a school ICSEA value of 909. Our distribution of students compared with the Australian average is shown in Figure 1.

In 2008 and after several years of little or no improvement in whole school data (AIM & VCE), and the placement of several numeracy coaches from the then Western Metropolitan Region, the authors of this paper began to construct a numeracy program which would support the conceptual understanding of all students. Prior to this the majority of mathematics classes at Sunshine College were teacher centred and followed a traditionally recognised structure. The teacher would complete worked examples on the whiteboard, students would copy the examples and then complete a number of almost identical questions from the prescribed textbook. Classes rarely, if ever, used concrete materials; students worked individually; assessment was summative and the opportunity for a tailored and individualised program was the prerogative of the classroom teacher, often resulting in lessons where weaker students were expected to complete fewer questions than the more competent students.

<table>
<thead>
<tr>
<th>Distribution of students</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bottom quarter</strong></td>
</tr>
<tr>
<td>School distribution</td>
</tr>
<tr>
<td>Australian distribution</td>
</tr>
</tbody>
</table>

Figure 1. Distribution of students (http://www.myschool.edu.au/SchoolProfile)

Context

At each junior campus of Sunshine College all students receive five 50-minute lessons of mathematics instruction per week. Each two-week cycle is divided into one of five elements, as illustrated in Table 1. Each element has been developed to specifically address a particular aspect of student learning and have been described in full detail in Siemon, Virgona, and Corneille (2006); Reilly, Parsons, and Bortolot (2009); Reilly, Parsons, and Bortolot (2010); Reilly and Parsons (2011), and in The Common Denominator (Jan, 2014). While each element of the Sunshine College Maths Program (SCMP) supports a different aspect of numeracy understanding, they all share a common philosophy, in that all students are encouraged to work within their ZPD in an environment which fosters the growth mindset.

<table>
<thead>
<tr>
<th>Week</th>
<th>Lesson 1</th>
<th>Lesson 2</th>
<th>Lesson 3</th>
<th>Lesson 4</th>
<th>Lesson 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Odd</td>
<td>Differentiated curriculum</td>
<td>Reciprocal teaching</td>
<td>Differentiated curriculum</td>
<td>Speedy maths</td>
<td>SNMY</td>
</tr>
<tr>
<td>Even</td>
<td>Differentiated curriculum</td>
<td>Reciprocal teaching</td>
<td>Differentiated curriculum</td>
<td>ICT</td>
<td>SNMY</td>
</tr>
</tbody>
</table>

Table 1. Sunshine College Maths Program (SCMP)
The results

Prior to the implementation of the SCMP the college was regularly identified as a school where students on average tested two or more years behind the national average for literacy and numeracy. As is demonstrated in Table 2 and Figure 2 the introduction of the SCMP has led to on average a faster rate of growth for students at the college when compared to the average rate of growth demonstrated by the State in the NAPLAN standardised tests for students between Year 7 and Year 9.

<table>
<thead>
<tr>
<th>Matched School Mean</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ardeer Campus</td>
<td>56</td>
<td>47</td>
<td>45</td>
</tr>
<tr>
<td>North Campus</td>
<td>47</td>
<td>51</td>
<td>53</td>
</tr>
<tr>
<td>West Campus</td>
<td>45</td>
<td>64</td>
<td>54</td>
</tr>
<tr>
<td>School Mean</td>
<td>49.3</td>
<td>54</td>
<td>50.7</td>
</tr>
<tr>
<td>State Mean</td>
<td>42</td>
<td>38</td>
<td>39</td>
</tr>
</tbody>
</table>

Table 2. The rate of growth between Years 7 and 9
In February 2014, Sunshine College was noted as a turnaround school by The Grattan Institute. It was heralded as one of four schools in Australia to have students improving at a rate faster than the state average in numeracy (Feb, 2014).

Anecdotal evidence also suggests students are now more confident in their mathematical ability and as a result more students are selecting General Mathematics (Advanced) in Year 11 compared to previous years. When students are questioned as to why they are selecting mathematics they say it is because they like maths or that they are good at it. It is the authors’ belief that a number of factors working together have contributed to the success of the program, most notably a fully differentiated curriculum where students are offered mathematics at their ZPD and the fostering of a growth mindset within each and every mathematics class.

A fully differentiated curriculum

The mathematics curriculum for schools is governed by the Australian Curriculum Assessment and Reporting Authority. It describes the chronological expectation of student learning in each year of formal schooling. In mathematics this means students in Year 8 are expected to develop an understanding of directed number while students in Year 9 progress to developing an understanding of Pythagoras’ Theorem and Trigonometry. This expectation notwithstanding, it is rare to find a classroom where all students are capable of learning a specific concept at the same time and in the same manner. In 2011, the authors described their model for differentiation which avoids the various negative connotations of streaming, grouping and withdrawal of students whilst demonstrating how the model is not just modifying or extending work (Reilly & Parsons, 2011). In addition to these benefits the authors have noted an additional point of difference to their model where the teacher provides for different learning needs by what they refer to as the ‘Drop-out Model’.

The Drop-out Model

In this traditional model the teacher often constructs an activity, assessment task or topic test, where the initial questions are easier. However, as the task progresses the questions become increasingly more difficult. While all students work on the same material they drop out when they have reached their capacity to understand. This model has two potential detrimental effects on student learning. Firstly, it provides the more able student with ample opportunity to demonstrate their knowledge and intelligence as they experience the metaphorical pat on the back as they successfully complete work that was well within their capability, or as with the initial activities, below their ZPD. These same students, who experience success often, when faced with small challenges have a reduced capacity to cope and can, on occasion, crumble. This Drop-out Model can mean that more capable students are not regularly presented with the opportunity to develop perseverance or resilience in their learning — thus supporting the development of a fixed mindset, where individuals believe that understanding or intelligence cannot be improved upon (Dweck, 2006).

Secondly, the Drop-out Model indicates very clearly to students who are less able that there are many things which they cannot do. Even when the task is delivered by the most caring teacher saying things like ‘Don’t worry, just do as many as you can’, the student still hears ‘You are not as good as everyone else; my expectations of you are much lower than my expectations of the good mathematicians.’

As previously described (Reilly & Parsons, 2011), the development of an alternative model of differentiation which incorporates ‘just right’ tasks not only provides learning opportunities for all students to work at their ZPD but also capitalises on the positive learning outcomes associated with a growth mindset.

The development of a growth mindset in mathematics

There are very few people in this country who would happily admit that they were illiterate, yet many highly educated and well respected individuals will publicly concede that they were ‘never any good at maths’. There is a widely held perception that being a good mathematician is a particular talent that only a lucky few individuals exhibit and that your natural ability determines or limits your achievement in this area. Psychologist Carol S. Dweck, PhD, describes this belief system as a fixed mindset, where your level of intelligence is seen as a fixed trait.
Blackwell, Trzeniowski and Dweck (2007) studied a group of 7th graders in the United States, where after transition from elementary school, the students perceived the work to get harder and as a result the students begin to struggle. In this study, students were identified as having either a fixed mindset or a growth mindset. The authors found students who had been identified as having a growth mindset exhibited a dramatic increase in maths grades when compared to the fixed mindset group (Blackwell et al., 2007).

Dweck (2006) describes how, in order to develop a growth mindset in learners, it is necessary to change the belief that intelligence is a fixed trait, and that if an individual needs to work hard at something it means they are no good at it, as opposed to working hard to become very good at it. Those with a fixed mindset also believe mistakes demonstrate failure as opposed to providing opportunities for learning and understanding. Fixed mindset students have little or no recipe for recovering from failure and instead tend to either give up or blame the teacher. In contrast, students who exhibit a growth mindset confront difficulties and seek solutions.

Our model of differentiation and a growth mindset

In conjunction with providing a differentiated curriculum, Sunshine College guides students towards developing a growth mindset. Students are encouraged to take control of their learning and to develop personal learning goals. In our classrooms the path travelled is as valued as the end result. We encourage students to determine their current level of understanding, help them to set realistic and achievable goals and then guide them to select tasks which best support their learning, i.e., the task which is ‘just right’ for them. A ‘just right’ task refers to a learning activity which allows students to work in small groups on a mathematics problem at their ZPD. All students within the one classroom work on the same task which is ‘just right’ for their learning. ‘Just right’ tasks focus on conceptual understanding of mathematics as opposed to procedural practice.

In order to support the development of a growth mindset while providing a fully differentiated curriculum the authors believe the following key elements are essential.

• Each task should be designed to teach more than one mathematical concept at a time, reinforcing the complex nature of mathematics.

• When the teacher introduces the tasks to the class, each level is described using the prerequisite knowledge the students will need to complete the selected task successfully. The teachers avoid labelling the tasks as ‘easy’, ‘medium’, or ‘hard’ because if the task is ‘just right’ for the student it should feel hard.

• Students work with someone who has chosen the same task as they have and who thinks at the same speed as they do, encouraging equitable mathematic conversation.

• Tasks are created to support conceptual understanding and not just to provide opportunity to practice procedures.

• As students are working at different levels of understanding, teachers are no longer able to stand at the front of the room and explicitly teach the class as a whole; instead explicit teaching is done at the point of need, with the teacher constructing small groups when necessary to increase efficiency.

• While using this model of differentiation teachers avoid telling the students anything, opting instead to guide them to discovery through effective questioning techniques. As stated by René Descartes in his book La Géométrie (1637), ‘I hope that posterity will judge me kindly, not only as to the things which I have explained, but also to those which I have intentionally omitted so as to leave others the pleasure of discovery.' When teachers offer students the short-cut, it is often because the teacher is under pressure to cover the curriculum and believes that the student will understand quicker if given the algorithm or short-cut alongside multiple practice questions, often confusing students who cannot learn without first understanding.

• The use of assessment and feedback to support development of a growth mindset. Student data is shared with the individual student and student improvement data is shared with the class, the emphasis is on improvement above absolute score.

Conclusion

The Sunshine College Maths Program demonstrates that by providing students with various levels of tasks from which they can self-select the most appropriate for their learning within a culture that promotes students responsibility for their own learning, whilst fostering self-confidence and self-belief and where improvement is valued more highly than absolute scores, excellent learning outcomes can be achieved for every student.
References


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BASTOW EVENING EVENTS FROM ANYWHERE IN VICTORIA

Bastow is offering government schools and early childhood networks, outside the Melbourne metropolitan area, the opportunity to participate in our regular evening Twilight Seminars and Horizon Forums via Polycom or Lync.

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