CENTRE FOR STRATEGIC EDUCATION
Leading educational thinking and practice

Anchoring computational thinking in today's curriculum: The urgent priority of changing school maths

Conrad Wolfram, Adrian Smith and Alec Titterton

OCCASIONAL PAPER 152

Centre for Strategic Education (CSE) is the business name for IARTV ABN 33 004 055 556

152 SEPT 2017

ISSN 1838-8558 ISBN 978-1-925654-06-6

(*The Centre for Strategic Education (CSE) is the business name adopted in 2006 for the Incorporated Association of Registered Teachers of Victoria (IARTV). Therefore, publications which were previously published in the name of IARTV are now published in the name of CSE.)

Produced in Australia by Centre for Strategic Education
Mercer House, 82 Jolimont Street, East Melbourne VIC 3002

Editorial Team: Tony Mackay, Keith Redman,
Murray Cropley, Andrew Miller

Introduction

Recently there has been a lot of talk of 'Computational Thinking' as a new imperative of education, so we 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? In particular, does our mainstream technical school subject of today – maths – teach computational thinking? If it does, how accessible is computational thinking in other STEM subjects and more broadly across the curriculum? What about our own Computer-Based Maths (CBM) – is it a Computational Thinking curriculum?

In our definition, Computational Thinking is a mode of thinking about life, in which you apply a rigorous and repeatable problem-solving process to ideas, challenges and opportunities you encounter. Although the terminology is relatively new, we would argue that computational thinking approaches have been widespread and spectacularly successful across a range of science, technology and business problems in the real world. Because of this success, computational thinking is important for everyone in education; but school subjects today only teach it very partially and rarely explicitly. Maths could be the core computational thinking subject but is not hitting the mark. Should maths be the place where the foundations of computational thinking are built for application across the curriculum?

It is our view that, every country – including those at the top of the PISA results – needs to radically rethink and redesign the school subject of mainstream mathematics so it truly reflects today's real-world subject with its vitally important applications. This can only happen if we use computers in school as we do in the real world: to replace humans for calculating, not just to improve the pedagogy of the existing subject. In doing so, we are convinced we will see the lines blur between maths and computational thinking or indeed see them become one and the same subject.

There are many consequences of this new approach, from changing what is taught, to the application of mathematics in other curricular areas, the relationship to coding and indeed to the very notion of what school-level mathematics is and what it should be called. We have termed the new curriculum subject we are creating 'computer-based maths' and in this paper we discuss why it is a computational thinking curriculum. We also discuss the significant steps we have taken towards anchoring computational thinking across the curriculum.

we are convinced we will see the lines blur between maths and computational thinking or indeed see them become one and the same subject.

Urgent priority

Why is this such a high priority action for governments? It is so this most vital of subject areas can truly empower societies and individuals, rather than always failing to match up to real-world needs. Today's subject is a struggle for most students – even to understand why they would need mathematics, let alone how to apply it. Consequently they then fail to use maths in later life beyond a basic level, or to be empowered by it or use it to help to empower and enrich their societies. The few who do get through are quickly snapped up by employers, often outside their home country.

Inability at maths is of great concern to parents, teachers, employers – and ultimately policy-makers – because of its economic consequences. There are also implications for democracy itself, as quantitative arguments are increasingly mainstream. The political significance of the maths problem has been growing across the world as its consequences increasingly affect each country's success.

Yet most missions to improve maths focus on improved pedagogy of today's subject or a slightly evolved version of that subject; but however well we teach the hand-calculating subject, it increasingly cannot match up to the required computer-based, real-world subject that is needed. Instead, it is necessary to reject hand-calculating as the core of mathematics curricula across the world and replace it with a fundamentally different subject, of higher-level problem solving, using a computer to do most of the calculating. Or, to put it another way: build a new maths curriculum that assumes computers exist. This is the definition of our mission at Computerbasedmath.org (CBM) – uniquely running in the right direction to catch up with the real-world subject requirements.

Update on CBM

We are pleased to report that we have made very good progress in conceptualising and delivering such a curriculum. In this paper we discuss how our ideas have evolved over the past seven years, where there have been incremental or step-changes, and how the landscape has shifted around us. Here are some updates.

Since the initial development of the CBM concept, coding and computational thinking have come to the fore in education and, as discussed, fit very powerfully with our ambitions and progress. This moving landscape has in many ways reinforced and strengthened our mission.

We are confident that the overarching vision and concept of computer-based mathematics is more relevant and critical today than it was seven years ago and is very different from any country's traditional offering. This is so much so that our thinking on 'mathematics' has translated into the broader STEM agenda. We have found it necessary to redefine broader outcomes – broader than we see for any country's maths agenda – which underpin and drive what we see as the required, core, computer-based mathematics curriculum and link into new assessment.

Let us consider these areas briefly before focusing on their link into computational thinking.

Resistance to Change Despite Increasing Relevance of Computer-Based Mathematics

Around the world we still have many children sitting in classrooms bored and bemused by the process-based, hand-calculation subject that is traditional, educational mathematics (eg, Hattie et al, 2016). We still have universities and industry saying that students coming out of schools do not have the skills and problem-solving capabilities to equip them for life, work or further education (eg, Science and Technology Committee – *Second Report, Higher Education in Science, Technology, Engineering and Mathematics (STEM) subjects)*. We still have economies desperate for better quantitative skills, to help them compete in an ever more demanding global environment and the evidence that it works (eg Hanuschek and Wößmann, 2007 and PISA OECD, 2010)

There is another level of challenge too. Whether it is managing one's own health or the health of the planet as a whole, we need a new generation of quantitative problem solvers who understand and embrace much more complexity and messiness in using modelling, data science and other computation thinking approaches, to get good answers.

A switch to computer-based mathematics is the central educational step required to achieve this – and we are well advanced in working out how to achieve it. Hard though these curriculum, content, delivery and technology challenges have been and difficult though the remaining challenges are, today's biggest barrier to this shift is the stuck ecosystem of educational change: convincing governments, policymakers, educational institutions and teachers to make the shift. There are plenty who see the benefits, but some of the system barriers can be particularly obstructive even when there is major agreement that change is essential. (See blog post by Conrad Wolfram, www.conradwolfram.com/evidence-innovation)

We believe that chief amongst these is the adherence to calculation-based assessment – closed-ended, right-or-wrong exams for maths which do not match open-ended messier problems in real life and do not have computers available for calculating. This is particularly driven in most countries by 'point system' approaches to university entrance, based on assessments which lend themselves to drill-and-practice learning. These assessment linchpins drive behaviours in both children and parents to such an extent that the introduction of any fundamentally new content, particularly an open-ended problem-solving curriculum is exceptionally challenging. There are really two underlying reasons. First, assessments are so high-stakes that agreement of points scored and efficiency of marking often trump content being examined closely matching the real world. Second, across the assessment system, there's major inertia preventing content change, from perceived risks for ministers, through to wish for continuity for comparison between years. Sometimes, as in Estonia and Ireland, there is a government policy-level vision but even then, shifting assessments, particularly for university admissions, often is the key.

Here is an essential role for governments: fix the ecosystem of education so it promotes content innovation rather than stifles it, so that the critical but slower-to-manifest risks of not innovating are evident.

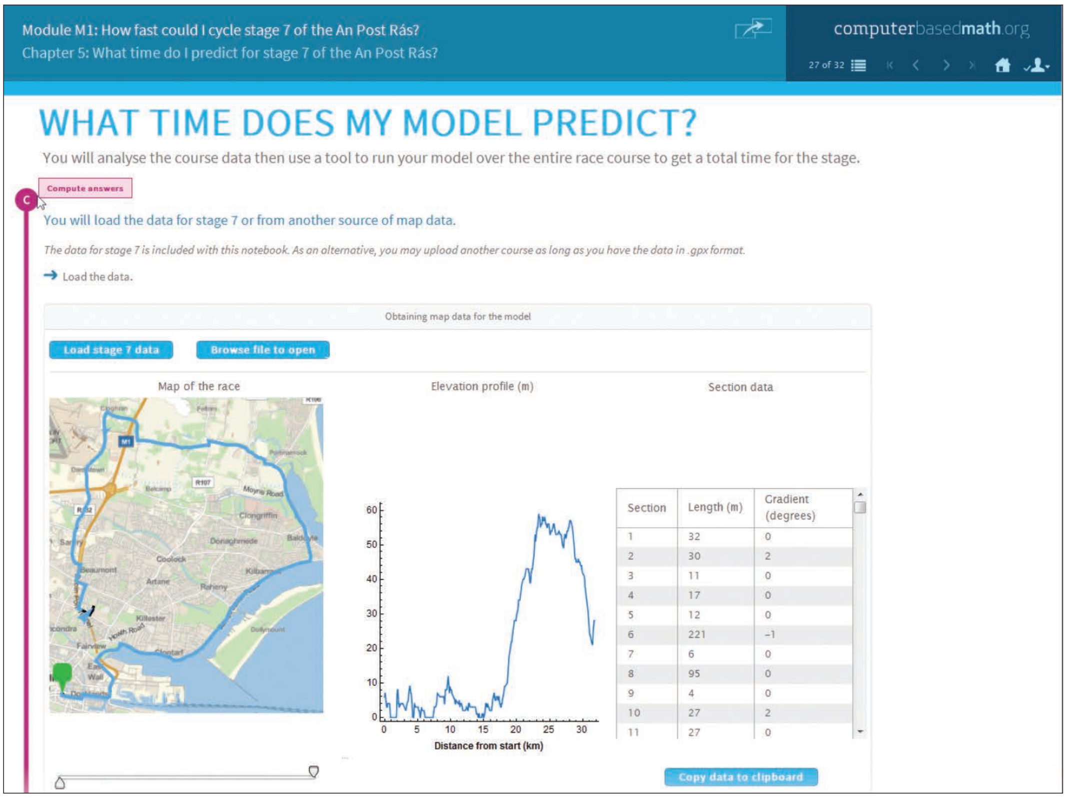
The broader STEM agenda

It has become increasingly obvious to us that computer-based, problem-centric approaches are key to all STEM subjects and potentially beyond. Why is this? It is because engaging and motivating students requires realistic, interesting problems and, across the STEM curriculum, these cannot be solved by hand.

As we have developed CBM content, the problems we have selected have been drawn from across the STEM curriculum. We have built our CBM materials around topics as diverse as how to win a bicycle race (see Figure 1), marketing the 'best' mobile phone, controlling a quadcopter, or deciding whether boys are better than girls at mathematics! Our aim has been to choose problems which will

- be as realistic as possible in terms of real problems they will actually face;
- motivate students to enjoy mathematics and want to learn more;
- build mathematical skills by introducing increasingly complex concepts, rather than increasingly complex processes and procedures;
- build an understanding of, and competence in using an iterative four-step problem-solving methodology that has broad applicability;
- give students as broad an experience as possible of today's mathematical tools (eg, machine learning);
- develop complementary coding skills;
- address a set of mathematics outcomes that is rather different from what has been seen in traditional mathematics education.

Figure 1. Illustration of sample CBM material



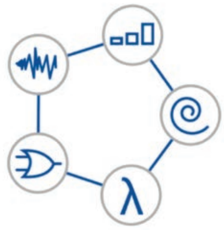
All of these skills and competences that we saw as at the heart of computer-based mathematics are at the heart of computer-based STEM. Moreover, it may well be that it is easier to introduce computer-based methodologies into other STEM studies than it is into mathematics, where there remains often staunch resistance to moving away from hand-calculation.

There is a related question around how we group topics in maths education. Traditional areas of mathematics like algebra, calculus or trigonometry do not seem a good way to think about subdividing the subject in the modern world and in a way which supports STEM education; but why subdivide at all? In a sense, you should not. The expert mathematician utilises whichever maths areas help solve the problem at hand. Breadth and ingenuity of application are often key.

Mathematics, however, represents a massive body of knowledge and expertise. Subdividing helps us to think about different areas, so curricula can focus energies enough that there is sufficient depth of experience gained by students, at a given time, to get a foothold.

However, the subdivisions should be grouped by modern uses of maths, not ancient divisions of tools. By this nature they are not mutually exclusive groups. They are as follows.

- Data Science (everything data, incorporating but expanding statistics and probability).
- Geometry (an ancient subject, but highly relevant today).
- Information Theory (everything to do with communication, whether datasets, images, sound or objects).
- Modelling (techniques for good application of maths for real-world problems).
- Architecture of Maths (understanding the coherence of maths that builds its power, closely related to coding).



CBM (Computer-Based Mathematics)/STEM outcomes

One of the key challenges we have faced is defining, clearly and explicitly, the educational outcomes that drive and complement our content.

In the mathematics domain we have been very clear that we are building a replacement curriculum and, as such, the traditional learning outcomes are as in need of replacement as much as the content.

At the outset we made comparisons of the sorts of topics we expected CBM to cover in comparison to traditional curricula; for example, see Table 1.

Table 1. Sample comparison of traditional and computer-based topics

Traditional – Mechanistic topics	Computer-based mathematics – Problem-centric
▪ Complete the square ▪ Invert a matrix ▪ Simplify a surd or recurring decimal ▪ Solve simultaneous equations ▪ Calculate angles in a triangle ▪ Use the chain rule	▪ Should I insure my laptop? ▪ How do I design controls for my game? ▪ How can I make a perfect login password? ▪ What makes a beautiful shape? ▪ How far can I compress photos, video or music before I notice? ▪ How many words do I know?

These problems were then mapped to an initial set of outcomes. We have now taken a step forward and relaunched the CBM outcomes. Now, not only have we mapped the required skills of problem solving as identifiable outcomes within our problem-solving cycle, we have begun to map out the primary contexts and areas of maths that are vital for computer-based mathematics students of the future to learn.

All new CBM materials are tethered more explicitly around the problem-solving cycle, with teacher modalities and student material clearly showing within which part of the problem-solving cycle the student is currently operating.

To see a full list of the required outcomes from a mainstream CBM curriculum, please visit www.computerbasedmath.org/outcomes.

Focus back on 'computational thinking'

It is worth reminding ourselves of the overriding purpose of education, which we believe is 'to enrich life' (yours, your society's, not just in 'riches' but in meaning). The different ways in which you can think about how you look at ideas, challenges and opportunities seem crucial to achieving that.

Therefore using a term of the form 'xxx Thinking' that cuts across boundaries but can support traditional school subjects (eg, History, English, Maths) and which emphasises an approach to thinking, is important to improving education. See Figure 2.

Figure 2. Cutting across boundaries, emphasising an approach to thinking

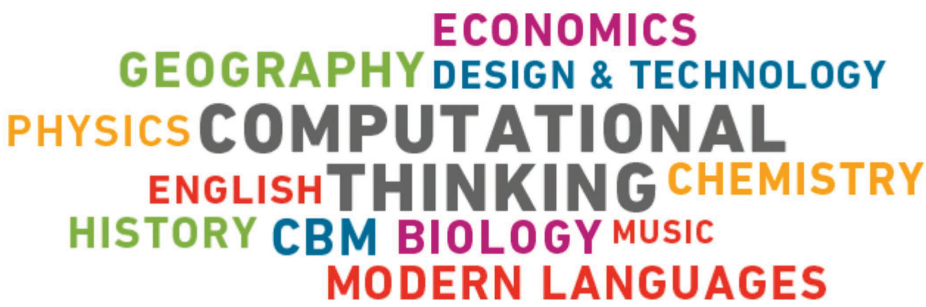
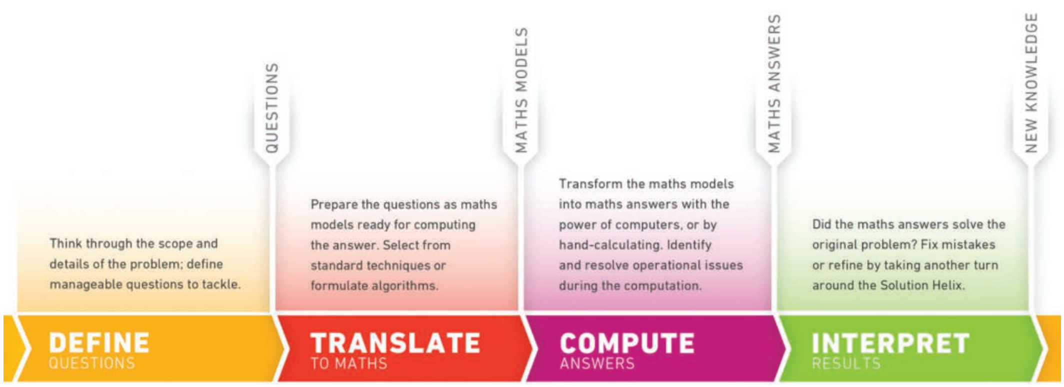


Figure 3. The 4-step problem-solving process



Now, we have had widespread use of the term 'Critical Thinking' for some time, but it seems to have 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, we would argue that Computational Thinking is a mode of thinking about life in which you creatively and cleverly apply a 4-step problem-solving process to ideas, challenges and opportunities you encounter, to make progress with them.

See Figure 3 to see how it works.

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

However, 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 have turned the question into a form ready for this high fidelity machinery to do its work. Another purpose of step 2 is in forcing a more precise definition of the question. In many cases this abstraction step is the most demanding of high conceptual understanding, creativity, experience and insight.

After abstraction comes the **computation** itself – step 3 – where the question is transformed into an abstract answer – usually by a 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.

> *Modern technology has dramatically shifted the effective process because you don't get stuck on [the Computational Thinking] helix roadway at step 3, so you may as well zoom up more turns of the track faster.*[1]

It is helpful to represent this iteration as ascending a helix made up of a roadway of the 4 steps, repeating in sequence until you can declare success.

Whilst emphasising the process end of computational thinking, its power of 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

This process of Computational Thinking (illustrated in Figure 4) is connected with mathematics – or it may even be one and the same subject; and what about coding? This is where the very heavy overlap with our Computer-Based Maths approach occurs much more so than with today's traditional maths education; coding is an important element, in particular as the way in which you manifest abstraction.

Real-world maths – defining it and its applications broadly – absolutely relies on Computational Thinking but there are also specific areas of knowledge that maths is considered to contain (eg, particular concepts and algorithms), and which are often important for 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 them.

Computational Thinking is a mode of thinking about life in which you apply a 4-step problem-solving process to ideas, challenges and opportunities you encounter

Even in the real world, this broad definition of the term 'mathematics' may be alien to engineers or scientists, who would consider what is being described simply as part of engineering or science respectively.

The magic is in optimising how process, computer and human can be put together to solve increasingly tough problems.

Figure 4. Computational Thinking helix

Figure 5. Following the process 'track'

There is 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 4 steps of the helix.

Before modern computers, step 3 – computation – was very expensive, because it had to be done by hand. Therefore, in real life, you would 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, more often than not, you might have a much more scientific or experimental approach, with a looser initial question for step 1 (such as 'can I find something interesting in this data'), an abstraction in step 2 to a multiplicity of computations (such as 'let me try plotting correlation of all the pairs of data'), because computation of step 3 is so cheap and effective you can try it lots and not worry if there is 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. (See Figure 5.)

> *[Applying the Computational Thinking process] might take just a minute for a simple estimation or a whole lifetime for a scientific discovery.*

A useful analogy is the change that digital photography has brought. Taking photos on film was relatively costly (though cheap compared with chemical-coated glass plates it replaced). You didn't want to waste film, so you would be more meticulous in setting up the shot before you took it. Now you may as well take the photo; it is cheap. That does not mean you should not be careful to set it up (abstract) 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 this has not always replaced the original approach.

> *Real-world mathematics absolutely relies on Computational Thinking.*

Back to mathematics. However we term the real-world need, whether as computer-based maths or computational thinking, what is sadly all too clear is how today's mainstream educational subject in this space of 'maths' is not meeting the need. Its focus on teaching how to do step 3 by hand might have made sense when that was the sticking point in applying maths in life: because if you could not do the calculating, you could not use maths or, in general, computational thinking. Conversely, primarily gaining experience in a very deliberate, meticulous, uncontextualised, pre-computer application of the computational process – rather than a faster-paced, computer-based, experimental, scientific-style use on real problems – cannot continue to be maths' primary purpose if the subject is to remain mainstream. Instead, its primary purpose ought to be Computational Thinking – as it is in our CBM manifestation.

Our aim is to build the anchor Computational Thinking school subject as we explicitly broaden CBM beyond being based in maths.

Like real-world maths, coding likewise relies on Computational Thinking but again is not the same subject or (by most definitions) anything like a complete route to it. You need Computational Thinking for figuring out how to extract 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 is the expertise needed for being the sophisticated manager of your computing technology, which 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 is a way of thinking – not the only way of thinking – but an important perspective across life. Whether in design (*'How can I design a streamlined cycle helmet?'*) or history (*'What was the key message each 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.

The Computational Thinking approach needs knowledge of what's possible, experience of how you can apply it, and know-how of today's machinery for performing it.

the Computational Thinking approach needs knowledge of what is possible, experience of how you can apply it, and know-how of today's machinery for performing it.

An important practical question is whether that can happen without a core educational subject of the learning of Computational Thinking itself? This is probably not possible, not at school levels anyway. That is because the Computational Thinking approach needs knowledge of what is possible, experience of how you can apply it, and know-how of today's machinery for performing it. You need to know which concepts and tools there are to translate and abstract to in step 2. We do not think you can only learn this in 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.

1. Introduce a new core subject.
2. Transform an existing one.

Either is a major undertaking, with coding and maths as the only possible 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 and with far less time or money, but with a zeal to go 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 – it is one that's principally around maths but applied to problems and projects from all subjects; one that we have ready for delivery.

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, being seen to be based only in maths. Look out for modules of CBM geography and CBM history!

Make no mistake. Whatever the politics or naming, whoever 'wins' or 'loses' – someday, a core, ubiquitous school subject will emerge in the space we are describing. The first countries, regions, schools and politicians that manage this new core and its cross-curricular application will be major winners.

Endnote

1. All quotations presented in this paper are drawn from Wolfram, www.conradwolfram.com/home/anchoring-computational-thinking-in-todays-curriculum.

References

Hattie, J A, Fisher, D B, Frey, N, Gojak, L N and Moore S D (2016) *Visible Learning for Mathematics, Grades K–12: What Works Best to Optimize Student Learning*, Corwin Mathematics Series, Sage Publications, Thousand Oaks, CA.

Select Committee on Science and Technology (2012) *2nd Report of Session 2012–13. Higher Education in Science, Technology, Engineering and Mathematics (STEM) Subjects*, House of Lords Select Committee, Stationery Office, London. publications.parliament.uk/pa/ld201213/ldselect/ldsctech/37/37.pdf.

Hanushek, E A and and Wößmann, L (2007) *The role of education quality in economic growth*, Policy Research Working Paper 4122, World Bank, elibrary.worldbank.org/doi/abs/10.1596/1813-9450-4122.

OECD (2010) *The High Cost of Low Educational Performance*, Programme for International Student Assessment (PISA), OECD, Paris. www.oecd.org/pisa/44417824.pdf.

CSE/IARTV PUBLICATIONS

Recent titles in the CSE Occasional Papers Series

No. 152 *Anchoring computational thinking in today's curriculum: The urgent priority of changing school maths* by Conrad Wolfram, Adrian Smith and Alec Titterton (September 2017)

No. 151 *What value does Australia place on its schools?* by Brian J Caldwell (July 2017)

No. 150 *Professional conversations in schools: A snapshot of Australian practice* by Peter Cole, Graeme Jane and Dahle Suggett (April 2017)

No. 149 *Changing the 'what' of education: Overcoming systemic inertia* by Charles Fadel and Maya Bialik (February 2017)

No. 148 *Professional conversations through a coaching lens* by Kristine Needham (November 2016)

No. 147 *Agile implementation for learning: How adopting an agile mindset can help leaders achieve meaningful progress in student learning* by Simon Breakspear (September 2016)

No. 146 *System performance uncovered: Why some education systems are better than others* by Alma Harris and Michelle Jones (July 2016)

No. 145 *We need to talk about change: No prescription without diagnosis* by Vic Zbar (April 2016)

No. 144 *Personalisation and globalisation: Three paradoxes facing educators* by Valerie Hannon (February 2016)

No. 143 *Why are we waiting? Education research and the lethargy of change* by Tim Patston (November 2015)

No. 142 *Leading change, changing leadership (Part 2). System change moving to the next level of performance – incorporating two case studies* by Patricia Collarbone (September 2015)

No. 141 *The rhetoric and reality of evidence-based practice and teaching reading: How to bridge the curriculum gap* by Jonathan Solity (July 2015)

No. 140 *Enhancing teaching and learning through enquiry-based collaborative R&D* by Louise Stoll (May 2015)

No. 139 *Big data in education: A guide for educators* by Mike Timms (February 2015)

No. 138 *The future of the teaching profession: A new scenario set* by David Istance and Anthony Mackay (November 2014)

No. 137 *The formative evaluation of teaching performance* by Dylan Wiliam (September 2014)

No. 136 *Meeting the challenge of 21st Century schooling* by Vic Zbar (July 2014)

No. 135 *Assessment: Getting to the essence* by Geoff N Masters (April 2014)

No. 134 *Education with a Capital E™* By Charles Fadel (February 2014)

No. 133 *Our Chosen Future: One school's learning reform blueprint* by Elisabeth Lenders and Liam King (November 2013)

No. 132 *Generating whole-school improvement: The stages of sustained success* by Vic Zbar (September 2013)

No. 131 *An 'Intercultural understanding' view of the Asia priority: Implications for the Australian Curriculum* by Eeqbal Hassim (July 2013)

Other publications

Leading the education debate Volume 4: Selected papers from the CSE's Seminar Series and Occasional Papers, 2011–2014. Editors Vic Zbar and Tony Mackay.

The Centre for Strategic Education has consolidated a selection of the best of its ground-breaking series of seminar papers from the last four years of cutting-edge contributions to educational discourse into its publication *Leading the education debate Vol 4*.

This collection includes some of the most recognised authors in education including Yong Zhao, Charles Leadbeater, Valerie Hannon, Charles Fadel, Paul Clarke, David Istance, Anthony Mackay, Nelson R González, Helen Timperley, Linda Kaser and Judy Halbert, Michael Fullan, David Hopkins, Brian J Caldwell and Jim M Spinks, Patricia Collarbone, Pamela Macklin, Graham Marshall, Vic Zbar, Dylan Wiliam, Peter Cole, Geoff Masters and Kathe Kirby with Dahle Suggett.

The 20 papers included in the publication constitute a major contribution to discussion on school improvement and reform, written in a clear and accessible way.

Volumes 1–3 of *Leading the education debate* by the same authors, collections of similar cutting edge papers from earlier CSE papers, are also available from CSE.

A complete back catalogue of the CSE/IARTV Seminar and Occasional Paper Series, subscription rates to both of these series and more detailed information on any of the publications listed are available on the Centre for Strategic Education's website www.cse.edu.au. Alternatively contact Centre for Strategic Education, phone (+61 3) 9654 1200, fax (+61 3) 9650 5396, email office@cse.edu.au.

L–R: Conrad Wolfram, Adrian Smith, Alec Titterton

About the Authors

Conrad Wolfram, physicist, mathematician and technologist, is Strategic Director and European Co-Founder/CEO of the Wolfram group of companies. He founded computerbasedmath.org (CBM) to rethink and rebuild fundamentally the mainstream maths education curriculum, to introduce computational thinking and to combine with coding, now computers can be assumed.

Adrian Smith is Business Development Manager for the CBM initiative. He is passionate about maths education. As well as having a strong digital learning background, he spent four years as a lecturer in the Department of Mathematics at Cranfield University. He has also worked in industries where maths is crucial, most notably as Chief Executive of one of the UK's leading Space software companies.

Alec Titterton left teaching in 2007 to work for the Specialist Schools and Academies Trust in the UK, as national coordinator for Mathematics and Computing specialist schools. He now heads up content development for Wolfram's CBM initiative. He has been instrumental in creating a transformational computer-based maths deployment solution that enables students to learn to model and solve real-life messy problems in the STEM field.

About the paper

The authors define Computational Thinking as a mode of thinking about life, in which you apply a rigorous and repeatable problem-solving process to ideas, challenges and opportunities that you encounter. They explain how this process should be applicable to a wide range of subject areas, extending well beyond mathematics in the current curriculum context. After all, it is a way of thinking – not the only way of thinking – but an important perspective across life. Whatever the politics or naming, they conclude, a core, ubiquitous school subject will emerge in the space they describe, and the first countries, regions, schools that manage this new core and its cross-curricular application 'will win big time'.

Papers in this CSE/IARTV series are intended to encourage discussion of major issues in education. Views expressed by the authors do not necessarily represent views of the Centre for Strategic Education. Comments on papers are most welcome.

The Centre for Strategic Education (CSE) is the business name adopted in 2006 for the Incorporated Association of Registered Teachers of Victoria (IARTV). Therefore, publications which were previously published in the name of IARTV are now published in the name of CSE.

The constituent bodies of CSE/IARTV are the Association of Heads of Independent Schools of Australia (Vic) and the Victorian Independent Education Union.

Mercer House 82 Jolimont Street
East Melbourne Victoria 3002
Phone +61 3 9654 1200
Fax +61 3 9650 5396
Email info@cse.edu.au

www.cse.edu.au

CSE CENTRE FOR STRATEGIC EDUCATION
Leading educational thinking and practice

ISSN 1838-8566 ISBN 978-1-925654-06-6