Code to joy

For years ICT was a neglected and low-status subject in schools. But now computing education is undergoing an astonishing transformation – and England is in the vanguard. The world is watching, writes Simon Peyton Jones

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We stand on the brink of a major revolution in our children's computing education. Not all revolutions are for the better, but this one is. In England, the school subject "ICT" has been re-titled "Computing" and, for the first time anywhere in the world, it contains a substantial strand of computer science and programming, starting at primary school. It is a change pregnant with opportunity and risk, and the rest of the world is watching us with intense interest.

But why do we need a revolution? How did we go wrong before?

The story starts in the early 1980s, the era of the BBC Micro, which single-handedly moved the microprocessor-based personal computer from the hobbyist's bench to the kitchen table and the school classroom. These early micros had fairly primitive software, and the chips themselves (microprocessor, memory chips, and so on) were barely hidden. All you could do was program them, in a language called Basic; kids thought it was fun to run into WH Smiths, type "10 PRINT "rude word"; 20 GOTO 10" and run out again.

Then came the IBM PC, and suddenly personal computers were useful, as well as fun. They were also more opaque, less programmable, and the office productivity software became the killer app. Employers started to demand basic IT skills, and schools responded. Vanishingly few students had a PC at home, so teaching children how to use them purposefully made a lot of sense. So when the first National Curriculum was launched in 1990 it included "IT Capability"; in 1996 it was called "Information Technology" as part of Design Technology; and in 2000 it became its own distinct subject, ICT. These were progressive ideas at the time; even today, many countries have no statutory provision at primary level for any form of computing.

But things change fast. By 2005 it had become clear that ICT was failing our children. By then, many students had computers at home and arrived at school already proficient with technology. Proficiency does not always imply understanding, but teaching them elementary software skills (which was what happened in too many schools) became counterproductive because it taught students things they felt they knew. ICT qualifications proliferated and, for understandable reasons, were heavily focused on coursework, which sometimes could be repeatedly resubmitted. League-table pressure then led schools to sweep large numbers of students into ICT, where they could get a good grade despite weak motivation. School leaders perceived ICT as a useful but easy subject, one that could be taught by a geography teacher with a spare period, something they would never do with science. ICT never became established as a high-status subject in its own right; it was often conflated with using technology to enhance learning across the curriculum, or even with the school's management information systems.

None of this was the fault of ICT teachers themselves, but all of it was deeply demoralising for them.

Students voted with their feet. The number of students taking A level Computing, a proxy for the level of engagement of students once they started to exercise subject choice, fell every year, halving over 2001-9 despite a low initial base of 10,000. (Maths has 80,000 entries.) Universities admissions tutors ignored ICT qualifications altogether; they were not mentioned in the Russell Group's influential "Informed Choices" guide. A succession of national reports in the late 2000's criticised the status quo, including Ofsted's 2009 report "The importance of ICT", which said "*Too many of the lessons seen during the survey emphasised the development of skills in using specific software at the expense of improving students' ICT capability*".

So much for symptoms. What of causes? At school we teach our children enduring, foundational subject disciplines, like maths, natural science, history, English, and the like. These subject disciplines have a body of knowledge, principles, methods, and ideas that equip our children to make sense of the world around them. Building on these disciplines we also teach our children some useful, immediately applicable skills: how to make an articulate presentation, play a musical instrument, make a dress, read a map, or ride a bicycle safely. What had happened in ICT is that we had unconsciously come to focus on the applicable skills (which are indeed useful) but had lost sight of the underlying subject discipline, namely computer science. Indeed this emphasis was implicit in the very title of the subject, Information and Communication *Technology*.

Motivated by this analysis, the Computing at School working group (CAS) was launched in 2007, as a grass-roots organisation with the single aim of establish computer science as a foundational subject that every child has the opportunity to learn, just like maths or science, from primary school onwards. This was, and remains, a radical change of perspective; after all, to most people computer science is a geeky university-level vocational subject that allows socially-challenged males to get a good job. CAS's goal was not to abandon ICT, much of which was good, but to re-envision it as part of a substantial subject discipline, one motivated primarily by ideas rather than by technology. Subject disciplines underpin an education that will last a lifetime, because they articulate principles and insights that survive successive waves of technology. Arthur C Clarke famously remarked that any form of sufficiently advanced technology is indistinguishable from magic. It is deeply damaging if our children come to believe that their sleek computers are essentially magic: powerful, but under someone else's control. We want them to create as well as consume, to understand as well as to use. This may be idealistic, but is also realistic. As Douglas Rushkoff put it, the choice is simple: program or be programmed.

By 2011 things were starting to move fast. There was an ongoing review of the entire National Curriculum, started by Michael Gove. The NextGen Skills report in 2011 made the case for computer science in the school curriculum alongside broader issues, and a year later the Royal Society's influential report "Shut down or restart: the way forward for computing in schools" focused exclusively on computing. Until 2009 there were no GCSEs in computer science, but by 2013 all the exam boards had announced one, and Mr Gove made computer science part of the English Baccalaureate. CAS grew explosively; it now has more than 16,000 members. Finally, in the summer of 2012 the DfE invited a working group hosted by the Royal Academy of Engineering and BCS, The Chartered Institute for IT, to draft the new Programmes of Study (POS) for Computing. This working group had broad representation across the community, including eSkills, Naace, ITTE, NextGen, and practicing school teachers. The result (after further editing by the Department for Education) is the 3-page programmes of study that launched in September 2014.

So what does computer science as a school subject look like? To read the press, you would think that the main purpose of the new curriculum is to give our children coding skills that will equip them for the jobs of the future. Make no mistake, if the new computing curriculum is delivered well, it will make a material contribution to the future knowledge economy. But to make the equation computer science = coding is like saying natural science = labwork. Practical work in a lab is fundamental to the science curriculum, but it would be stupid to put children in a lab with ball bearings and stopwatches and hope they would discover Newton's laws of motion. Rather we teach principles, and bring it to life with labwork. So with computing. If the new curriculum ends up being little more than programming, we will have failed.

If not coding, then what? Computing is about information and computation, about data and algorithms. Take something like web search. When you type in a query, the search engine has to find relevant pages, and put them in priority order. Simply finding the relevant pages is an astonishing feat, given the sheer size of the Web. Putting them in order is hard too: which ones should be near the top? Google's famous page-rank algorithm (which, incidentally, launched the company) works by treating pages as more important if lots of other pages point to them. Search algorithms, ranking algorithms, and the like, can all be explored without using a computer at all, using pencil and paper, cups, balloons, and games with simple rules. If you doubt this, take a look at csunplugged.org, one of the most creative contributions to computer science pedagogy of the last two decades.

But even if computer science is a foundational discipline, should *every* child learn it? We don't teach law at primary school! But we do teach science; why? Because it equips children to act as well-informed, empowered citizens in a complex world. And we believe that is so important that we teach it to every child including the majority who will not become professional scientists. So with computer science: an elementary understanding of computer science equips you to make informed choices in the digital world, and this is important not only for the minority who will become the software engineers of the future, but also those who will become plumbers or lawyers or salespeople. Moreover, computing develops a child's capacity to think in distinctive new ways, known as computational thinking. As Seymour Papert, the father of Logo, wrote: *"The child programs the computer. And in teaching the computer how to think, children embark on an exploration about how they themselves think. The experience can be heady: thinking about thinking turns the child into an epistemologist, an experience not even shared by most adults."*

Several things are worth noting about the new curriculum, too. First, while the new POS has a clear strand of computer science, it by no means abandons the creative skills nurtured by the previous ICT curriculum. Quite the opposite: of the four aims of the POS, two explicitly concern the purposeful use and application of technology. The POS is careful not to say “this is CS and this is ICT”; the two are symbiotic and it would be a pity to treat them in silos.

Second, much current teaching is absolutely in line with the new POS. Primary schools have been using floor turtles and Bee-Bots for years; many have enthusiastically adopted the visual programming languages Scratch and Kodu. But we now see these activities in a new light: they are not primarily to gain programming skills, or even to have fun (though fun they are), rather they illustrate and bring to life the principles of information and computation that make up computer science.

Third, technology-enhanced learning (TEL), which is the use of technology to support teaching and learning in every subject, can and should be transformational, but it is not part of the Computing curriculum, nor is it the responsibility of the Computing teacher. It is a whole-school issue. For example, the school where I am a governor has recently introduced 1-1 tablets for each child; but the project is run entirely separately from the computing department.

All that said, no other country in the world specifies that every child should be able “understand and apply the fundamental principles and concepts of computer science”, from primary school onwards. Even if it is the right thing to do in principle, it is a wrenching change, which amounts to establishing an entirely new school subject from scratch. Can our teachers do it? Have we done enough, or have we done too much? Will the rocket blow up on take-off?

My overwhelming impression is that teachers feel that the direction of travel is right; that they are eager to develop their practice; but that they often feel under-qualified and hence are at least anxious and sometimes terrified. After all, we are asking them to do something that they have never been asked to do before. In the past the DfE would have stepped in with a major teacher training programme. But not this time. So our task is this: to encourage, support, equip and train our existing ICT teachers to deliver the new POS with confidence and enthusiasm. By “our” task, I mean the entire professional community: teachers, universities, IT professionals, software developers, publishers, training organisations, and so on. Although the term is now out of fashion, it’s a big-society thing. CAS is part of that effort, running CPD programmes like QuickStart Computing, the Network of Teaching Excellence in Computer Science, and Barefoot Computing.

The result is and will be, of course, anarchic and patchy: some CPD courses are better than others; some areas are better served than others. But it is also diverse, creative, and innovative.

Although the new curriculum is, I believe, a hugely positive step, there are still big questions. What is the trade-off between big centrally managed training programmes and anarchic decentralised ones? Other subjects have centuries of experience of teaching (say) maths to school children; there is a crying need for careful research, as well as innovative practice, in the pedagogy of computer science. And how should computing best be assessed? Good assessment drives learning; bad assessment actively impedes it.

This is not a one-day wonder. We have set our feet to the beginning of a ten-year journey, at the end of which my daughter, who started Reception this September, will start her GCSEs. The journey will require sustained attention (including funding) from the Department for Education, from Ofsted, from the awarding bodies, from school leaders, and from the professional community.

The rest of the world is watching us with intense interest. In the last year speakers from CAS have been invited to national meetings in Denmark, Germany, the Netherlands, South Korea, Japan, Slovenia, and more. In October, in presenting the Informatics Europe Best Practice Award to CAS, Carlo Ghezzi said *“The UK is now, in effect, establishing computing as a brand-new school subject,* *from primary school onwards...This is a huge step in the right direction.... The rest of Europe is watching with great interest".*

I want my daughter to be excited by the ideas of computing, as well as engaged with its technology. I want her to feel in control of it, rather than a powerless servant of a computer system. I want her to experience the creative joy of making a computer do things that no one has ever made it do before. I want her to look at the natural world, and see information and computation everywhere. And, yes, I want her to have a job. We are now travelling in the right direction, but we have a lot of work to do.