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BCS, The Chartered Institute for IT

in association with the Computing At School group

Consultation Response to:

National Curriculum Review - Call for Evidence

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BCS, The Chartered Institute for IT

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Computing At School

Computing At School" (CAS) is a membership association in partnership with BCS, The Chartered Institute for IT. Its membership includes teachers from over 350 schools, as well as university academics, GCSE and A-Level examiners, educational consultants, and representatives of industry and professional societies. CAS was born out of excitement with the discipline of Computing, combined with a serious concern that many students are being 'turned off' Computing by a combination of factors that have conspired to make the subject seem dull and pedestrian. Their goal is to put the thrill and intellectual rigour back into Computing at school. CAS is non-partisan, but has institutional support from Microsoft, Google, and the Council of Heads and Professors of Computer Science.

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Read this first

The contents of this document formed the BCS response to the Department for Education's National Curriculum review. BCS wishes to endorse the views of E4E, the Royal Society and NESTA in their responses to the review, with whom we have consulted during the preparation of our response.

Our response is guided by the following fundamental principle of Computing and ICT Education in Schools. Schools must educate our children so that by the time they become adults they are capable of making intelligent and informed choices about the digital technology that underpins their world and they are capable of making valuable contributions to our digital society and economy. The purpose of ICT and Computing in schools is to equip every child with the basic understanding of computers and with the IT capabilities necessary to take their proper place in a digitally enabled, knowledge based society and economy.

Acknowledgements

Many people and groups have been of assistance in supporting our response. Without them this response would not have been possible. BCS would particularly like to acknowledge the following people for providing significant input: Simon Peyton Jones (Microsoft Cambridge), John Woollard (School of Education, University of Southampton), Bill Mitchell (BCS Academy of Computing), Simon Humphreys (BCS Coordinator for CAS), Steve Hunt (University of Hertfordshire), Jeremy Barlow (BCS) and the many other working members of CAS who were part of the debate and shaped the overall thinking behind this response.

Executive summary

The National Curriculum review should modernise the entire ICT curriculum by re-establishing Computing as a distinct subject discipline. Currently a great many schools focus on teaching digital literacy, and very few teach the underpinning principles, concepts and methods that describe the essential knowledge in Computing that all pupils should encounter.

- **Computing should be recognised as a rigorous, knowledge-based subject discipline,** as important to the modern citizen as traditional science, history or modern languages. An education in Computing provides unique thinking skills, encourages the creativity and innovation that drive hi-tech industry and commerce, and equips citizens to understand, and contribute to, an increasingly digital society. An increasing supply of Computing professionals and graduates is crucial for the economic health and security of our nation.
- **Computing is so important, both educationally and economically, that it should be part of the National Curriculum**:
    - *Every student should have the opportunity to learn Computing throughout their education (from Key Stage 1 onwards),* and should have the opportunity to specialise in Computing (by way of GCSEs and A levels) at Key Stage 4 and post-16.
    - *Computing should be one of the subjects that count towards the English Baccalaureate.* The goal of the E-Bacc is to increase the emphasis on core subject knowledge and rigour. Computing does just that.
- **A clear policy distinction should be made between the discipline of Computing on the one hand, and digital literacy on the other**. Like the literacy of reading and writing and mathematical numeracy, basic digital literacy — such as the ability to use office applications confidently, to safely browse the internet, or to efficiently use a search engine — is vital to every student. However, digital literacy should not be confused with the rigorous subject discipline of Computing, any more than numeracy should be confused with Mathematics. The current ICT curriculum includes both digital literacy and (a small amount of) Computing, but in practice, it is focused on the former, particularly at Key Stage 3 and 4. The confusion created by a single label damages both digital literacy and Computing.
    - *Digital literacy should be included in the curriculum, but could be delivered by embedding it across the curriculum* if that is accompanied by additional CPD for all subject teachers and support from specialists. In addition, pupils digital literacy ability should then also be measured through a qualification that demonstrates they have obtained the necessary capabilities required for study across the curriculum.

There is widespread agreement[1] that our young people find ICT in its current form to be dull and de-motivating[2,3], that it does not satisfy employers[4,5,6], and that it is a major source of concern to Ofsted[7], to universities[8], and to professional bodies[9].

The National Curriculum Review is a once-in-a-generation opportunity to set a new course for our nation's education in this crucial area.

The way to tackle this challenge is to radically re-focus the ICT curriculum on the discipline of Computing, giving both a real improvement in the education we offer to our children, and substantial economic benefits to the UK. To make this proposal concrete, we offer a model Curriculum for Computing, prepared by the Computing at School Working Group, and available here:

http://www.computingatschool.org.uk/data/uploads/ComputingCurric.pdf.

1. Computing should be recognised as a distinct subject discipline in school

Computing[a] is the study of the principles and practices that underpin an understanding of computation, and of its application in the design and development of computer systems. Computing provides insights into a broad range of systems — not only ones that include computers — and computational thinking influences fields such as biology, chemistry, linguistics, psychology, economics and statistics. Computing allows pupils to solve problems, design systems, and understand the power and limits of human and machine intelligence. Pupils who can think computationally are better able to conceptualise and understand computer-based technology, and so are better equipped to function in modern society.

Computing is also a practical subject, where innovation and resourcefulness are encouraged. Pupils must apply underlying principles in order to understand real-world systems, and to create purposeful artefacts for themselves. This combination of principles, practice, and invention makes it an intensely creative subject, suffused with excitement, both visceral ("it works!") and intellectual ("that is so beautiful").

1.1 Computing is a discipline

Education enhances pupils' lives as well as their life skills. It prepares young people for a world that does not yet exist, involving technologies that have not yet been invented, and that will present technical and ethical challenges of which we are not yet aware.

To do this, education aspires primarily to teach *disciplines* with long-term value, rather than *skills* with immediate application. A "discipline" is characterised by:

- **A body of knowledge**, including widely applicable ideas and concepts, and a theoretical framework into which these ideas and concepts fit.
- **A set of rigorous techniques and methods** that may be applied in the solution of problems, and in the advancement of knowledge.
- **A way of thinking and working** that provides a perspective on the world that is distinct from other disciplines.
- **Longevity**: a discipline does not "date" quickly. Although the subject advances, the underlying concepts and processes remain relevant and enlightening.
- **Independence from specific technologies**, especially those that have a short shelf-life.

Computing is a discipline with all of these characteristics. It encompasses foundational principles (such as the theory of computation) and widely applicable ideas and concepts (such as

[a] We use the term "Computing" because that is the term used by UK teachers. A university lecturer would use the term "Computer Science".

the use of relational models to capture structure in data). It incorporates techniques and methods for solving problems and advancing knowledge (such as abstraction and logical reasoning), and a distinct way of thinking (computational thinking) and working that sets it apart from other disciplines. It has longevity (most of the ideas and concepts that were current 50 or more years ago are still applicable today), and every core principle can be taught or illustrated without relying on the use of a specific technology.

Not only is Computing a discipline in its own right, it embodies essential knowledge that is distinct from any other subject discipline, as E4E point out in their response:

- General scientific, engineering, mathematical and business principles, concepts and methods can be encoded in formal languages that a human can understand and a digital computer can execute automatically
- The rigorous design and automation of different kinds of machine executable languages is unique to Computing; in particular designing and building languages capable of describing elegant, efficient solutions to hard real-world problems that affect our societal wellbeing as well as our future economic prosperity

1.2 Computational thinking is transforming all aspects of our society

Many subjects teach problem-solving skills to some degree, but Computing develops a particularly systematic and deep approach to thinking about complex problems, often called "computational thinking[10]". Computational thinking is the process of *recognising* aspects of computation in the world that surrounds us, and *applying* tools and techniques from Computing to understand and reason about both natural and artificial systems and processes. Pupils learn to think about the same problem at many levels of abstraction, and to recognise that a single solution may apply to many other apparently different problems.

More profoundly, thinking about other disciplines through a computational lens has radically changed the way those subjects are studied, whether physics or biology, psychology or economics. For example, viewing biological processes as computational systems that process information has led to fundamental new insights in understanding disease that would not have been obtained through traditional thinking. Computational thinking has, indeed, led to whole new disciplines such as bioinformatics, and all scientists now need a core understanding of this kind of thinking.

Computational thinking is made concrete in programming. Programming takes computational thinking skills and empowers pupils to take charge of computers and create new software of their own, rather than simply to consume things made by others. This ability unleashes enormous creativity, drives innovation, and opens up completely new horizons and possibilities. (To get some sense of this diversity, look at the Greenfoot Gallery[11] or the Scratch Project gallery[12].) To take an analogy, every child should understand algebra, be capable of abstracting appropriate problems into algebraic expressions, and be able to solve simple algebraic equations. In the same way, every child should be able to construct elementary algorithms in programmatic form that encapsulate simple ideas and concepts. Programming is a way of expressing creativity, of communicating and sharing ideas, just as mathematics does in a different area of discourse.

1.3 Computing education is important for the future of our economy

The digital revolution is gathering pace, not slowing down. It is a vital contributor to economic growth. According to the Royal Society[13] *"The 'digital revolution' over the past two decades has fundamentally changed the way many services are delivered and consumed (through the enablement of disruptive business models), as well as the internal processes of firms themselves. Computing, communications, IT, the internet, the worldwide web, massive distributed databases, large scale computer modelling and deep numerate analysis are fundamental STEM underpinnings to many areas of service innovation."* The service sector accounts for around 80% of the UK economy. Hence, future IT professionals need an understanding of the underpinning principles of Computing, and the UK needs a plentiful supply of these professionals for our future prosperity.

New disruptive digital business models have led to an e-commerce market in the UK of over £100bn in 2010[14]. The same digital revolution also means that online attacks are constantly developing in sophistication and severity. The Cabinet Office estimates[15] that cyber attacks cost the UK economy £27bn per year, and this figure is growing rapidly. If we expect to continue to be part of this digital revolution and to protect ourselves adequately in future, the UK will need more professionals with a Computing background than ever before.

Many have the mistaken belief that all IT jobs in the UK are being outsourced to China and India. This is false. While approximately 3% of low level IT jobs are outsourced each year, around the same number of higher level, more technically demanding IT jobs are created each year. According to the OECD[16], in 2009 slightly more than 28% of all jobs in the UK economy were IT intensive jobs. Of all OECD states, only Luxemburg has a higher proportion. What is more, the IT workforce is predicted to grow at four times the rate of the overall UK workforce[17]. According to the sector skills council for IT[18], *"Despite weaknesses in the UK economy, demand for IT & Telecoms professionals in the UK rose in each of the four quarters up to and including Q2.10 at which point there were estimated to be around 94,000 advertised positions in the UK, 75,000 of which were for permanent professionals and 18,000 for contractors."* Even in a recession, there is a continually increasing demand for IT and telecommunications professionals.

Given the strong demand, what of the supply, and what of the quality?

According to the annual CBI skills survey the percentage of UK employers dissatisfied with basic IT skills in their workforce has increased year on year for the last three years (CBI do not separate out high level from basic level skills in their survey at present). Last year two thirds of employers were dissatisfied:

- in 2008 - 55% dissatisfied
- in 2009 - 57% dissatisfied
- in 2010 - 66% dissatisfied

Over 80% of employers with a workforce of more than 5,000 were dissatisfied with IT skills in their workforce in the 2010 survey. This dissatisfaction is increasing at the same time that, according to Ofqual[19], the number of non-standard 'Other' (i.e. not one of GCE, GCE AS, GCSE or Key Skills) ICT qualifications taken by young people has nearly doubled. Some of these qualifications are of a high standard, but some of them are not. In some cases, it appears that the quality of learning outcomes for a given qualification is highly variable and determined mainly by the quality of the teacher, even though pass rates are 100%. Without proper guidance from subject specialists, schools and colleges may find they are enrolling pupils on qualifications that do no have worthwhile learning outcomes. It is worth noting that the take-up of GCSE ICT has nearly halved since 2006.

There is now a shortage of IT professionals with the right experience and expertise in the UK. According to the Royal Academy of Engineering[20] *"Too often, the UK lacks adequate ICT competence in senior positions in government, industry, schools and institutions to support ICT related project decision making and delivery. This lack of depth of understanding extends through middle management and needs addressing now, rather than waiting for the next generation to reach management positions."*

This shortage is apparent even in the computer games industry, which has been a flagship sector of our economy. According to NESTA[21], *"in just two years, it seems the UK's video games industry has dipped from third to sixth place in the global development rankings"*. This is an especially alarming statistic given that the UK Games industry has always been able to take the pick of the crop. The shortage of developers is, according to the NESTA report *"reinforced by a school curriculum that focuses in ICT on office skills rather than the more rigorous computer science and programming skills which high-tech industries like video games and visual effects need"*.

The trend in undergraduate recruitment to Computing courses reflects the shortage of able young people entering the IT profession. According to HESA data, in 2010 the number of graduates in Computer Science and Software Engineering was 11,095, whilst at its peak in 2002 the number was 22,630 — a drop of slightly more than 50%. We do not believe that the purpose of Computing in school should be to produce University applicants, but such a critical shortage of applicants is a danger sign that ICT in school does not provide a worthwhile professional progression route.

There is thus a mismatch between ICT qualifications based on the current National Curriculum, the majority of which do not provide a pathway to the IT profession, an increasing demand for IT professionals, and a University sector suffering from a collapse in student numbers. If the National Curriculum included the principles of Computing, and Ofqual stipulated that these would have to be tested in future qualifications, then the situation would begin to reverse.

1.4 Computing is essential for rounded citizens

We want young people to understand and play an active role in the digital world that surrounds them, not to be passive consumers of an opaque and mysterious technology. A sound understanding of Computing concepts will equip them to get the best from the systems they use, to recognize poorly designed systems rather than blame themselves, and to solve problems when things go wrong. Moreover, citizens able to think in computational terms would be able to understand and argue rationally about issues involving computation, such as software patents, identity theft, genetic engineering, electronic voting systems for elections, and so on. In a world suffused by computation, every school-leaver who lacks a basic appreciation of Computing is at a distinct disadvantage.

2. Computing at school

For a discipline such as Science or History, we take it for granted that every student should learn the elementary concepts, after which some will choose to study further at GCSE. Some will choose to take an A-level, and some of them will go on to University. Moreover, there is a range of choices at each level, varying in the level of intellectual demand and vocational emphasis.

Exactly the same pattern should apply to Computing.

2.1 Computing should be encountered by every school pupil

Every student should encounter elementary Computing concepts, from Key Stage 1 onwards, *whether or not they intend to specialise in Computing*. From the pupil's point of view, Computing is important because:

- Computing develops a unique way of thinking about issues, problems and situations that uses the powers of logic, algorithm, precision and abstraction.
- Computing empowers them to create new things and to make things happen, to move from being consumers of technology to producers and shapers of technology.
- Computing supports their own personal employability and economic well-being, and can be a powerful lever for social and economic mobility.
- Computing equips them to understand and contribute to societal issues involving computation, issues that are becoming more and more important.

2.2 Pupils should have the opportunity to specialise in Computing

There is a wide range of ICT qualifications at Key Stage 4, including GCSEs, BTECs, and Diplomas. In contrast, *there were no GCSEs in Computing at all*, until 2010 when OCR launched a small pilot. The A-level menu is similarly restricted. As a result, most young people cannot specialise in Computing until very late, by which time many have become bored and de-motivated by ICT qualifications that lack rigour and challenge.

By establishing a subject called Computing and by giving schools the encouragement to support it, we will ensure that young people with the aptitude and motivation can choose to make Computing part of their education and career. It is therefore important to establish a clear progression path, from basic Computing concepts in the primary and secondary curriculum, through GCSE and A levels, to University, just as in any other mainstream school subject.

2.3 Computing and the English Baccalaureate

The creation of the English Baccalaureate is an opportunity to establish the importance of Computing as a school subject, thereby directly encouraging head teachers to focus resources on developing capability in Computing.

Experience shows that intellectually challenging subjects that are not mandatory have tended to become sidelined and neglected. For example, when modern languages became optional there was a subsequent collapse in the number of pupils taking modern language GCSEs[22]: only 44% of GCSE candidates took a language in 2010, compared to 78% in 2001.

This is not just a UK phenomenon. In the US, where ICT and Computing of any sort is optional, only 40% of high schools offer any kind of Computer Science course (CSTA survey 2007[23]). Indeed the US is so worried by the lack of Computing education in schools that Congress set up the National Computer Science Education Week in 2010[24] in an attempt to raise its profile. Conversely, in the EU where countries see a subject as of strategic national importance they tend to make it a compulsory part of the curriculum. For example, a 2004 report from the EC[25] stated that 20 out of 32 EU countries have computer programming included in their national curricula.

We therefore recommend that

- **Computing is considered to be a science and so contribute to the EBacc portfolio** of: English, Maths, two sciences, a humanity, and a language. This will encourage schools to offer Computing, giving the opportunity to pupils with an aptitude to further their studies.
- **Schools should be strongly encouraged to offer Computing,** regardless of the ultimate form of the EBacc**.**

3. Digital Literacy

Computing related elements of the current ICT national curriculum have been sidelined by the need for all school children to develop digital literacy. In turn, the development of technology related capabilities are undervalued by schoolchildren and parents, since they have become confused as somehow part of Computing because the two are mixed together within the ICT curriculum. Every professional in every walk of life and every citizen needs to be digitally literate in order to function in our digital society. As one schoolteacher explains “Whatever happens, students will still need to know how to operate a PC successfully. When they need skills they will have to learn them from somewhere – they don’t just magically appear”.

There is no need to teach digital literacy as a distinct subject. It can be embedded across the curriculum. Digital Literacy should extend beyond the standard office productivity applications in to other things such as digital video, photography, podcasting, data gathering from field trips etc. This kind of activity clearly has significant benefits for enhancing the rest of the curriculum. Moreover, there is no need for a particular focus on it within the curriculum beyond KS3.

Schools will not effectively embed digital literacy across the curriculum unless pupils digital literacy is measured. That is best measured through attainment of a qualification of sufficiently high standard but also at the right level, for example possibly at the end of KS3. This effective incentive ensures head teachers in the rush for league table points do not forget digital literacy and acts as a safeguard to ensure all children have the necessary digital literacy required for subjects they continue with to GCSE level. Modern technology means examining digital literacy can be achieved through automated online testing, which is light touch, robust, efficient, and immediate.

If objective, transparent, independent testing of digital literacy is not used the mistakes of the past will be repeated. The last attempt to embed ICT across the curriculum was in 2004 by the (then) DfES[26]. This attempt did not really result in significant impact or lasting benefit. Schoolteachers in other subjects, even without the right specialist IT background, can and should use IT to enhance the teaching experience. That however does not improve digital literacy in the pupils, it improves digital literacy in the schoolteacher.

This quote from one school policy document highlights the difficulties of the previous attempt at embedding "Students' ability to apply their ICT capability across the curriculum is largely dependent on the effective teaching and learning of ICT in the first place. Students' use of ICT in other subjects may be ineffective if they do not already have an appropriate level and understanding of ICT capability. This may result in a lack of progress in both ICT and the subject area. Students who try to learn new areas of ICT at the same time as new subject content will often fail in both endeavours." As explained by other schoolteachers "its not just about having ICT skills – You need to be able to demonstrate that you have them too", also "Without having a stretching curriculum with a qualification at the end students ICT skills will suffer."

We should also be cautious not to assume that because all young people are "Digital Natives" they have a meaningful understanding that underpins their ability to use technology . Whilst it is true that many young people develop very specific ICT capabilities via the use of technology in everyday life, it is dangerous to assume that these pupils understand what they're doing rather than learning 'tricks' that just work.

4. Conclusion

The National Curriculum review should modernise the entire ICT curriculum by re-establishing Computing as a distinct subject discipline. In support of this goal we offer a draft curriculum for Computing:

> Computing - A curriculum for schools
> http://www.computingatschool.org.uk/data/uploads/ComputingCurric.pdf

Modelled on the structure of the National Curriculum Programmes of Study, it specifies key processes, concepts, principles, and attainment targets for the subject.

We are committed to the principles and processes of the National Curriculum and would welcome the opportunity to discuss the ideas, opinions, and experience of the membership of the Computing at School Working Group.

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