The case for Computer Science as an option in the English Baccalaureate
Foreword from the Expert Panel

The Government’s ambitions for the UK economy in the Plan for Growth\(^1\) aim to achieve strong and sustainable growth by making the UK one of the best places to start a business and invest. UK public policy also expressly sets out to remove barriers to growth in sectors critical to our international competitiveness. Key to this is a more educated workforce, one which is able to work more flexibly and create or adapt to new markets.

This paper argues that the study of Computer Science at school is essential to the competitiveness of our digital economy and to ensure the UK has a strong supply of people capable of creating the technology of the future. To respond to the Secretary of State and the Deputy Prime Minister’s recent call to “equip pupils for the challenges of the 21\(^{st}\) century”\(^2\), and to have the best chance of success as a digital citizen, whatever walk of life they eventually follow, we believe every pupil needs to be exposed to the principles of computational thinking from an early age and to specialise in Computer Science if they wish.

Computer Science teaches the underpinning principles that explain how and why digital technology and software works, and also develops pupils’ ability to make new digital technology and software for themselves. Computer Science has been shown to unleash creativity, imagination and ingenuity in pupils from primary school age onwards, as explained in the Royal Society report ‘Computing in School: Shut down or Restart’\(^3\).

Computational thinking also has important Research and Development and innovation functions. It increasingly influences disciplines such as biology, chemistry, physics, linguistics, psychology, economics and statistics, amongst others. The recent Royal Society report\(^27\) ‘Science as an open enterprise’ explains that computational modelling and computer controlled experiments are transforming both how science is done and what science is done across all scientific disciplines.

The means by which we see Computer Science properly embedded in schools is by inclusion as an option in the English Baccalaureate. When the EBacc was introduced Computer Science did not exist as a separate GCSE subject. Since then the Royal Society\(^3\) and Next Gen\(^14\) reports have been published explaining that Computer Science is a rigorous, intellectually challenging subject that should be taught in schools, and that should be included as an EBacc option. Four new Computer Science GCSEs have now been created by the leading exam boards, removing a major obstacle to progress. These new qualifications have been welcomed by many technology-creating companies, which all believe that it is vital for the UK’s education and workforce needs that our schools teach Computer Science.

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\(^1\) HM Treasury, ‘The Plan for Growth’
However **these qualifications will have limited impact if few schools offer them.** Currently, schools have dis-incentives for offering a GCSE in Computer Science: the subject starts from a base of close to zero; teachers need training; courses need planning; and (most telling of all) the Computer Science GCSEs are challenging, and do not offer an easy route to a crop of A*s. Offering Computer Science will do nothing to improve a school’s league table position. The EBacc is designed to give schools an incentive to offer challenging but essential subjects like maths and science – and Computer Science is no different.

Led by the BCS, we have performed an in depth review of some of these new qualifications to test if they are suitable for inclusion in the EBacc and could also therefore be used to develop a Computer Science EBacc Certificate qualification. Our assessment is based on the intellectual rigour they require and the progression they provide towards further education and a professional career. The demanding and exacting benchmark standard we measure the new GCSEs against means we are confident that any qualification that is above the benchmark threshold is suitable to be included in the EBacc. Our analysis finds that the published Computer Science GCSEs we have tested significantly exceed our benchmark and are therefore worthy qualifications to be included in the EBacc and could be developed into an EBacc Certificate qualification.

Google Chairman Eric Schmidt is the most high profile employer to publically express the view that he is ‘flabbergasted’ we in the UK do not teach pupils how to create software⁴, but he is by no means alone in this opinion⁵. We believe it is the business of Government not to prescribe detail, but to create a playing field that incentivises the behaviour it wants to encourage. At a time when ministers have indicated clear support for rigour in general, and Computer Science in particular, the EBacc is the crucial instrument to create the incentives they desire.

The Expert Panel, October 2012

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1. Executive Summary and Recommendations

**Main Recommendations and Findings:**

- Computer Science should be included as an optional subject within the EBacc and a new Computer Science EBacc Certificate should be developed as soon as possible.
- Computer Science is a distinct science and engineering discipline which, when realised as an appropriate key stage 3 and 4 curriculum, equips pupils with the core knowledge, competency and capabilities to support progression into further education and a professional career.
- There are new GCSE qualifications in Computer Science that would easily qualify for inclusion in the EBacc if they were eligible, because they meet exacting standards of intellectual rigour and support progression into further education and a professional career (Section 6). Also, it is feasible and desirable to develop a Computer Science EBacc Certificate qualification that could be introduced at the same time as the other EBacc certificates. This could be developed from any of the GCSE that already exceed our EBacc benchmark.
- The EBacc was created precisely in order to incentivise schools to offer and resource subjects that the Government considers to be important, and are in danger of being avoided because the subjects are considered too rigorous and challenging (Section 2). It has been extremely effective in that role. Computer Science is quintessentially such a subject. It is not just in danger of being neglected: it manifestly has been neglected, to the point where it is starting from a near-zero base.
- Making Computer Science an option within the EBacc would signal the educational and economic importance Government attaches to the subject, and at the same time give head teachers a concrete incentive to offer and resource the subject, and encourage students to take it.

On 11 January 2012 at BETT Secretary of State for Education Michael Gove MP signalled a fundamental change in the way Information and Communication Technology and Computer Science are viewed in our education system. In addition to launching a major reform into the teaching of ICT at Key Stage 4, the Secretary of State also recognised the role of Computer Science as “a rigorous, fascinating and intellectually challenging subject” and set a challenge to Computer Science community for the future:

“If new Computer Science GCSEs are developed that meet high standards of intellectual depth and practical value, we will certainly consider including Computer Science as an option in the English Baccalaureate.”

The purpose of this report is to make the case that Computer Science should be included as an optional subject\textsuperscript{7} in the English Baccalaureate\textsuperscript{8} and that Computer Science should be introduced as a new English Baccalaureate Certificate\textsuperscript{9} qualification.

The report represents the considered opinions\textsuperscript{10} of a wide range of experts from technology creating companies such as Microsoft, Google, IBM, BT, Facebook, Eidos, Metaswitch Networks, Double Negative, Raspberry Pi and Bloodhound, Russell Group university Computer Science departments such as Edinburgh, Manchester and Queen Mary, professional bodies such as BCS, the trade association Intellect, Next Gen Skills campaign and CAS the subject association for Computer Science.

Having reviewed the new Computer Science GCSEs from examining bodies against exacting standards with regards to their intellectual rigour and support for progression towards further education and a professional career, we strongly recommend them for inclusion as EBacc qualifications until a new Computer Science EBacc Certificate is introduced.

The report splits consideration of whether Computer Science should be included in the EBacc into two parts:

1. **First, as a matter of principle**, should the school subject of Computer Science be an option within the EBacc?
2. **Second, in practice**, is there clear evidence to suggest some existing GCSEs in Computer Science should qualify for inclusion within the EBacc and that it is possible to develop a new EBacc Certificate in Computer Science?

Following guidance from the DfE, we have looked at the following principles when considering Question (1), whether it is appropriate to include Computer Science as an optional subject in the EBacc:

- **Rigour**: is there a rigorous, academic model curriculum for Computer Science as a discrete school subject at key stage 3 and 4 that is widely recognised by universities, employers, schools, learned societies and professional bodies and that can be used to outline suitable attainment criteria?
- **Progression**: 
  - Would the academic study of Computer Science at school equip pupils with the core knowledge, competency and capabilities to support progression into further education and a professional career?

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\textsuperscript{7} In the sense that if a pupil obtains a grade C or above in a suitable Computer Science GCSE qualification then that should count towards the EBacc performance measure.

\textsuperscript{8} For the rest of the report we will follow common practice and abbreviate English Baccalaureate to ‘EBacc’.

\textsuperscript{9} \url{http://www.education.gov.uk/schools/teachingandlearning/qualifications/gcses/b00213896/ks4-qualification}

\textsuperscript{10} Note: experts have expressed their personal opinions in this document, which should not be interpreted as an official endorsement by their employers of those opinions.
– Specifically, does the study and practice of Computer Science in school support the educational progression of pupils in science and engineering?

• **Feasibility**: are there suitable classroom ready educational resources available that will enable teachers to effectively teach the underpinning principles and concepts of Computer Science in a way that is rigorous, academic and at the same time inspirational?

Sections 3 and 4 will demonstrate that Computer Science does satisfy these principles. When considering Question (2), concerning specific Computer Science GCSE qualifications, it clearly makes sense to consider them in light of the above principles, and in comparison with other EBacc GCSE science subjects. The criteria used for assessing the current Computer Science GCSE are therefore:

• **Rigour**:
  – are new GCSE in Computer Science equally as rigorous as other EBacc science qualifications in terms of curriculum and assessment?
  – do they have an academic curriculum that compares well when benchmarked against existing recognised model Computer Science curricula for schools?

• **Progression**:
  – are existing Computer Science GCSE qualifications valued by employers, universities, professional bodies and learned societies?
  – do new GCSE in Computer Science offer the same opportunities for progression in terms of further education and professional careers as other GCSE qualifications?

Section 6 considers how these criteria apply to the new Computer Science GCSE being offered from next year.

2. **The EBacc; background and criteria for inclusion of Computer Science**

The EBacc is a performance measure that is dramatically changing the subjects offered by schools at GCSE. The EBacc was introduced as a performance measure in the 2010 performance tables. It recognises where pupils have secured a C grade or better across a core of academic subjects, which are English, mathematics, history or geography, the sciences and a language. At present science in the EBacc is defined as Physics, Chemistry and Biology. The aim of the EBacc is to ensure all pupils, from whatever economic or social background, are given the same opportunities to progress to further education and a professional career.

[http://www.education.gov.uk/schools/teachingandlearning/qualifications/englishbac/a0075975/theenglishbacalaureate](http://www.education.gov.uk/schools/teachingandlearning/qualifications/englishbac/a0075975/theenglishbacalaureate)
It is quite clear that head teachers see the EBacc as a very important performance measure. The number of students enrolled on EBacc subjects has more than doubled since its introduction; from 22% in 2010 to 47% in 2011\(^2\). Subjects included in the EBacc are seen by schools as of particular academic merit, and particularly relevant to their pupils’ chances of progression into further education and a professional career. It has recently been announced that EBacc subjects will in future be assessed through new more rigorous EBacc Certificate qualifications. Such a major reform is clearly going to demand a great deal of time and attention from head teachers, which will make them reluctant to introduce a new, hard school subject such as Computer Science unless it is also included as one of the new EBacc Certificate qualifications.

3. What is Computer Science?
Computer Science is the study of how and why computers and computer systems work, how they are constructed and programmed, and the foundations of information and computation, in both artificial and natural information processing systems. Computer science includes (among many other things)

- **Algorithms**: re-usable procedures (often a sequence of steps) for getting something done. For example, plan the shortest delivery routes for a fleet of lorries, given the required stops on the route.

- **Data structures**: ways to organise data so that a program can operate quickly on it. For example, there are many different ways to represent numbers (two's complement, floating point, arbitrary precision, etc) with different trade-offs. Another example: a lookup table might be organised as a sorted array or as a hash table, depending on the size of the table and key distribution.

- **Programs** tell a computer exactly what to do. Every program is written in some programming language, each with different strengths. Good languages embody many “abstraction mechanisms” that allow a piece of code to be written once, and reused repeatedly without reference to its internal structure. These mechanisms are the key to controlling the enormous complexity of real programs (e.g. a web browser), which consists of dozens of layers of such abstractions.

- **Architecture** is the term used to describe the large scale structure of computer systems. At the bottom is real physical hardware. On top of that are layered virtual machines. Compilers translate from a high level programming language to the low-level binary that the hardware or virtual machine executes. Operating systems manage the resources of the machine. Hardware and software interfaces, including device drivers, are required for interactions with other things, e.g. if the system is controlling a chemical plant or interacting with humans.

\(^2\) [http://www.education.gov.uk/schools/teachingandlearning/qualifications/englishbac/a0075975/theenglishbaccalaureate](http://www.education.gov.uk/schools/teachingandlearning/qualifications/englishbac/a0075975/theenglishbaccalaureate)
Communication. Almost all computer systems consist of a collection of sub-computers, each running one or more programs, and communicating with the others by sending messages or modifying shared memory. The internet itself is a large-scale example, and uses protocols (standardised procedures) that keep data flowing smoothly despite all the control being decentralised. Increasingly computers need to be given natural language competences for communicating with humans, along with abilities to understand pictures, drawings and gestures.

Alongside these concepts are a set of Computing ‘methods’ or ways of thinking, including:

- **Modelling**: simulate chosen representations of real-world phenomena with a computer to predict future outcomes and test hypotheses. This includes both modelling new engineering designs in order to test them and modelling natural information processing systems in the course of understanding and predicting their behaviours.

- **Decomposing** problems into sub-problems, and decomposing data into its components

- **Generalising** particular cases of algorithm or data into a more general-purpose, re-useable version. This is often followed by discovering new applications for such generalisations.

- **Designing, writing, testing, explaining, and debugging** programs.

Computer Science 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.

Computer Science is also a practical subject, where innovation, creativity, 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”).

**Conclusion**

- Computer Science is a distinct science and engineering discipline that, if realised as an appropriate Key Stage 3 and 4 curriculum, would equip pupils with the core knowledge, competency and capabilities to support progression into further education.
4. The case for Computer Science at school

Before considering how the EBacc is shaping the school curriculum, and why Computer Science should be included as an option, it is worth recapping the case for Computer Science as an important academic school subject. A complete justification with comprehensive supporting evidence can be found in the Royal Society report\(^\text{13}\) ‘Computing in Schools: Shut down or restart?’ and also the Livingstone Hope skills review of the Video Games and Visual Effects industries\(^\text{14}\), which was called for by Ed Vaizey, Minister for Creative Industries.

4.1 Computer Science has a rigorous academic school curriculum

Computer Science is a discipline, like Maths, Physics, or History as explained in Section 3. In 2011 CAS in collaboration with BCS published the Computer Science Curriculum for schools\(^\text{15}\) (known as the CAS curriculum) that incorporates the principles, concepts and methods outlined in Section 3. This was written over eighteen months with support from the Universities of Cambridge, Southampton, Birmingham, Glasgow and Hertfordshire amongst others as well as with support from technology experts at Microsoft and Google and close collaboration with a host of schools. Extensive consultation with schoolteachers in the CAS group also provided valuable input into the final version. The curriculum is officially endorsed by Microsoft, Google, BCS and Intellect.

The CAS curriculum comprehensively demonstrates that Computer Science is a distinct academic discipline that can be meaningfully described as a distinct school subject running through Key Stage 2 to Key Stage 4. This view was firmly supported by the Advisory Group to the Royal Society Computing in School study\(^3\). The CAS curriculum encompasses:

- **A body of knowledge**, including widely-applicable ideas and concepts, and a theoretical framework into which these ideas and concepts fit.
- **A set of 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.
- **Independence from specific technologies**, especially those that have a short shelf-life.

The curriculum was directly modelled on the UK National Curriculum Programmes of Study\(^\text{16}\) that was in place at the time of writing, in the hope that it would thereby have a familiar “shape” to schools. This consisted of splitting the curriculum into five main sections:

- **Importance** of Computer Science at school.


\(^{14}\) [http://www.nesta.org.uk/events/assets/features/next_gen](http://www.nesta.org.uk/events/assets/features/next_gen)


\(^{16}\) [http://curriculum.qcda.gov.uk/key-stages-3-and-4/subjects/key-stage-3/](http://curriculum.qcda.gov.uk/key-stages-3-and-4/subjects/key-stage-3/)
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- **Key Concepts** that arise repeatedly in Computer Science.
- **Key Processes** that pupils should be able to carry out.
- **Range and Content** of what pupils should know.
- **Level descriptions** of Computer Science attainment.

**Conclusion:**
- There is a rigorous, academic model curriculum for Computer Science as a discrete school subject at Key Stage 2, 3 and 4 that is widely recognised by major universities, employers, schools, learned societies and professional bodies and that can be used to outline suitable attainment criteria.

### 4.2 The educational case for Computer Science as a school subject

It is important to realise that Computer Science can be successfully taught as a rigorous academic school subject, not just as a university-level discipline. We have ample evidence that, with the appropriate tools, it is accessible to children from primary school onwards; see the Royal Society report for detailed case studies[^3] and also the Computing At School Key Stage 3 teaching guide[^17]. The latest Ofsted ICT report[^18] illustrates that year 6 children at primary school are perfectly capable of understanding and using sophisticated programming constructs such as iteration, conditional branching and use of variables to construct abstract data representations when they are presented in the right way.

Not only *can* Computer Science be taught, but it *should* be taught: it is important for the education needs of both students and the country that we establish Computer Science as a distinct, rigorous, academic discipline at school. We wholeheartedly endorse what we see as the central vision in the Royal Society report as quoted verbatim here:

> “Every child should have the opportunity to learn Computing at school. We believe that:

- *Every child should be expected to be ‘digitally literate’ by the end of compulsory education, in the same way that every child is expected to be able to read and write.*
- *Every child should have the opportunity to learn concepts and principles from Computing (including Computer Science and Information Technology) from the beginning of primary education onwards, and by age 14 should be able to choose to study towards a recognised qualification in these areas.*”

Computer Science is equally important to both engineering and science education. Education for Engineering (E4E) is the mechanism by which the engineering profession offers coordinated and clear advice on education to UK Government and the devolved institutions.

[^17]: www.ofsted.gov.uk/resources/ict-schools-2008-11
[^18]: www.ofsted.gov.uk/resources/ict-schools-2008-11
Assemblies. It deals with all aspects of learning that underpin engineering. E4E represents the collective views on education and training policy of 36 Professional Engineering Institutions, the Engineering Council, EngineeringUK and the Royal Academy of Engineering.

E4E made the following points in their response to the National Curriculum review explaining why Computer Science is important for the educational needs of pupils. In their view school pupils should encounter Computer Science because:

- Universal scientific, engineering, mathematical and business principles, concepts and methods can be encoded in formal programming 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 Computer Science; 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.
- Computer Science develops a way of thinking about issues, problems and situations that uses the powers of logic, algorithm, precision and abstraction (understanding through analysis and reconstructing from the constituent parts) - it is a scientific, engineering and mathematical approach.
- Computer Science supports economic well-being at the personal (intellectual), vocational (employability), social (stronger work force) and national (more competitive market force) levels.

There is a strong analogy with the other sciences. We take it for granted that every student should learn the elementary concepts of (say) Physics at primary school and Key Stage 3, 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 study Physics at 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 Computer Science, from primary school onwards.

**Conclusion**

- There are strong educational arguments that demonstrate Computer Science should be taught at school.
- There are suitable educational resources available that will enable teachers to effectively teach the underpinning principles and concepts of Computer Science, in a way that is rigorous, academic and at the same time inspirational, as explained in the Royal Society report and illustrated by the latest 2011 Ofsted report.
- The academic study of Computer Science at secondary school, as outlined by the CAS curriculum, would equip pupils with the core knowledge, competency and capabilities to support progression into further education and a professional career.

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4.3 The economic case for Computer Science at school

“There just aren’t enough Computer Scientists in the UK. And we need Computer Scientists, we don’t need – what do they call it – ICT trained people. We need real Computer Scientists who do software engineering and programming.”

Tech City entrepreneur Demos publications  20, ‘A Tale of Tech City’, July 2012

"I think Eric Schmidt is right... we’re not doing enough to teach the next generation of programmers. One of the things you hear from the businesses here in Tech City is "I don’t just want people who are literate in technology, I want people who want to create programs”, and I think that’s a real wake up call for us in terms of our education system."

Prime Minister David Cameron, BBC Tech City interview, November 2011

"Britain has a proud history of invention and industrial creativity, and we want to make sure this continues. That is why we have launched an overhaul of the way that computing is taught in schools, marking a move away from simply teaching young people how to use technology, and instead equipping them with the skills to write software and design apps."

The Rt Hon George Osborne, Chancellor of the Exchequer, FT March 2012

Every parent wants their child to get a good job after their education, and there is almost no surer way to achieve that goal than to study Computer Science. The following statistics illustrate the immense impact of Information Technology on the economy.

- The IT sector will show the highest level of output and productivity in both short to medium (2010-2015) and longer term (2015-20) out of all sectors.  21 Output growth and productivity in the medium term is forecast to be around three times the all sector average.
- London high-tech start-ups already struggle to recruit high quality graduates as the City currently soaks them up.  22 Banks in the City now also recruit from Eastern Europe for IT professionals due to UK shortage of high quality Computer Science graduates.
- The same shortage is now affecting the Computer Games industry  23, where the UK has now sunk from third in the game development league table to sixth  24. This is

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20 http://www.demos.co.uk/publications/ataleoftechcity
21 Warwick Institute for employment Research ‘Working Futures 2010-2020’ see also e-skills Technology Insights 2012.
22 http://eu.techcrunch.com/2011/05/30/silicon-milkroundabout-how-london-startups-took-hiring-back-into-their-own-hands/

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significant as the Games industry has always been able to take its pick of talented software developers and has never suffered a shortage before.

- 27% of UK jobs are already IT-related - and the demand for IT specialists is predicted to grow at four times the rate of the overall UK workforce.\(^{25}\)

Many have the mistaken belief that all IT jobs are being outsourced to China and India. This is false. While approximately 3% of low level IT jobs were outsourced each year during the period 1999 to 2003, around the same number of higher level, more technically demanding IT jobs have been created each year.

Even in a recession, there is a continually increasing demand for IT and telecommunications professionals. According to the 2011 IDC Microsoft Economic Impact study, the UK has an IT workforce of 1.45m, which is expected to grow by 113,000 by 2015. Moreover there were over 110,000 IT vacancies in 2011.

This shortage is apparent even in the computer games industry, which has been a flagship sector of our economy. According to NESTA\(^{14}\), “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”.

It is also important to remember that there is a close link between software engineering skills and modern business entrepreneurship and innovation. In California’s Silicon Valley, the two most successful recent start-ups – Facebook and Google – were catalysed by software engineers. Closer to home, the same is true of Silicon Roundabout and Silicon Fen.

The trend in undergraduate recruitment to Computer Science 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%. Such a critical shortage of applicants is a danger sign that ICT in schools as it currently exists has not provided a worthwhile professional progression route.

\(^{25}\) New Industry New Jobs, Skills System Case Studies, BIS report, March 2010, URN 10/930  
Conclusion

There are strong economic arguments that demonstrate Computer Science should be taught at school.

4.4 Computer Science is vital to the advancement of science and engineering

In the 21st Century advances in science and engineering will depend on the ability of scientists and engineers to create computational models that can effectively and correctly describe the phenomena they wish to study. Computational thinking is fundamentally transforming scientific research as explained in the recent report ‘Science as an Open Enterprise’ from the Royal Society27:

“This [computer] simulation techniques so pervade scientific practice that they have added a third basic tool to those of theory and experiment. They have moved on from assisting scientists in doing science, to transforming both how science is done and what science is done. They are fundamental to many open questions in science, in domains that span from Climate and Earth System science to Epidemiology, from Species Distribution modelling to Immunology.”

The following list illustrates important advances in science, engineering and technology that have required scientists and engineers in a wide variety of fields to develop a much greater aptitude for computational thinking.

- The Human Genome Project was successful because of advances in computer controlled robotics and data analysis techniques28. "From the beginning, laboratory automation has been recognized as an essential element of the Human Genome Project," says Ed Theil a computer systems engineer with the Human Genome Centre’s instrumentation group. According to Tony Hansen, a physicist in the instrumentation group: "Automation also allows the development of new biochemical procedures that would otherwise be inconceivable due to the impracticality of numbers or the volume of work."

- The ongoing experiments at the Large Hadron Collider generate 15 Petabytes (15 million Gigabytes) of data annually, which is creating significant data analysis challenges29. As a result CERN is now a leading developer of a global computing infrastructure called the Grid spanning 50 countries. According to CERN30: "The

infrastructure built by integrating thousands of computers and storage systems in hundreds of data centres worldwide enables a collaborative computing environment on a scale never seen before.”

- Predicting global climate change is only possible because of advanced computer models. According to the UK Met Office “The only way to predict the day-to-day weather and changes to the climate over longer timescales is to use computer models.”

- Methods of mathematics and computer science have become important tools in analysing the spread and control of infectious diseases. Partnerships among computer scientists, mathematicians, epidemiologists, public health experts, and biologists are increasingly important in the defence against disease.

- The Airbus fly by wire system is critically dependent on advanced computer controlled digital technology. According to Airbus “fly-by-wire (FBW) technology is one of Airbus' principal competitive advantages” and “this technology has made significant progress, especially in the field of digital computers”. This is an example of a system that depends on ‘embedded software’, which is becoming commonplace across a number of manufacturing industries.

- The Chevrolet electric car known as the Chevy Volt has ten million lines of embedded software. According to a recent New York Times article car manufacturers “view leadership in control software as strategically vital” in developing new electric hybrid vehicles.

Example, Computational Biology
The following example illustrates why essential computing knowledge is relevant to a much wider group than just Computer Scientists. It also illustrates the remarkable speed at which new disruptive technologies arise. This explains why the study of particular technologies is necessarily only of short term value unlike the study of underpinning principles that evolve slowly over the long term.

The UK pharmaceutical sector is the leading UK sector for investment in R&D, investing £4.3bn in 2008, which represents over a quarter of all business R&D expenditure in the UK. According to the University of Cambridge Computational Biology Institute, “Whether operating on a large or small scale the use of mathematical and computational methods is becoming an integral part of biological research”. Computational biology is not about

32 http://sciencecareers.sciencemag.org/career_magazine/previous_issues/articles/2004_02_06/noDOI.1366586
1607928732511
33 http://www.airbus.com/innovation/proven-concepts/in-design/fly-by-wire/
34 http://www.eetimes.com/discussion/-include/4215057/Ten-million-lines-in-29-months--model-driven-development-on-the-Chevy-Volt

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number crunching. It requires, for example, sophisticated computer models describing how molecules can interact, which requires defining the principles and techniques of molecular biology in computational terms. This fundamental shift whereby computing now underpins advances in biology has happened over a remarkably short space of time.

According to Google Trends, the phrase ‘computational biology’ did not appear as a search term in any location from 2004 until 2009, when it did first appear. On July 31, 2011 a search on Google returned 171,000 hits for computational biology jobs in the UK\(^{37}\) (that does not mean there are 171,000 jobs being advertised, simply a measure of the websites containing the phrase ‘computational biology job’). On that same date the NewScientist website had slightly more than 1000 actual job vacancies including the keywords computational biology.

That illustrates the speed at which digital technology is changing, and reinforces why teaching the principles of computing is essential. Although new technologies are appearing at an incredible rate, they are still based on computing principles that will remain relevant over the long term.

The following verbatim text is taken from an advert at GlaxoSmithKline Pharmacokinetics and Translational Biology group in Ware, Hertfordshire, UK for July 2011 (bold emphasis added to highlight computing relevant keywords):

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Verbatim text taken from GlaxoSmithKline UK advert for R&D position in July 2011:

GlaxoSmithKline R&D, has opened two positions for experienced modellers in the Pharmacokinetics and Translational Biology group in Ware, Hertfordshire, UK.

These investigator/senior investigator positions are an exciting opportunity to improve the lives of patients by applying mathematical modelling, computing and scientific knowledge to find novel solutions to accelerate the drug discovery and development process.

We are looking for those rare individuals who can successfully integrate biochemistry, biology and drug metabolism with sophisticated mathematics and computational techniques to bring novel insights and solutions in drug discovery and development.

Responsibilities

- Develop and use mathematical modelling to solve practical problems in preclinical development
- Perform and champion interdisciplinary work at the boundary of biology, physics, chemistry, pharmaceutics, numerical analysis and computer

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\(^{37}\) https://www.google.co.uk/search?q='computational+biology+job'+UK
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- Use modelling as a thinking tool to generate an experimentally testable question.
- Coach and mentor staff, providing training when required and general scientific support.

Basic Qualifications
- PhD or equivalent in chemical, mechanical or biomedical engineering, biochemistry, physics, applied mathematics, scientific computing or related field.
- Core competency in numerical analysis and scientific computing focusing on optimization and differential equations (ODE, DAE, DDE, PDE, SDE), particularly using FEM and CFD approaches.
- Experience in scientific computing, software engineering and programming; Matlab and Comsol experience a plus.
- Proven experience in applying mathematical modelling techniques in pharmaceutical industry to integrate and interpret available data and answer practical questions.
- Familiarity with the challenges of drug discovery and forward thinking with respect to the general application of mathematical models in pharmaceutical development.
- Expertise in drug discovery, drug delivery, physiological based modelling, systems biology, computational biology, data and image analysis.

This advertisement is interesting since it stresses the value of computing, software engineering and the interdisciplinary nature of research at the leading edge of the pharmaceutical industry.

The rise of computational biology in industrial R&D over such a short period of time is the result of revolutionary improvements in digital technology that were necessary before biological computation could be useful to the pharmaceutical industry. This revolution is still ongoing, which makes an understanding of computing principles the best hope for future scientists to be capable of applying computational thinking to their own discipline.

Clearly, a student now wanting to follow Biology as a career should have a sound understanding of computing in the same way that they need a sound grasp of mathematics. The same case is equally valid for other sciences, such as Chemistry or Physics.

This section has illustrated why our next generation of scientists and engineers need to be good at computational thinking, which will best be supported by teaching Computer Science in school.
Conclusion

How science is done and what science is done has been transformed by computational simulation and computer controlled experimentation. An aptitude for computational thinking is now essential for scientists and engineers in all disciplines.

The study and practice of Computer Science in school supports the educational progression of pupils in science and engineering and supports their progression into a science or engineering profession.

Recommendations

- Combining the conclusions of the previous sections, there is an overwhelming case to support the recommendation that as a matter of principle Computer Science should be included as an option within the EBacc.
- In terms of the education and economic needs of the UK it is important that Computer Science is included as an option in the EBacc.

5. Other levers of influence on school behaviour

This section looks at other factors that could affect whether schools decide to introduce Computer Science. The purpose of looking at these is to show that the EBacc is the most effective reward mechanism available at the national level.

Before considering incentives that can be used to encourage the introduction of Computer Science it is worth recapping on some of the issues around ICT as it currently exists. This is useful as it provides a wider context that throws light on why implementing such change will be difficult for many schools and requires rewards in terms of performance measures.

The difficulties surrounding the teaching of ICT in schools were concisely summed up in the main findings of the Computing in School Royal Society report, which reinforce the findings of the Next Gen report. The reader should note that the Royal Society report defines Computing to mean Computer Science, Information Technology and digital literacy:

- The current national curriculum in ICT can be very broadly interpreted and may be reduced to the lowest level where non specialist teachers have to deliver it;
- there is a shortage of teachers who are able to teach beyond basic digital literacy;
- there is a lack of continuing professional development for teachers of Computing;
- features of school infrastructure inhibit effective teaching of Computing.

To quote from DfE, evidence indicates that recent curriculum and qualifications reforms have not led to significant improvements in ICT education in schools; that the number of students progressing to further study in ICT-related subjects is in decline; and that the ICT...
curriculum in its current form, particularly beyond KS3 is viewed as dull, repetitive and de-motivating for pupils.\footnote{E-skills UK: ‘Raising the bar for ICT: securing KS4 curriculum and relevant ICT pathways’ (2009); National Curriculum Review call for evidence: BCS The Chartered Institute for IT in association with the Computing At School Group (April 2011);}

Introducing Computer Science into a school would have a beneficial effect in resolving many of the issues just highlighted. It would drive up standards of rigour and academic content that support progression, it would gain the direct support of local university Computer Science departments keen to see a renewed interest in their subject, it would gain support from employers keen to improve computational thinking skills in the workforce, it would create a demand for more expert teachers and enhance the status of those teachers. In that case, surely schools will jump at the chance to innovate at the earliest opportunity? We know that many ICT schoolteachers would welcome such a chance. The reality however is that their head teachers are under a great deal of pressure to deliver results against a variety of performance targets and to achieve or maintain the gold standard of an outstanding Ofsted report.

In the rest of this section we will see that the overall systemic pressures in the school system do not incentivise a headteacher to introduce a new, rigorous, academic GCSE subject such as Computer Science that might adversely affect their league table position. On the contrary, headteachers face significant dis-incentives: resources are very tight, their ICT teachers need training in Computer Science, and the GCSEs in Computer Science are, by design, challenging and are unlikely to lead to as many A* results as ICT qualifications.

5.1 Performance measures.

As already mentioned, the EBacc has had a dramatic effect on school behaviour as shown by the percentage of students enrolled on EBacc GCSEs since 2010:

- September 2010: 22%
- September 2011: 47%

The EBacc is not the only performance measure currently used in schools. There are also performance league tables based on qualifications included in the Register of Regulated Qualifications. There are currently 27 ICT qualifications that are listed by the Department for Education that will still count in the 2014 key stage 4 performance tables.\footnote{http://media.education.gov.uk/assets/files/pdf/q/qualifications%20included%20in%20ks4%20performance%20tables%202014.pdf} According to an analysis of these by the Royal Academy of Engineering\footnote{Computing qualifications included in the 2014 Key Stage 4 Performance Tables: a guide for schools; Royal Academy of Engineering, July 2012} (not including Level 1 courses, IGCSEs or Level 3 courses):

- 11 are a mix of IT and digital literacy
– 10 are a mix of IT, Computer Science and (often) digital literacy
– 3 are devoted to Computer Science
– 2 are devoted to digital literacy
– 1 is devoted to IT

The analysis uses the same terminology as outlined in the Royal Society report when characterising computing as the combination of digital literacy (ICT user-skills), IT (applications of Information Technology to solve real world problems) and Computer Science (the academic discipline of Computer Science). The analysis is based on the syllabus descriptors from each awarding body.

There are examples of schools where ICT GCSE is taken by year 9 pupils, because the school feels it helps their pupils use IT to enhance learning in their other GCSE subjects and because they are perfectly capable of passing the qualification at that stage. Interestingly in some of these schools many of their pupils achieve grade A in their ICT GCSE whilst in year 9. This reinforces the view that all pupils should be digitally literate by the end of year 9 and that good schools are capable of achieving this. Good schools having ensured their pupils are digitally literate by year 9 are likely to want to focus on core EBacc subjects in years 10 and 11. If they have taken the sensible step of ensuring their year 9 pupils have already taken an ICT qualification then there is no additional reward from a league table perspective in introducing Computer Science in years 10 and 11 as well. Of course some schools will introduce Computer Science simply because they believe it is the right thing to do, but that is despite the league table reward system not because of it.

For the medium term there will be a broad range of at least 27 qualifications all of which sit under the ICT umbrella that count towards league table points. There is no distinction from a league table perspective between those ICT qualifications that do not necessarily support a progression route into the IT, science and engineering professions, and those rigorous, academic Computer Science qualifications that do support further education and career progression. Hence, purely in terms of these performance tables there is no compelling incentive for schools to introduce a new rigorous Computer Science GCSE compared to simply sticking with an existing ICT qualification.

5.2 The National Curriculum

At present Computer Science is not part of the DfE National Curriculum, whereas ICT is a statutory component. The current intention is to remove the statutory ICT programme of study and attainment targets from September 2012 as an interim measure. From 2014 a new programme of study for ICT will be introduced that is statutory at all key stages, which

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42 http://www.education.gov.uk/schools/teachingandlearning/curriculum/nationalcurriculum/b0075667/national-curriculum-review-update

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of course includes key stage 4⁴³. The expectation is that the new programme of study will be much shorter than the present one and therefore be more visionary and less prescriptive. DfE has expressed their hope that during the interim period schools will choose to be innovative in their approach to ICT and introduce Computer Science.

Many headteachers are focused on making the right strategic choices to successfully navigate the uncertainties around the future of the whole National Curriculum and potential changes to future qualifications. These uncertainties are likely to result in headteachers being hesitant about introducing Computer Science when it is clear they are expected to focus on the core subjects that are included in the EBacc.

5.3 Ofsted

Schools have strong incentives to get good reviews from Ofsted. Yet the current criteria that Ofsted uses to review standards of ICT education in schools⁴⁴ makes no reference to Computer Science, instead mentioning “use of ICT” and “all strands of the statutory National Curriculum are covered” and “use of ICT skills in realistic situations”. Even with the existing ICT inspection criteria there are significant issues according to the 2011 Ofsted report:

“In outstanding secondary schools ICT was seen by the headteacher as an engine for innovation and raising standards. In contrast, half of the secondary schools surveyed in which leadership and management of ICT were no better than satisfactory had common weaknesses that included insufficient attention given to progress in ICT across the curriculum and lack of support for staff in teaching more challenging topics.” Moreover, the 2008 and 2011 Ofsted reports on ICT point out that even the small amounts of computer programming that are a statutory part of the current curriculum are often not taught.

Although a new statutory ICT programme of study will come into force in 2014 that is expected to give much greater prominence to Computer Science, it is not expected to make Computer Science a statutory component. Indeed making Computer Science compulsory at Key Stage 4 may well be inadvisable, any more than making Physics or Chemistry compulsory at Key Stage 4. Ofsted at present can only measure schools against the National Curriculum, which means they will have to decide on appropriate educational standards for ICT based on any new statutory programme of study that comes into force in 2014. It is reasonable to assume that Ofsted will not discriminate against schools that do not choose to include Computer Science since that will be an optional element of the new ICT. This means there will probably be no new Ofsted inspection criteria that specifically encourage schools to introduce Computer Science.

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⁴³ http://www.education.gov.uk/consultations/index.cfm?action=conResults&consultationId=1802&external=no &menu=3
5.4 The wider Computer Science community

Just before Easter, BCS with support from the Royal Society, Intellect, Google and Microsoft, sent a strategic information pack\(^{45}\) to all head teachers in state-maintained secondary schools in England, which asked them to register an interest in joining a network of teaching excellence in Computer Science. The request for registration made it clear the network did not yet exist, so those who registered are a subset of the potential schools that may join once the network comes into being. Over 540 schools registered an interest in the scheme between April and June. Figure 1 shows the approximate geographical spread of the schools, which demonstrates that the interest is spread right across England. Note, due to the scale of the map, the red circles show groups of schools and not necessarily individual schools.

![Figure 1: 540 schools registered an interest in joining a network of teaching excellence April-June 2012](http://www.bcs.org/CSteachingexcellence)

The following seventeen universities have expressed an interest in helping with the scheme and almost all of them already do provide support for local CAS groups or direct CPD for local schoolteachers: Cambridge, Imperial, Manchester, Southampton, Birmingham, Glasgow, Warwick, Coventry, Bath, Kent, Manchester Metropolitan, Anglia Ruskin, Cardiff Metropolitan, Swansea, Greenwich, Hertfordshire, and Reading.

The computing community is of course much wider than just those directly involved in the Network initiative. The following lists a few examples of some of the organisations currently helping schools to demonstrate the breadth of support from the computing community.

\(^{45}\) [http://www.bcs.org/CSteachingexcellence](http://www.bcs.org/CSteachingexcellence)
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- **CAS** ([Computing At School](#)) is the subject association for computer science teachers. There are already twenty five CAS regional hubs helping to introduce computer science to schoolteachers from approximately 800 schools around the UK. CAS has ongoing support from Microsoft, Google, Intel, Intellect and BCS. CAS will be a key stakeholder in establishing the network.

- Many universities provide significant amounts of pro-bono effort to support CAS. Most of these have already expressed their intention to join the network. Universities in the network will host their own local CAS hubs to bring together teachers, IT professionals and university academics.

- Over 1500 computing professionals already voluntarily work with CAS and STEMNET to support schoolteachers, from companies such as ARM, BT, Microsoft and Google.

- The [Royal Society of Edinburgh with BCS](#) is producing inspirational classroom ready resources for key stage 3 that exemplify key principles and concepts of computer science, which have been endorsed by the Scottish Government.

- The [Royal Academy of Engineering](#) runs several hundred after school STEM clubs.

- [CS4FN](#), sponsored by EPSRC and Google, creates inspirational computer science related material distributed to over 1500 schools.

- The [National STEM centre](#) is already working with CAS to provide support for teachers, including hosting CPD courses to teachers.

- Global technology creating companies such as Microsoft and Google are putting considerable resource into supporting schools. For example Microsoft has been very proactive in supporting the creation of the new AQA Computer Science GCSE, and Google recently announced financial support to Teach First to enable them to recruit new Computer Science teachers.

This demonstrates that many schools have the aspiration to become excellent at the teaching of Computer Science and the wider computing community is committed to helping them. However this is still only a minority of all the secondary schools in England. It is also the case that there are no performance measures that reward a school for introducing Computer Science compared to any of the 27 existing ICT qualifications. Given an EBacc incentive, it seems highly likely that many more schools would decide to offer Computer Science as a Key Stage 4 option.

**Conclusion**
Including Computer Science as an option in the EBacc is likely to significantly increase the number of schools that introduce Computer Science.
6. Qualitative analysis of new Computer Science GCSE

This section provides a qualitative analysis of new Computer Science GCSEs.

To make an objective statement about the suitability of the new Computer Science GCSEs we have defined an **EBacc profile for GCSE qualifications** (Section 6.2). The EBacc profile provides a mechanism for making qualitative comparisons between different STEM GCSEs. We use three criteria (explained in Section 6.2) to score each GCSE assessment question. These scores collectively give a detailed profile of the intellectual rigour and academic content required for a grade C, and whether the qualification helps students progress into further education and a professional career. Grade C is chosen since the EBacc counts achievements at grade C and above.

Using these definitions, we define an **EBacc benchmark profile** based on the AQA GCSE Physics from 2011 for comparison purposes (Section 6.3). To create an exacting standard in the benchmark we focus only on the higher tier Physics GCSE exam papers together with the practical component (that is, to deliberately create a high threshold value we do not include the lower tier Physics exam paper in the benchmark profile). For the practical component we use only one of the most challenging topics for the benchmark.

We then create EBacc profiles for the new Computer Science GCSEs and compare them to the EBacc benchmark profile, a comparison that forms the basis of our recommendations. Due to the exacting standard of the EBacc benchmark profile, when a new Computer Science GCSE compares favourably to the benchmark we have a high degree of confidence that it is of a higher standard than is currently required to be included in the EBacc. We felt it important that the benchmark profile is of a particularly high standard, to support the case that it is possible to develop a Computer Science EBacc Certificate from a qualification that surpasses our benchmark profile.

Specifically, we analyse the Computer Science GCSEs from **OCR** (Section 6.4) and **AQA** (6.5). Both OCR Computing GCSE and AQA Computer Science GCSE are rigorous academic qualifications that are intellectually demanding and give students the right grounding to progress towards further education and a professional career. Both of these GCSE cover the fundamental principles, concepts and techniques outlined in the CAS curriculum. In comparison to the EBacc benchmark profile we define in this section they compare very favourably, being more rigorous and intellectually demanding than the benchmark when measured against the knowledge levels described by Bloom’s taxonomy. Both of these qualifications could readily be adapted to form the basis of a Computer Science EBacc certificate. Based on these criteria they should be included in the EBacc as appropriate Computer Science qualifications until the new EBacc Certificates are introduced.

The new Computer Science GCSEs include a relatively large amount of controlled assessment (see section 6.1). We have found that this increases the depth of rigour and is particularly helpful in supporting progression. In both of the OCR and AQA GCSEs it would...
be possible to modify the examinations in order to convert them into EBacc Certificate qualifications by extending the written examination component and reducing the controlled assessment. Maintaining a significant project based assessment component is one of the best ways to ensure pupils have the chance to solve complex, challenging computational problems that also demonstrates their potential for being innovative and creative, which we feel is a very important aspect of developing computational thinking.

For this report we were able to make only an initial assessment of the Edexcel GCSE in Computer Science (Section 6.6), which is still under development and the weighting scheme is not yet finalised. The specification for the course is of a high standard. Assessment for this GCSE is split between two written exams (one online) and a controlled assessment. The specimen exam papers seen for this analysis have a great deal of academic content at a rigorous and intellectually demanding level. Overall the standard of the two exams combined is easily of a high enough standard to merit inclusion in the EBacc. If the controlled assessment component is of a similar standard when it is completed then the Edexcel GCSE in Computer Science will also qualify for inclusion in the EBacc.

There was insufficient time to include other GCSE in the current analysis, notably the GCSE from WJEC. We recommend that our analysis methodology is applied to other GCSE if they are to be considered for inclusion in EBacc.

6.1 English Baccalaureate Certificates and project based learning

The DfE announced in September that EBacc subjects would be assessed through new more rigorous qualifications from 2017, which would replace GCSEs for those subjects. These new qualifications would be known as English Baccalaureate Certificates. The qualitative analysis here shows that some of the new GCSEs in Computer Science are highly rigorous and could readily be developed into a new EBacc Certificate.

For students to progress towards a professional career in IT or other STEM based professions they must develop an aptitude for computational thinking whilst at school, which means they must have repeated opportunities for developing their intellect through creating computational solutions to challenging problems. These computational solutions will not be the result of a single classroom session. For students to fully develop their intellect they need to be exposed to problems that require multiple classroom sessions to solve, where solutions require new knowledge that is built on previous knowledge and understanding is reinforced and mastered through the design and implementation of computer programs. This means students need to engage in substantial computer science projects that are rigorously assessed and count towards a GCSE level qualification. The principle that to a significant extent computational ability should be assessed through project based work is well established in universities, where a major component of the final year in a Computer Science degree course is project based.
For this reason we are satisfied that the controlled assessment component of a Computer Science GCSE can safeguard the rigour of the qualification and that it does support progression into further education and a professional career.

It is currently envisioned that EBacc Certificates will involve a single three hour exam. In this case it will be possible to set more challenging questions that require students to demonstrate a greater depth of understanding and solve more complex composite problems than at present. It will be perfectly possible to set rigorous, intellectually challenging Computer Science examinations suitable for the envisioned EBacc Certificate format. It is however important that students still have the opportunity to work on a significant Computer Science project in order to be given the best chance of progression into a professional career. If schools are to take this seriously such a project will have to count towards a new Computer Science EBacc Certificate.

6.2 EBacc profile for a GCSE qualification

The EBacc performance measure counts whether a student obtains a grade C or above in certain GCSE subjects. Hence, when considering whether a GCSE qualification should be included in the EBacc the determining factor is quantifying what it takes for a student to obtain grade C in that qualification. This can only be determined accurately by considering what is being tested in individual examination questions and controlled assessment components and how that is then measured by marking schemes. Even when subject specifications and grade criteria define rigorous and intellectually challenging learning outcomes, what matters is whether these are tested to exacting standards in exams and controlled assessments, which is why we focus on these.

We will take 50% as the proxy pass mark for a grade C at GCSE. This analysis looks at the depth of intellectual rigour and academic content that a student is tested on in order to gain at least 50% of the marks in each assessment question that contributes to the GCSE. It also looks at the value of a GCSE qualification in terms of whether it provides students the right foundations to progress into further education and a professional career if they achieve 50% or better.

For each of the GCSE qualifications we provide a profile against the following key criteria for inclusion in the EBacc. Each GCSE assessment question (including written exam paper questions and controlled assessment tasks) is assessed for each of the following:

- **Principles and Concepts**: does the question require knowledge of principles and concepts in order to answer correctly? This equates to considering the academic content of the question. This is scored as simple yes or no, where a question is only scored as ‘yes’ if all the content of the question relates to some level of knowledge of principles and concepts. The exact intellectual level of knowledge required is measured separately by the Rigour score.
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- **Rigour**: the intellectual rigour required to obtain at least 50% of the marks for a question, based on Bloom’s taxonomy (scored on scale of 1 to 4, see section on rigour below for details)

- **Progression**: is this question relevant to the kind of career a student may eventually follow in IT, Maths, Science or Engineering (scored as simple yes or no, where a question is only scored as ‘yes’ if all the content of the question is relevant)?

**EBacc Profile**: An EBacc profile for a GCSE consists of the above scores for each assessment question (exam and controlled assessment) collated as a set of tables (one for each assessment component of the qualification) together with histograms of rigour-levels and the weighting scheme between the different assessment components.

**Warning**: Great care must be used when comparing two GCSE qualifications based on this profile. When comparing two GCSEs the overall weighting between different assessment components needs to be taken into account. For example, if the controlled assessment for a GCSE scores very highly in terms of rigour and has a large weighting with respect to the overall qualification then that may well compensate for a written exam that is not so rigorous but also accounts for less of the overall marks.

**Bloom Taxonomy for Computational Thinking: scoring for intellectual rigour**

We take it as axiomatic that the intellectual worth of a Computer Science GCSE is determined by the level of computational thinking required to answer a question or complete a task. Bloom’s Knowledge taxonomy\(^\text{46}\) interpreted with respect to computational thinking is used to describe different levels of intellectual rigour for this analysis.

We will assess GCSE questions (in exam papers and controlled assessments) for rigour on the following scale of 1 to 4 based on Blooms taxonomy of knowledge. Note the levels of knowledge within the GCSE being assessed will be interpreted in terms of what a year 11 (typically a 16 year old) should be capable of.

- **Rigour-level 1: Remember** (accurately summarise information in a concise form)
  This is the level of computational thinking required to accurately summarise knowledge that has already been provided in course material to the student. (e.g. describe the bubble sort algorithm)

- **Rigour-level 2: Understand** (organizing, comparing, translating, interpreting)
  This is the level of computational thinking required to explain how something works or why something works in terms of the underlying computational principles and concepts that are relevant. (E.g. explain the benefits of a 128 bit address bus rather than a 64 bit address bus for a given example of computer architecture)


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• **Rigour-level 3: Apply**  
  This is the level of computational thinking required to describe a computational solution to a problem that is a variation of a well understood problem. (E.g. find and correct the logic errors in some code that should implement a well-known algorithm, or write an SQL query to find all data in a table satisfying some composite property.)

• **Rigour-level 4: Create, Evaluate, Analyse**  
  This is the level of computational thinking required to create a computational solution to a new type of problem by adapting and combining solutions to other known types or problems. This level also requires the student is able to verify their solution is technically correct and determine how computationally effective the solution is. (E.g. given a graph traversal algorithm implement a maze solving program. This is an example from an OCR project)

At GCSE it is most likely that only the lower three levels of rigorousness are tested in a written exam since exams are generally time constrained to be less than two hours. It is possible to some extent to test for the highest rigour-level with a controlled assessment since they give candidates much more time. Thus when looking at written exams that must be completed in less than two hours (which is true for any GCSE subject) we would not expect to see questions that would reach rigour-level 4.

For scoring purposes in making a qualitative analysis of GCSEs we will use a simple score of 1 to 4 based on this taxonomy, where a score of X means a question mostly assesses knowledge at level X in the Bloom taxonomy of rigorousness. That is a question is given a score of X if to get at least 50% of the marks in that question the student must have demonstrated intellectual rigour at level X in Bloom’s taxonomy. E.g. suppose a question is in three parts, each worth the same mark and where the first two parts are at rigour-level 1 and the third is at rigour-level 3. Then the whole question is given a score of rigour-level 1 since it will be possible to gain 66% of the marks for that question without answering the harder third part.

**6.3 An EBacc benchmark profile**

This section defines a benchmark EBacc profile to compare Computer Science GCSE against based on the 2011 AQA Physics GCSE. For this benchmarking exercise we have looked at the higher tier Physics exam papers for parts 2 and 3 of the qualification together with part 1 exam papers (part 1 is not split into separate higher and lower tier papers) and with the practical skills assessment components. By only looking at the higher tier papers and not the lower tier papers we are creating an exacting benchmark that is of a very high standard. The point of creating such a high standard is to remove any inadvertent subjectivity from the final recommendations.
Note when using Bloom’s taxonomy for a Physics GCSE the different levels of rigour will be interpreted with respect to the level of physics knowledge required to pass the question with at least 50%.

**Definition**

The EBacc benchmark profile is defined to be the set of EBacc profiles for the 2011 AQA Physics GCSE derived from the higher tier elements of papers 2 and 3, plus paper 1 and the practical component as explained above. The EBacc benchmark profile also includes Figure 2 (EBacc benchmark profile histogram for written exam papers), Figure 3 (EBacc benchmark profile histogram for controlled assessment components) and the weighting scheme for the 2011 AQA Physics GCSE.

**EBacc Benchmark Profile based on AQA Physics GCSE June 2011**

This benchmark assessment is based on the AQA Physics GCSE from June 2011, excluding the lower tier Physics papers. We deliberately exclude the lower tier papers from the benchmark in order to define an exacting standard.

Note for AQA Physics 75% of the overall GCSE marks come from the written exam papers and 25% comes from the practical element.

This qualification consists of up to four different written exam papers. There are two possible combinations of papers that can be adopted to obtain the AQA Physics GCSE from 2011. We will look at the combination consisting of:

- Physics papers 1a and 1b, each worth 12.5% of the total GCSE, collectively worth 25%
- Physics paper 2 Higher Tier only, worth 25% of the total GCSE
- Physics paper 3 Higher Tier only, worth 25% of the total GCSE

The following table describes the EBacc profile for written exam PHY1AP F&H June 2011 Unit Physics P1a (Energy and Electricity).
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Table 1: EBacc profile for written exam PHY1AP F&H June 2011 Unit Physics P1a (Energy and Electricity)

<table>
<thead>
<tr>
<th>Question</th>
<th>Part</th>
<th>Principles &amp; Concepts</th>
<th>Rigour for part</th>
<th>Rigour</th>
<th>Progression</th>
<th>Comments on rigour</th>
</tr>
</thead>
<tbody>
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<td>yes</td>
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</table>

The histogram for the rigour-level required to obtain 50% of the marks in each of these questions is given in the following graph.

![Histogram](image)

The following table describes the EBacc profile for written exam PHY1BP F&H Unit Physics P1b (Radiation and the Universe).
The case for Computer Science as an option in the English Baccalaureate

Table 2: EBacc profile for written exam PHY1BP F&H Unit Physics P1b (Radiation and the Universe)

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The histogram for the rigour level required to obtain 50% of the marks in each of these questions is given in the following graph.
The following table defines the EBacc profile for the written exam profile for PHY2H Unit Physics P2.

### Table 3: EBacc written exam profile for PHY2H Unit Physics P2

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</table>

The histogram for the rigour level required to obtain 50% of the marks in each of these questions is given in the following graph.

![Histogram](image)

The following table defines the EBacc profile for the written exam PHY3H Unit Physics P3.
The case for Computer Science as an option in the English Baccalaureate

Table 4: EBacc profile for written exam PHY3H Unit Physics P3

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</table>

The histogram for the rigour level required to obtain 50% of the marks in each of these questions is given in the following graph.
The following graph combines the histograms from all four Physics papers into a single chart, but does not take into account the relative weightings of each exam paper.

The following graph shows the weighted distribution of rigour levels for all written exam questions in the Physics papers. This takes into account that Papers 1a and 1b collectively account for 25% of the marks and contain 9 questions each while Papers 2H and 3H each have 7 questions and each contribute 25% of the overall marks.

We take Figure 2 as defining the EBacc benchmark rigour-level histogram for written exam papers, against which we will compare other EBacc profiles.

**AQA Physics GCSE practical component benchmark**

The practical component of the AQA Physics GCSE accounts for 25% of the overall GCSE marks (consisting of Independent Skills Assessment and the Practical Skills Assessment components). The work submitted for each candidate consists of their best Investigative
Skills Assignment (ISA) and a Candidate Record Form showing the marks for this ISA and the Practical Skills Assessment (PSA).

The following table gives the EBacc profile for the assessment paper AQA Physics ISA P3.2 Transformers PHYC/P3.2 (which includes questions concerning the practical experiment that formed part of the assessment and also the supplementary questions that essentially form an additional written exam and can be found at [http://web.aqa.org.uk/qual/gcse/qpm/AQA-4451-ISA32S2-QP.PDF](http://web.aqa.org.uk/qual/gcse/qpm/AQA-4451-ISA32S2-QP.PDF)). We take this as representative of one of the harder ISA that candidates could submit. Since they only submit their best ISA and we are looking for a demanding EBacc benchmark profile we will use this harder ISA as input to the EBacc benchmark profile.

Table 5: EBacc profile for Physics ISA P3.2 Transformers PHYC/P3.2

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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>f</td>
<td>yes</td>
<td>3</td>
<td>3</td>
<td>yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>g</td>
<td>yes</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>yes</td>
<td>2</td>
<td>4</td>
<td>yes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The histogram for the rigour-levels to gain 50% of the marks in each question of this ISA paper is given by the following figure.

![Histogram of EBacc profile rigour-level for ISA P3.2](image)

Figure 3: Histogram of rigour level for EBacc profile of ISA Physics ISA P3.2 Transformers PHYC/P3.2

The following is taken from the AQA Physics GCSE grade descriptor that outlines the knowledge required to obtain Grade C in the practical component, which we have annotated with the Bloom taxonomy rigour levels:

1. **Rigour-level 1**: Candidates demonstrate an awareness of how scientific evidence is collected and are aware that scientific knowledge and theories can be changed by new evidence.
2. **Rigour-level 3**: Candidates use and apply scientific knowledge and understanding in some general situations. They use this knowledge, together with information from other sources, to help plan a scientific task, such as a practical procedure, testing an idea, answering a question, or solving a problem.
3. **Rigour-level 2**: They describe how, and why, decisions about uses of science are made in some familiar contexts. They demonstrate good understanding of the benefits and risks of scientific advances, and identify ethical issues related to these.
4. **Rigour-level 2**: They carry out practical tasks safely and competently, using equipment appropriately and making relevant observations appropriate to the task.
5. **Rigour-level 2**: They use appropriate methods for collecting first-hand and secondary data, interpret the data appropriately, and undertake some evaluation of their methods. (Note evaluation in this context does not correspond to our rigour-level 4 defined for computational thinking, since it does not require candidates to demonstrate that the experimental methods they use are correct. In this context evaluation means demonstrate that the data is valid not the experiment, which we have defined as level 2).
6. **Rigour-level 2:** Candidates present data in ways appropriate to the context. They draw conclusions consistent with the evidence they have collected and evaluate how strongly their evidence supports these conclusions.

This EBacc profile suggested by these criteria is given in the following table.

**Table 6: EBacc benchmark profile for AQA Physics GCSE grade descriptor**

<table>
<thead>
<tr>
<th>Skills Assessment</th>
<th>Principles &amp; Concepts</th>
<th>Rigour</th>
<th>Progression</th>
<th>Comments on rigour</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISA + PSA</td>
<td>yes</td>
<td>2</td>
<td>yes</td>
<td>Some at level 3</td>
</tr>
</tbody>
</table>

This is qualitatively of a less rigorous standard than the EBacc profile for the ISA paper represented by Figure 3, since in that figure half of the questions are at level 3. We will therefore take Figure 3 to represent the EBacc benchmark profile for the controlled assessment component of the AQA Physics GCSE as we wish to ensure the EBacc benchmark profile is exacting.

**6.4 OCR Computing GCSE**

The subject specification for the OCR Computing GCSE[^47] is of a high standard and closely matches the majority of the CAS curriculum in terms of principles and concepts.

- 60% of marks are from controlled assessment (which are very rigorous and require in depth problem solving and computational thinking as well as extensive programming, hence equates to level 4 in Bloom’s taxonomy). This requires at least as much rigour as any maths GCSE exam question, and in terms of depth far more problem solving ability and analytical skill than any EBacc GCSE papers seen during the study.
- 40% exam. This comprehensively tests knowledge of principles and concepts. Since this is a 1h 30m exam it cannot test problem solving in the same way as the controlled assessments. It compares very favourably to the EBacc benchmark profile for the written exam in terms of depth and rigour.

In the rest of the section we examine each assessment component of the OCR Computing GCSE and create an EBacc profile for them in order to compare them with the EBacc Benchmark profile. A full list of the OCR Computing GCSE specimen papers and specification can be found at [http://www.ocr.org.uk/qualifications/type/gcse_2010/ict_tec/computing/documents/](http://www.ocr.org.uk/qualifications/type/gcse_2010/ict_tec/computing/documents/).

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**OCR Computing Written Exam**

This assessment is based on the OCR GCSE in Computing, specimen paper Unit A451 Computer Systems and Programming\(^{48}\), 1hrs 30m. The following table shows the EBacc profile for this written exam.

**Table 7: EBacc profile for written exam paper**

<table>
<thead>
<tr>
<th>Question</th>
<th>Principles &amp; Concepts</th>
<th>Rigour</th>
<th>Progression</th>
<th>Comments on rigour</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>yes</td>
<td>1</td>
<td>yes</td>
<td>All at 1</td>
</tr>
<tr>
<td>2</td>
<td>yes</td>
<td>2</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>yes</td>
<td>3</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>yes</td>
<td>1</td>
<td>yes</td>
<td>Some at 2</td>
</tr>
<tr>
<td>5</td>
<td>yes</td>
<td>2</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>yes</td>
<td>2</td>
<td>yes</td>
<td>Some at 3</td>
</tr>
<tr>
<td>7</td>
<td>yes</td>
<td>2</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>yes</td>
<td>3</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>yes</td>
<td>3</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>yes</td>
<td>3</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>yes</td>
<td>3</td>
<td>yes</td>
<td>Some at 2</td>
</tr>
<tr>
<td>12</td>
<td>yes</td>
<td>4</td>
<td>yes</td>
<td>Surprising to see such a hard question in a GCSE written exam</td>
</tr>
</tbody>
</table>

The following graph shows the histogram of exam question rigour as defined by the Bloom taxonomy:

---


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The overall level of rigour, as described by Bloom’s taxonomy, in the OCR Computing GCSE written exam is significantly higher than for the EBacc benchmark profile given in Figure 2.

This profile demonstrates that in a short Computer Science exam it is possible to test academic knowledge and intellectual development to a high standard. If this exam were extended to a three hour exam it would then be possible to introduce more questions at level 4, which would make it eminently suitable as an EBacc Certificate qualification.

OCR controlled assessment 1, A452CA Specimen Paper
The controlled assessment is marked against four areas:

- Practical investigation (marked out of 15)
- Effectiveness and efficiency (marked out of 10)
- Technical understanding (marked out of 10)
- Testing Evaluation and Conclusions (marked out of 10)

In each of those areas it is not possible to obtain more than half marks without demonstrating understanding at level 3 or above of the Bloom taxonomy. Of note is that the assessment does measure understanding up to level 4 of Bloom’s taxonomy, which has not been observed in EBacc GCSE sample Maths papers, for example. The following table gives the EBacc profile for this controlled assessment component.

---

Figure 4: histogram of exam question rigour for OCR GCSE written exam component

The table gives the EBacc profile for this controlled assessment component.

---

49 http://pdf.ocr.org.uk/download/assess_mat/ocr_31051_sam_gcse_2010_csam_a452.pdf?
Table 8: EBacc profile for Controlled Assessment Part 1

<table>
<thead>
<tr>
<th>Controlled Assessment</th>
<th>Principles &amp; Concepts</th>
<th>Rigour</th>
<th>Progression</th>
<th>Comments on rigour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part 1</td>
<td>yes</td>
<td>3</td>
<td>yes</td>
<td>Several aspects at level 4</td>
</tr>
</tbody>
</table>

OCR controlled assessment 2, A453CA specimen paper

The controlled assessment is marked against four areas:

- Programming techniques (marked out of 18)
- Design (marked out of 9)
- Development of solution (marked out of 9)
- Testing and evaluation (marked out of 9)

The following table gives the EBacc profile for this controlled assessment component.

Table 9: EBacc profile for Controlled Assessment Part 2

<table>
<thead>
<tr>
<th>Controlled Assessment Part 2</th>
<th>Principles &amp; Concepts</th>
<th>Rigour</th>
<th>Progression</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
<td>yes</td>
<td>3</td>
<td>yes</td>
<td>Goes to level 4</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>yes</td>
<td>3</td>
<td>yes</td>
<td>Goes to level 4</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>yes</td>
<td>3</td>
<td>yes</td>
<td>Goes to level 4</td>
</tr>
</tbody>
</table>

Of note again as with the other controlled assessment is that the assessment does measure understanding up to level 4 of Bloom’s taxonomy, which has not been observed in EBacc GCSE sample Maths papers, for example.

Overall the EBacc profile for the OCR written exam and the controlled assessment are both of a higher standard than the corresponding benchmark profile. Therefore the OCR GCSE is suitable for inclusion as an EBacc subject.

Recommendation

Based on the above EBacc profile for the controlled assessment component and written exam component the OCR GCSE is clearly of a higher standard than the EBacc profile benchmark and could be developed into an EBacc Certificate qualification.

http://pdf.ocr.org.uk/download/assess_mat/ocr_31052_sam_gcse_2010_csam_a453.pdf?
6.5 AQA Computer Science GCSE

The AQA specification is of a very high standard. It compares very well with the CAS curriculum in terms of principles and concepts that are covered.

The AQA GCSE marks are split between 60% controlled assessment and 40% written exam. The AQA exam profile contains a higher proportion of rigour-level 2 questions than the benchmark profile and a lower proportion of rigour-level 1 and 3 questions than the benchmark profile. The AQA exam also includes a question at rigour-level 4, whereas the benchmark profile contains no rigour-level 4 questions. The controlled assessment requires a level of knowledge that matches Bloom’s taxonomy at level 3 in order for a candidate to achieve 50% or better. Therefore overall the level of rigour to obtain 50% for AQA is significantly higher than compared to the EBacc benchmark profile.

The specimen papers and specifications we considered can be found at http://web.aqa.org.uk/qual/newgcses/ict/computer-science-materials.php.

Controlled Assessment

The controlled assessment consists of a choice of two from four scenarios. Each of the two scenarios contributes up to 30% of the entire GCSE. The marking scheme for each scenario breaks down as

- Design of solution 9 marks
- Solution development 9 marks
- Programming techniques used 36 marks
- Testing and evaluation 9 marks

In each of those areas it is not possible to obtain more than half marks without demonstrating understanding at rigour-level 3 or above of the Bloom taxonomy. Of note is that the assessment does measure understanding up to level 4 of Bloom’s taxonomy, which has not been observed in EBacc GCSE sample Maths papers, for example.

Table 10: EBacc profile of controlled assessment

<table>
<thead>
<tr>
<th>Controlled Assessment</th>
<th>Principles &amp; Concepts</th>
<th>Rigour</th>
<th>Progression</th>
<th>Comments on rigour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
<td>yes</td>
<td>3</td>
<td>yes</td>
<td>Goes to level 4</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>yes</td>
<td>3</td>
<td>yes</td>
<td>Goes to level 4</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>yes</td>
<td>3</td>
<td>yes</td>
<td>Goes to level 4</td>
</tr>
</tbody>
</table>

Written Exam: Computing Fundamentals

The written exam is worth 40% of the overall GCSE. The following table gives the EBacc profile for the written exam component.
Table 11: EBacc profile of written exam component

<table>
<thead>
<tr>
<th>Question</th>
<th>Principles &amp; Concepts</th>
<th>Rigour</th>
<th>Progression</th>
<th>Comments on rigour</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>yes</td>
<td>2</td>
<td>yes</td>
<td>Some at 3</td>
</tr>
<tr>
<td>2</td>
<td>yes</td>
<td>1</td>
<td>yes</td>
<td>Some at 2</td>
</tr>
<tr>
<td>3</td>
<td>yes</td>
<td>2</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>yes</td>
<td>2</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>yes</td>
<td>2</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>yes</td>
<td>2</td>
<td>yes</td>
<td>Some at 3</td>
</tr>
<tr>
<td>7</td>
<td>yes</td>
<td>4</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>yes</td>
<td>3</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>yes</td>
<td>1</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>yes</td>
<td>2</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>yes</td>
<td>2</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>yes</td>
<td>2</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>yes</td>
<td>2</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>yes</td>
<td>2</td>
<td>yes</td>
<td>Essay</td>
</tr>
</tbody>
</table>

The following graph gives the histogram of the rigour-level scores for the written exam EBacc profile.

![Histogram of rigour-level for AQA written exam](image)

**Figure 5: histogram of exam question rigour for AQA GCSE written exam component**

**Recommendation**

Based on the above EBacc profile for the controlled assessment component and written exam component the AQA GCSE is clearly of a higher standard than the EBacc profile benchmark and could be developed into an EBacc Certificate qualification.
6.6 Edexcel Computer Science GCSE

The Edexcel Computer Science GCSE is split between

- Paper 1: Computer Science in Everyday Life, written exam worth 40% of total
- Paper 2: Computational Thinking, written exam worth 35% of total
- Controlled Assessment: Computational Practice, controlled assessment worth 25% of total

The weighting given to the written exam components of this GCSE mean that it is possible to gain at least 50% of the total GCSE without attempting the controlled assessment. The overall rigour for these two exams is very different. Paper 1 contains a high proportion of rigour-level 2 questions with many also at rigour-level 1 and a small proportion at rigour-level 3. Approximately 88% of the questions in Paper 2 are at rigour-level 3 of the Bloom taxonomy, which is far higher than the EBacc benchmark profile for written exam papers.

Combining the two papers using the exam weighting scheme gives an EBacc profile as shown in Figure 8. This combined profile is of a higher standard than the EBacc benchmark profile for written exams in Figure 2. As yet the controlled assessment for the Edexcel GCSE is not fully developed, so that it is too early to be able to derive an EBacc profile for that component. However, based on the exam profile it looks very likely that the Edexcel GCSE in Computer Science will be eligible for inclusion in the EBacc.

Computer Science in Everyday Life, written exam

The Edexcel format for this specimen written exam consists of four main questions, but each of these consists of many parts often worth one or two marks each. Hence, to provide an accurate analysis of this paper we have included the rigour score for each part of every question. The following table is the qualitative analysis for this component of the GCSE.

<table>
<thead>
<tr>
<th>Question</th>
<th>Part of Question</th>
<th>Principles &amp; Concepts</th>
<th>Rigour</th>
<th>Progression</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 a</td>
<td>yes</td>
<td>1</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>1 b</td>
<td>yes</td>
<td>1</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>1 c</td>
<td>yes</td>
<td>2</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>1 d</td>
<td>yes</td>
<td>2</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>1 e (i)</td>
<td>yes</td>
<td>1</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>1 e (ii)</td>
<td>yes</td>
<td>1</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>1 f (i)</td>
<td>yes</td>
<td>1</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>1 f (ii)</td>
<td>yes</td>
<td>2</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>1 g (i)</td>
<td>yes</td>
<td>1</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>1 g (ii)</td>
<td>yes</td>
<td>2</td>
<td>yes</td>
<td></td>
</tr>
</tbody>
</table>
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<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>a (i)</td>
<td>yes</td>
<td>1 yes</td>
</tr>
<tr>
<td></td>
<td>a (ii)</td>
<td>yes</td>
<td>1 yes</td>
</tr>
<tr>
<td>b</td>
<td>yes</td>
<td>2 yes</td>
<td></td>
</tr>
<tr>
<td>c</td>
<td>yes</td>
<td>1 yes</td>
<td></td>
</tr>
<tr>
<td>d</td>
<td>yes</td>
<td>2 yes</td>
<td></td>
</tr>
<tr>
<td>e (i)</td>
<td>yes</td>
<td>1 yes</td>
<td></td>
</tr>
<tr>
<td>e (ii)</td>
<td>yes</td>
<td>2 yes</td>
<td></td>
</tr>
<tr>
<td>f</td>
<td>yes</td>
<td>2 yes</td>
<td></td>
</tr>
<tr>
<td>g</td>
<td>yes</td>
<td>2 yes</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>a</td>
<td>yes</td>
<td>2 yes</td>
</tr>
<tr>
<td>b</td>
<td>yes</td>
<td>2 yes</td>
<td></td>
</tr>
<tr>
<td>c</td>
<td>yes</td>
<td>2 yes</td>
<td></td>
</tr>
<tr>
<td>d</td>
<td>yes</td>
<td>1 yes</td>
<td></td>
</tr>
<tr>
<td>e</td>
<td>yes</td>
<td>1 yes</td>
<td></td>
</tr>
<tr>
<td>f (i)</td>
<td>yes</td>
<td>2 yes</td>
<td></td>
</tr>
<tr>
<td>f (ii)</td>
<td>yes</td>
<td>3 yes</td>
<td></td>
</tr>
<tr>
<td>f (iii)</td>
<td>yes</td>
<td>3 yes</td>
<td></td>
</tr>
<tr>
<td>g</td>
<td>yes</td>
<td>3 yes</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>a</td>
<td>yes</td>
<td>2 yes</td>
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<tr>
<td>b</td>
<td>yes</td>
<td>2 yes</td>
<td></td>
</tr>
<tr>
<td>c</td>
<td>yes</td>
<td>1 yes</td>
<td></td>
</tr>
<tr>
<td>d</td>
<td>yes</td>
<td>1 yes</td>
<td></td>
</tr>
<tr>
<td>e</td>
<td>yes</td>
<td>2 yes</td>
<td></td>
</tr>
<tr>
<td>f</td>
<td>yes</td>
<td>3 yes</td>
<td></td>
</tr>
<tr>
<td>g</td>
<td>yes</td>
<td>3 yes</td>
<td></td>
</tr>
</tbody>
</table>

The following histogram shows the level of rigour required in this assessment component.

![Histogram of Exam Question Rigour for Edexcel GCSE Written Exam Component, Paper 1](image)

The histogram for this component of the assessment shows a greater proportion of questions at level 1 and a smaller proportion of questions at level 2 than the EBacc
benchmark profile for written exams. However, it should be seen as only one part of the written exam component of the Edexcel GCSE. The ‘Computational Thinking’ exam is the other component that needs to be taken into account to gain a fuller understanding of the rigour required by the Edexcel GCSE.

**Computational Thinking**

This exam is an online assessment component that equates to a written exam. The following table shows the qualitative assessment for this component.

<table>
<thead>
<tr>
<th>Question</th>
<th>Principles &amp; Concepts</th>
<th>Rigour</th>
<th>Progression</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>yes</td>
<td>3</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>yes</td>
<td>3</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>yes</td>
<td>3</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>4</td>
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<td></td>
</tr>
<tr>
<td>5</td>
<td>yes</td>
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<td></td>
</tr>
<tr>
<td>6</td>
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</tr>
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<td>7</td>
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<td></td>
</tr>
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<td>8</td>
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<td>yes</td>
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<td></td>
</tr>
<tr>
<td>11</td>
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<td>3</td>
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<td></td>
</tr>
<tr>
<td>12</td>
<td>yes</td>
<td>3</td>
<td>yes</td>
<td></td>
</tr>
<tr>
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<td>18</td>
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</table>

The following histogram shows the level of rigour required in this component to achieve 50% of the marks.
Compared to the histogram for the EBacc benchmark profile for written exam papers this component has a far greater proportion of questions at level 3, with 88% of the questions at this level. The following figure gives the weighted histogram of exam question rigour for the combination of the two exam papers.

The EBacc profile for the combination of the two Edexcel written exam papers is clearly of a higher standard than the EBacc benchmark profile shown in Figure 2.


**Controlled Assessment: Computational Practice**

The assessment criteria for the Edexcel controlled assessment component was still under development at the time of writing. It is not therefore possible to make any objective comment for the time being on the academic content or rigour of this assessment.

**Conclusion**

At the time of writing the Edexcel GCSE is still under development, which means the best that can be provided is a preliminary evaluation. The second exam paper of the qualification is of a very high standard, whereas the first exam paper is of a lower standard than the EBacc benchmark profile. The weighted combined EBacc profile for these exam papers is of a higher standard than the EBacc benchmark profile. Until the controlled assessment component is finalised it is not possible to give a final recommendation for the Edexcel GCSE in Computer Science.
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