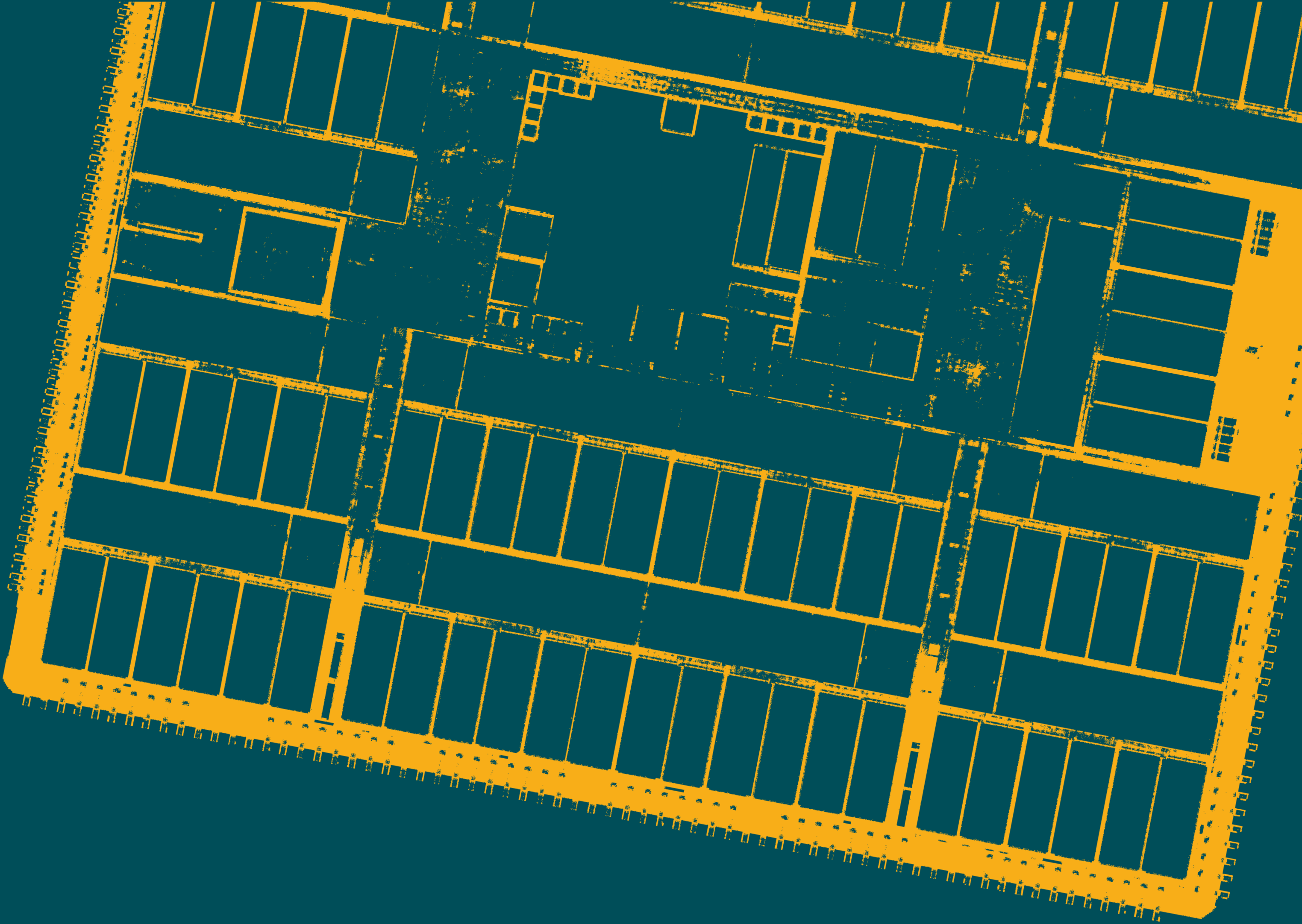

Shut down or restart?

The way forward for computing in UK schools

January 2012

EXCELLENCE IN SCIENCE

THE ROYAL SOCIETY

The Royal Academy of Engineering

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Cover image: The illustration shows the physical layout of the $1cm^2$ SpiNNaker chip, developed at the University of Manchester. The chip incorporates 18 ARM processor cores in an architecture based on, and designed to simulate, the very high levels of connectivity of cells in the brain.

President's Foreword Sir Paul Nurse FRS

This report analyses the current state of Computing education in schools and sets out a way forward for improving on the present situation. With support from the Royal Academy of Engineering and others the Royal Society has used its 'convening' role to bring together a wide range of distinguished Computer Scientists and stakeholders to explore problems and propose solutions.

Computing is of enormous importance to the economy, and the role of Computer Science as a discipline itself and as an 'underpinning' subject across science and engineering is growing rapidly. This alone is motivation enough, but as this report shows, the arguments for reforming Computing education are not purely utilitarian. It is becoming increasingly clear that studying Computer Science provides a 'way of thinking' in the same way that mathematics does, and that there are therefore strong educational arguments for taking a careful look at how and when we introduce young people to the subject.

The Government has recognised the need for more high quality Computer Science teaching, and has committed to exploring the best ways to achieve this. Our report therefore provides a particularly timely source of evidence that will be needed to inform important policy decisions relating to the National Curriculum in England and to support a drive towards improving Computing education throughout the UK.

I am grateful to Professor Steve Furber for leading this study and to the project Advisory Group for their hard work on this report. I hope that the Royal Society's work will provide a solid foundation which the community can build on, to ensure that the next generation of young people in this country can be creators of technology – not just consumers of it. Just as describing and analysing the problems in this report has been a joint activity, it is clear now that ensuring that the solutions are taken forward is a shared responsibility.

Paul Nurse

Paul Nurse
President of the Royal Society

Chair's Introduction Professor Steve Furber FRS

This report is published 30 years to the month after the launch of the BBC Microcomputer. The BBC Micro, and its competitors, introduced a generation to Computing, and I still regularly meet individuals who tell me that the BBC Micro was their introduction to programming and had a significant influence on their subsequent career.

The BBC Micro was the result of an imaginative (and not uncontroversial!) initiative by the BBC, reinforced by an ambitious UK government Computer Literacy project that put computers in every UK school. It has been credited with establishing the UK's strengths in the computer games industry, and clearly led to the establishment of ARM Ltd, the world's leading supplier of microprocessors for mobile consumer electronics.

Computer technology advances rapidly, and the 1990s saw the BBC Micro give way to the PC, a machine designed for business and office use, not for education. At the turn of the century, the government responded to business needs by establishing Computing as a component of the National Curriculum, under the heading of 'ICT' – Information and Communications Technology – a mixture of many related components. The ICT National Curriculum has accommodated a wide range of teaching and content, and in the course of this study we have found examples of imaginative and inspiring teaching under the ICT heading. Sadly, however, these positive examples are in a minority, and we have found far too many examples of demotivating and routine ICT activity, and a widespread perspective among pupils that "ICT is boring". Fears now abound in the Computing community that we have somehow lost our way in recent years. We appear to have succeeded in making many people comfortable with using the technology that we find around us, but this seems to have been at the expense of failing to provide a deeper understanding of the rigorous academic subject of Computer Science and exposure to the opportunities for interest, excitement and creativity that even a modest mastery of the subject offers.

A dwindling enthusiasm for Computing is now widely reported. Some even go so far as to say that it would be better not to try to teach Computing at school at all, given the lack of specialist teachers and the limited number of hours in the school day – perhaps it would be better for schools to focus on mathematics instead, a subject with which Computer Science has much in common? It seems reasonable and timely, therefore, to ask ourselves now whether the subject called 'ICT' in schools should be 'shut down' or 'restarted' – particularly in the light of the 2011-12 review of the National Curriculum in England. It is unlikely to come as a surprise to readers of this report that we come down firmly on the side of a restart.

This report aims to analyse the status quo and to find ways that it can be improved upon. A primary route to improvement will be to displace some of the routine ICT activity with more creative, rigorous and challenging Computer Science. We have met 'sparkling' teachers who are clearly already capable of delivering Computer Science lessons in schools, but many others will find these proposals daunting. Head teachers should start by recognizing the importance of Computer Science to the future lives and careers of the pupils in their care, and take this into account when appointing teachers by looking for those with relevant training and/or experience. But we recognise that in most cases Computer Science will be taught by existing staff, and they will need help.

We aspire to an outcome where every primary school pupil has the opportunity to explore the creative side of Computing through activities such as writing computer programs (using a pupil-friendly programming environment such as Scratch). At secondary school every pupil should have the opportunity to work with microcontrollers and simple robotics, build web-based systems, and similar activities. We recognise that not all pupils will wish to seize these opportunities, but they should be able to do so if they do wish to.

In addition to curriculum opportunities to explore the creative side of Computing, we would like to see this taken further in extra-curricular activities such as computer clubs. These clubs would encourage motivated pupils to explore the creative side of Computing further, and universities and industry should get involved. Perhaps there is even a new role here for the BBC in encouraging and supporting creative Computing education in school and wider populations?

The UK has produced a galaxy of Computer Science stars from Alan Turing to Tim Berners-Lee – both Fellows of the Royal Society – and we want to be sure that the UK returns to the forefront of development in Information Technology and Computing. The scale of the challenge should not hold us back.

Steve Furber
January 2012

Executive summary

Background

This report is the outcome of a project initiated by the Royal Society in August 2010. The project was prompted by a high degree of concern, expressed in many quarters and documented in several earlier reports, about aspects of the current provision of education in Computing in UK schools. That such concern had been expressed by so many with such different perspectives – including in schools, in business and industry, and in universities – was indicative of a significant problem. The project was guided by an Advisory Group that brought together individuals and representatives with a wide range of professional interests and views, and it sought and achieved a good level of consensus.

The main findings and recommendations of the project are set out below. First, however, a word is needed on terminology. In this report, the term 'Computing' is used with a very broad sense. Computing is concerned both with computers and computer systems – how they work and how they are designed, constructed, and used – and with the underlying science of information and computation. The influence of Computing in shaping the world in which we now live has been profound, and it is hard to imagine that Computing will become less important in the future. It is argued in this report that it is essential for all school pupils to gain some familiarity with aspects of Computing and for there to be opportunities for pupils to develop their aptitudes in the subject, for their individual benefit and for the future prosperity of the nation.

Main findings

1. The current delivery of Computing education in many UK schools is highly unsatisfactory. Although existing curricula for Information and Communication Technology (ICT) are broad and allow scope for teachers to inspire pupils and help them develop interests in Computing, many pupils are not inspired by what they are taught and gain nothing beyond basic digital literacy skills such as how to use a word-processor or a database.

This is mainly because:

- 1.1 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;
- 1.2 there is a shortage of teachers who are able to teach beyond basic digital literacy;
- 1.3 there is a lack of continuing professional development for teachers of Computing;
- 1.4 features of school infrastructure inhibit effective teaching of Computing.

2. There is a need to improve understanding in schools of the nature and scope of Computing. In particular there needs to be recognition that Computer Science is a rigorous academic discipline of great importance to the future careers of many pupils. The status of Computing in schools needs to be recognised and raised by government and senior management in schools.

Terminology used in this report (see also Chapter 2):

Computing
The broad subject area; roughly equivalent to what is called ICT in schools and IT in industry, as the term is generally used.

ICT
The school subject defined in the current National Curriculum.

Computer Science
The rigorous academic discipline, encompassing programming languages, data structures, algorithms, etc.

Information Technology
The use of computers, in industry, commerce, the arts and elsewhere, including aspects of IT systems architecture, human factors, project management, etc. (Note that this is narrower than the use in industry, which generally encompasses Computer Science as well.)

Digital literacy
The general ability to use computers. This will be written in lower case to emphasize that it is a set of skills rather than a subject in its own right.

3. Every child should have the opportunity to learn Computing at school, including exposure to Computer Science as a rigorous academic discipline.

4. There is a need for qualifications in aspects of Computing that are accessible at school level but are not currently taught. There is also a need for existing inappropriate assessment methods to be updated.

5. There is a need for augmentation and coordination of current Enhancement and Enrichment activities to support the study of Computing.

6. Uptake of Computing A-level is hindered by lack of demand from higher education institutions.

What needs to be done?

It is clear that over the 30 years since the introduction of the BBC Micro, Computing has grown enormously in importance and now underpins almost all areas of the modern world. Almost all citizens need a certain level of computer literacy to access online resources, which today are found in every walk of life. A substantial and increasing workforce earns its living in the IT and IT-related industries. A simple stroll down the carriage of any railway train will attest to the extraordinary use to which every citizen puts these devices.

This world enriched by information technology is, in part, a consequence of educational initiatives. In 1982 the BBC Micro itself was one aspect of a sustained drive to inform and educate the young. Ten years ago, in response to a skills crisis in industry, schools were equipped to teach ICT to all young people. The result is a generation at ease with the complex software used in business and able to pass on its knowledge to generations who would otherwise have missed out.

Surprisingly, despite the near-ubiquity of computer technology, there is now a dwindling interest in studying Computing at school.

To address these issues urgent and immediate action needs to be taken:

- The review of the National curriculum in England should be used as an opportunity to look at a radical overhaul of ICT in schools including rebranding and providing clarity on the different aspects of Computing currently lumped together under this heading.

- Targets should be set and monitored for the number of specialist Computing teachers. Training bursaries should be available to attract Computer Science graduates into teaching. Education Scotland should ensure that the entitlement of all learners to third-level outcomes in Computing Science is fully implemented.

- Government should set a minimum level of provision for continuing professional development (CPD) for Computing teachers, should seek support from business and industry to make that provision, and should ensure that the provision is well coordinated and deepens subject knowledge and subject-specific pedagogy.

- Providers of school infrastructure services should offer greater flexibility to schools to rebalance network security against requirements for effective teaching and learning in Computing. Suitable technical resources (robotics kits, etc) should also be made available.

- Information, guidance and positive incentives should be offered to heads of schools to enable them to appreciate the nature and scope of Computing and how problems described in this report can be addressed.

- A review of qualifications, curricula, and the means of delivering them should ensure that all pupils gain exposure to essential aspects of Computing and that those pupils with an aptitude for the subject are able to develop it to a higher level.

- Awarding organisations should review assessment methods for qualifications in Computing – such as documenting coursework with screenshots – to ensure that they are effective and do not have a negative impact on learning and teaching.

- A framework to support both non-formal learning in Computing and teachers of Computing should be established, to include after-school clubs, school speakers, and mentoring for teachers. In order to determine the focus of future investment, the effectiveness of different Enhancement and Enrichment activities in Computing should be assessed.

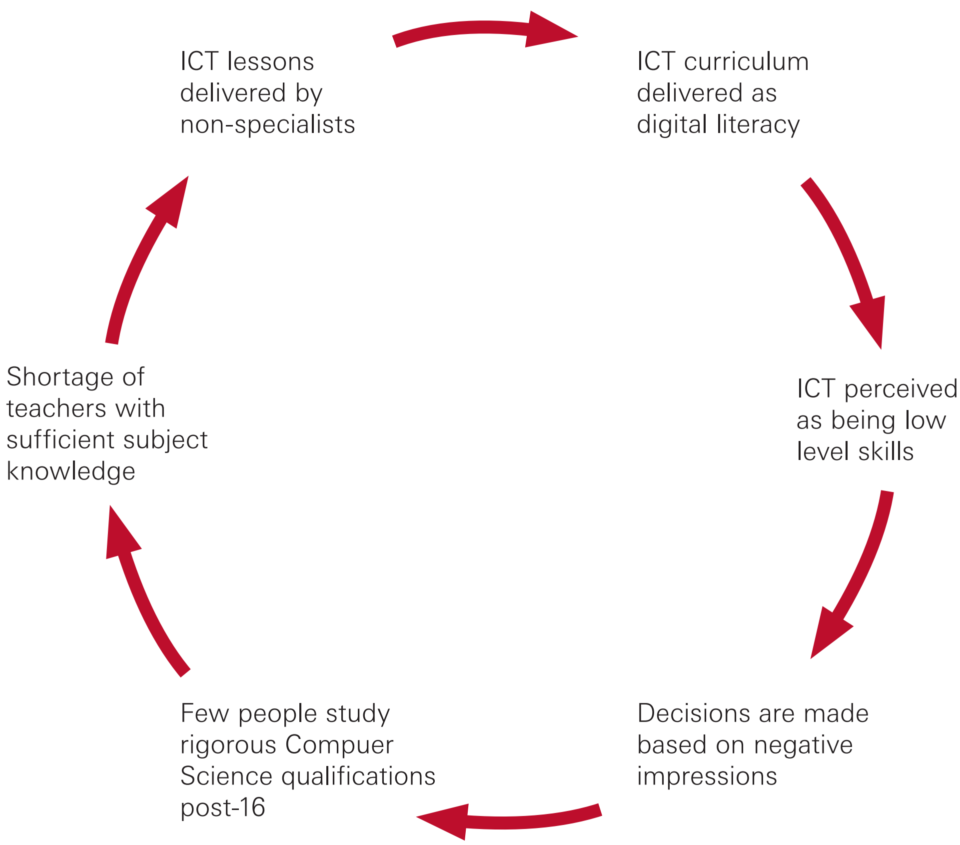
- Awarding organisations should develop rigorous Level 3 (A-level or equivalent) academic qualifications in Computer Science.

In order to progress the recommendations within this report a UK Forum should be formed for joint working and coordination between the many Computer Science and ICT bodies.

A nexus of inter-related factors reinforces the status quo

This cycle is driven by terminological confusion, and is connected to other issues such as access to Continuing Professional Development, the perceived quality of qualifications, HE entry requirements, the status of the subject amongst head teachers, and many others.

These issues interact so as to preserve the status quo. Interventions are required at more than one point to break the cycle.



Issues and recommendations

1. The current delivery of Computing education in many UK schools is highly unsatisfactory

1.1 The current National Curriculum in England lumps together a range of aspects of Computing including Computer Science, Information Technology and digital literacy under the heading 'ICT'.

A consequence is that Computer Science is often forgotten or ignored within the heading of ICT, resulting in teaching being biased towards 'how to use office software' rather than the knowledge that will form a foundation for the rest of a pupil's life. This has led to many people holding a very negative view of 'ICT', to the extent that terminological reform and careful disaggregation is required.

Fundamentally, industry, academe and teachers lack a consistent language within which to communicate business needs, careers advice and curriculum content to policy stakeholders including Government. Existing terminology gives rise to considerable confusion which can affect young people's subject choices and lead to poor policy-making.

Every section of the community appears to use different words in different ways. 'ICT' is an unusually problematic term because it has at least five separate meanings in the school context (see section 2.1).

The focus of this report is principally on the current, English, Welsh and Northern Ireland National Curriculum subject called ICT but with the existing terminology it is difficult to express this.

This confusing situation should not be allowed to continue.

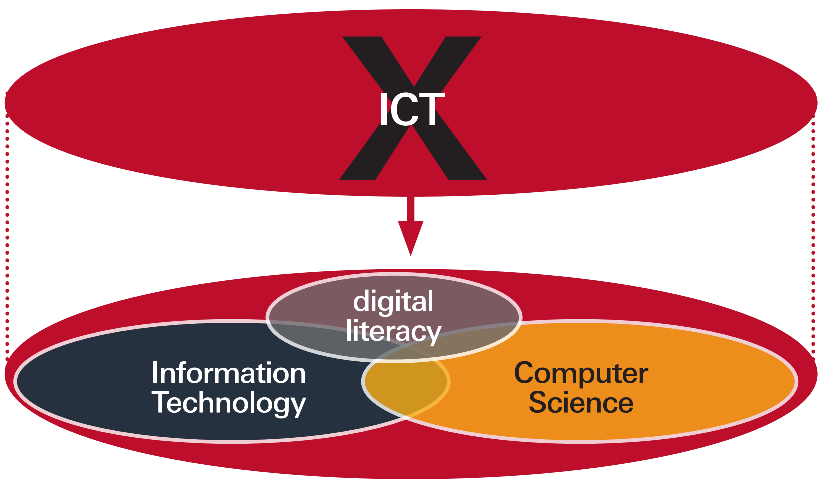
Recommendation 1 (see Chapter 2)
The term ICT as a brand should be reviewed and the possibility considered of disaggregating this into clearly defined areas such as digital literacy, Information Technology and Computer Science. There is an analogy here with how English is structured at school, with reading and writing (basic literacy), English Language (how the language works) and English Literature (how it is used).

The term 'ICT' should no longer be used as it has attracted too many negative connotations.

1.2 There is a shortage of specialist teachers able to teach Computing

There are simply not enough teachers with sufficient subject knowledge and understanding to deliver a rigorous Computer Science and Information Technology curriculum in every school at present. An action plan needs to be put in place to correct this, with a view to enabling all young people to have the opportunity to study Information Technology and Computer Science.

Suggested terminological reform



Recommendation 2 (see Chapter 7)
The government should set targets for the number of Computer Science and Information Technology specialist teachers, and monitor recruitment against these targets in order to allow all schools to deliver a rigorous curriculum. This should include providing training bursaries to attract suitably qualified graduates into teaching – for which industry funding could be sought.

Education Scotland should ensure that the declared entitlement of all learners to third-level outcomes in Computing Science is implemented in all schools for all learners using appropriately qualified teachers.

1.3 There is a lack of continuing professional development (CPD) for teachers

There is a lack of support for CPD that deepens subject knowledge and subject-specific pedagogy in this area, particularly in Computer Science. This needs to be addressed – it is important that teachers have access to good quality CPD, particularly given the lack of specialist teachers. This will be essential to support a new curriculum in schools.

Recommendation 3 (see Chapter 7)
Government departments with responsibility for Education in the UK should seek industry support to extend existing funding in this area, and should ensure that there is coordination of CPD provision for Computer Science and Information Technology teachers that deepens subject knowledge and subject-specific pedagogy.

Government should set a minimum level of provision for subject-specific CPD for Computing teachers, should seek support from business and industry to make that provision, and should ensure that the provision is well coordinated and deepens subject knowledge and subject specific pedagogy.

1.4 School infrastructure is holding back good teaching

Important aspects of Computer Science and Information Technology teaching and learning are being compromised by the need to maintain network security – an analogue to health and safety myths holding back practical science.

Recommendation 4 (see Chapter 7)
School infrastructure service providers, working with others, should prepare a set of off-the-shelf strategies for balancing network security against the need to enable good teaching and learning in Computer Science and Information Technology, and should encourage schools to discuss and adopt them with their service providers. Such a "Guide to Best Practice" should be used by schools and local authorities as part of any tendering process for outsourced service provision.

1.5 Technical teaching resources are often inadequate

Although some schools are already making exemplary use of microcontrollers and robotics kits alongside PCs, it is clear that many are not yet equipped to do so.

Recommendation 5 (see Chapter 7)
Suitable technical resources should be available in all schools to support the teaching of Computer Science and Information technology. These could include pupil-friendly programming environments such as Scratch, educational microcontroller kits such as PICAXE and Arduino, and robot kits such as Lego Mindstorms.

2. Computer Science is a rigorous academic discipline and needs to be recognised as such in schools

Computer Science is a rigorous academic discipline, distinct from, but on an equal footing with, other disciplines such as mathematics, physics, chemistry, geography or history. Like mathematics, Computer Science underpins a huge range of subjects, and has concepts and ways of working that do not change quickly over time, including programming, algorithms and data structures. Our definitions of these terms are given on page 5.

Mirroring the expansion of computers into all areas of modern life, the academic discipline of Computer Science has advanced and has introduced new, important ways to view and understand the world in which we live. "Computational thinking" offers insightful ways to view how information operates in many natural and engineered systems.

Computer Science is also highly creative. This may be self-evident in the case of computer games, electronic art and computer-generated music, but these examples from the "creative" industries perhaps conceal the fact that writing any computer program involves creativity in the virtual universe behind the screen, and the fact that this is not widely realised or recognised reflects a need to communicate the intrinsic beauty and creativity of the discipline.

The time has come for Computer Science to be recognised in schools as a subject in its own right.

3. 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.
- Pupils should be exposed to, and should have the option to take further, topics such as: understanding of the internet and the design of web-based systems; the application of computers in society, business, the arts, science and engineering; computer programming, data organisation and the design of computers; and the underlying principles of computing.

These principles should apply across the UK. We make the following recommendation to achieve this in England.

Recommendation 6 (see Chapter 4)

The Department for Education should remedy the current situation, where good schools are dis-incentivised from teaching Computer Science, by reforming and rebranding the current ICT curriculum in England. Schemes of work should be established for ages 5 – 14 across the range of Computing aspects, e.g. digital literacy (the analogue to being able to read and write), Information Technology, and Computer Science.

These should be constructed to be implementable in a variety of ways, including a cross-curricular approach for digital literacy at primary and early secondary school. Schools may prefer not to impose a timetable or separately staff these elements at this age, but the existence of separately-defined learning experiences will ensure that each strand is always properly developed – unlike at present.

A timetable distinction should then be in place from the age of 14, allowing pupils to make a well-informed choice to study for recognised qualifications in Information Technology and/or Computer Science.

Given the lack of specialist teachers, we recommend that only the teaching of digital literacy is made statutory at this point. However, the long-term aim should be to move to a situation where there are sufficient specialist teachers to enable all young people to study Information Technology and Computer Science at school. Accordingly, the Government should put in place an action plan to achieve this.

The schools inspectorates should monitor the implementation of this change to ensure that the problems of the current curriculum are not replicated.

This approach aims to ensure that pupils are equipped with the basic skills they need at an early age but are not subjected to repeating things they already know. It provides a route for specialisation at the age of 14, and maintains a separation between basic level skills and the rigorous discipline of Computer Science. It also mirrors the existing science curriculum – with minimal distinction between strands at the early ages and greater differentiation at secondary school.

4. There is a need for qualifications in aspects of Computing that are accessible at school level but are not currently taught. There is also a need for existing inappropriate assessment methods to be updated.

The range of ICT and Computer Science-related qualifications at Level 2 in England, Wales, and Northern Ireland is overly diverse and confusing. Many of these qualifications do not appear to provide what employers and HE are looking for; others lack the currency of GCSEs and A-levels. The progression routes (e.g. from level 2 to level 3, or to employment or HE) are poorly defined.

The number of people entering ICT and Computing at GCSE and A-level has declined significantly in recent years. There is a similar trend in Scottish Highers and Advanced Highers.

Conversely, there has been a significant increase in the numbers studying OCR Nationals and other vocational ICT qualifications; however, perception of these is mixed and there has clearly been a shift away from academic Computer Science qualifications.

Recommendation 7 (see Chapter 5)
In order to redress the imbalance between academic and vocational qualifications in this area – and to ensure that all qualifications are of value to those who take them – the departments for education across the UK should encourage Awarding Organisations to review their current provision and develop Key Stage 4 (KS4) qualifications in Computer Science in consultation with the UK Forum (see recommendation 11), universities and employers.

Awarding Organisations across the UK should review and revise the titles and content of all new and existing qualifications in this area to match the disaggregation described above (e.g. Computer Science, Information Technology and digital literacy).

Assessment methods that rely on taking screenshots to document coursework (rather than take advantage of more modern submission methods) are a contributor to the negative perception of ICT.

Recommendation 8 (see Chapter 5)
The UK Forum (see recommendation 11) should advise Awarding Organisations on appropriate assessment methods for qualifications in digital literacy, Information Technology and Computer Science.

5. Enhancement and Enrichment (E&E) activities are needed to support the curriculum

There are many successful science, engineering and mathematics E&E activities in existence but there is lack of understanding in schools of what opportunities are available; rather than introducing further new schemes the existing activities need to be augmented, with better coordination between them to avoid fragmentation.

Many out-of-school STEM club schemes exist and have been shown to be effective. With sufficient support these could be extended to complement a Computer Science curriculum, thereby raising awareness of the subject and inclination towards further study.

Recommendation 9 (see Chapter 4)
The UK Forum (see recommendation 11) should put in place a framework to support non-formal learning in Computer Science and to support teachers. Considerations include after-school clubs, school speakers and mentoring for teachers in developing their subject knowledge. Bodies such as STEMNET will have a role to play in implementing this.

To inform the focus of investment in non-formal learning in Computing, the UK Forum should also look at establishing a rigorous evidence base for the effectiveness and value of various Computer Science E&E activities. Affordability will also be a relevant consideration.

6. Uptake of Computing A-level is hindered by a lack of demand from HE

Few HE departments appear to hold Computing A-level in high esteem and development of rigorous high-quality post-16 courses is required with the label 'Computer Science'.

There is a follow-through effect in numbers studying Computer Science courses in HE, which suffers from a high first-year attrition rate – possibly as a result of students arriving without a clear understanding of what Computer Science is.

Recommendation 10 (see Chapter 6)
Awarding Organisations should consult with the UK Forum (see recommendation 11 in Chapter 2) and HE departments to develop rigorous Level 3 academic qualifications in Computer Science.

How can these recommendations be taken forward?

A broad range of professional bodies, subject associations, academies and learned societies have an interest in this area, arising from the underpinning nature of Computer Science and the all-pervading nature of Information Technology in the modern world. Meeting the challenges of this report is a shared responsibility, and coordination between these bodies will be essential to provide a clear voice to government and to carry forward the recommendations in this report.

Many institutes and societies associated with other areas of science, engineering and mathematics such as the Royal Society of Chemistry, the Institute of Physics and the Society of Biology, have their origins in a community of many small organisations, and to some extent the process of subject division and recombination is a natural part of the evolution of a discipline. The bodies working in this area must now work closely together if the desired change is to be achieved.

Recommendation 11 (see Chapter 2)
The Computing community should establish a lasting UK Forum for joint working and coordination between the many Computing bodies, in order to progress the recommendations within this report. The Forum should provide regular progress reports on the implementation of the recommendations.

Summary

The UK has a proud history of contributions to Computing and especially to the discipline of Computer Science, but current terminology, curricula and qualifications are holding us back from being a nation of technology creators. Whilst a lot has been achieved in establishing a digitally literate population, our aspirations should not stop there. There are many barriers to progress, and a joined up approach is required. This report sets out a positive way forward for the community.

Introduction

1.1 Background and motivation

In autumn 2009, the Royal Society was approached by representatives of the computing community with concerns about the state of Computing education in the UK and a request that the Society turn its attention to this area.

At an initial meeting on 4 February 2010 convened by the Royal Society it was agreed that there was a fundamental issue in schools relating to the current ICT curriculum. It was agreed that Computer Science was now a mature, intellectual, science and engineering academic discipline, yet there was a disconnect with how and which aspects are presented in schools. Several factors pointed to a problem with the teaching of Computer Science and Information Technology in school:

- The publication of several high-profile reports describing negative attitudes towards the subject and criticising curriculum and qualifications, including:
  - The 2007 report, *Developing the future*[1], sponsored by Microsoft, City University, the British Computer Society, and Intellect, which says "learning to use a computer and learning Computer Science have become indistinguishable as far as students are concerned. The skew in emphasis has a direct bearing on a student's view of the IT industry; one that results in many negative perceptions".
  - The 2008 *IT & Telecoms Insight Report*[2], published by e-skills UK, which says "The image of IT-related degrees and careers was that they would be repetitive, boring, and more-of-the-same; for example use of IT office applications such as word processing, spreadsheets, and databases... The ICT GCSE had a major part to play in creating their (negative) impressions".
  - The 2009 Ofsted report, *The importance of ICT*[3], has a particularly detailed assessment of ICT and the issues described are referred to again in a follow-up report in 2011. The chapter *Rethinking ICT qualifications and progression routes* amounts to a strong critique of the educational value of teaching ICT skills when the focus of the teaching is on their vocational usefulness: "Students had plentiful opportunities to use ICT for presenting their work well and communicating their ideas....[but] coverage of control, sensors and databases was limited in many of the schools, as was the provision for students to learn the logical thinking necessary to program, write scripts or macros, which was cursory and superficial."

    [Concerning vocational courses at Key Stage 4] "Most of the competencies related to spreadsheets and databases that students are required to demonstrate for accreditation have already been covered at Key Stage 3. Many students therefore repeat work"

    "The predominance of vocational GCSEs also has ramifications for post-16 study. The vocational courses are poor preparation for the demands of A-level computer studies and ICT courses. Consequently, the number of students choosing these sixth-form courses is low. Compared to 2004, in 2007 around 25% fewer students were entered for A-level ICT, with the decrease comprising boys and girls equally. Over the same period, the decline in A-level computer studies was more severe with a 32% drop in entries (45% drop in girls' entries and 31% for boys)."

1 Microsoft 2007 *Developing the future: a report on the challenges and opportunities facing the UK software development industry.* Reading: Microsoft. (See http://download.microsoft.com/documents/uk/citizenship/developing_the_future2006.pdf)

2 *E-skills 2008 IT & Telecoms insight report*. (See www.e-skills.com/research/research-publications/insights-reports-and-videos/insights-2008)

3 Ofsted 2009 *The importance of ICT: information technology and communication technology in primary and secondary schools, 2005/2008*. London: Ofsted.

- Surprising trends in the number of students taking ICT or Computing courses in recent years[4]: a 60% decrease since 2003 in numbers achieving A-level Computing, down to just 4,002 in 2011; a 34% decrease at ICT A-level over the same period; and a 57% decline in ICT GCSE during 2006 – 11.

A further motivation for this study was the 'economic case'. Many studies describe the economic value of Computer Science and Information Technology education, and our concern was that the dwindling enthusiasm for these subjects generated by current educational systems was having a detrimental effect on 'UK plc'. The economic power of technology-driven nations such as Japan, China, and India underlines the need to be sure that Computing education in the UK produces a globally competitive society.

The case for curriculum reform was a particular source of interest, and the situation in this area has developed considerably in the last 18 months. A full review of the National Curriculum in England is now underway, and Science Minister David Willetts MP has announced details of a pilot scheme for an industry-supported project to introduce software development courses in schools[5]. In early 2011 a report by NESTA on Next Gen Skills was also released – this examined the needs of the computer games and visual effects industries in the UK and recommended that Computer Science should be a National Curriculum subject.

Attention to this area is therefore timely and significant.

There is a wide range of professional bodies, subject associations and learned societies working in this area, each of which through its own work was drawing similar conclusions and raising similar concerns. The Royal Society was asked to bring leadership to this area; to lend a critical eye to existing evidence, conduct its own investigations, and to validate the community's concerns.

The Royal Academy of Engineering has been an important partner in this work given the role of Academy Fellows in the study and the interplay between Computing as a science and as an engineering discipline. The Academy was a lead sponsor and enhanced its support for the study by organising a workshop for Academy Fellows to feed in their views.

This study therefore represents an unprecedented level of collaboration within a diverse community, and an excellent opportunity to investigate whether anecdotal evidence can be supported by reliable data.

1.2 The Computing in Schools project

1.2.1 Methodology

With generous financial support from a wide range of sponsors across professional bodies, industry and HE, the Computing in Schools study was launched in August 2010. The study was supported by an Advisory Group, Chaired by Professor Steve Furber FRS (for membership see Appendix A). The Group provided direction to the study and feedback on the development of this report, before it was submitted for formal review under the Society's usual guidelines[6]. The study was conducted in three parts – a call for evidence, a series of stakeholder meetings and a set of research projects.

The initial call for evidence in August 2010 invited interested stakeholders to provide reflective comments and suggestions of relevant reports, and this process prompted over 120 submissions (see Appendix C and summary below), from industrial leaders and membership societies to individual teachers, parents and even students themselves.

A series of focused stakeholder engagement workshops was then held in March 2011 at locations across the UK (see Appendix D for attendance). These allowed us to explore issues in greater depth, and to start to consider what possible conclusions and recommendations could be drawn. The events were separated according to audience, with workshops set up specifically for teachers in England and in Scotland, and events for employers, Higher Education and others.

Research was subsequently commissioned to supplement and analyse available evidence.

4 Source: JCQ – all UK figures, all ages – available from jcq.org.uk/national_results/index.cfm

5 See www.ft.com/cms/s/0/ee58426a-df9a-11e0-845a-00144feabdc0.html#axzz1iOVIrKc0

6 See Appendix B for Review Panel membership

We did not set out to define a curriculum for Computer Science, Information Technology or digital literacy; this report instead describes the structures that will need to be in place in order to allow suitable curricula to be developed.

1.2.2 Results of the Call for Evidence

The results of the call for evidence provided a clear picture of the strength of feeling on this issue – many were motivated to write at great length, with near unanimity that there were serious issues in this area for the Society to explore. Responses were received from learned societies, professional bodies, subject associations, industry, university departments, awarding bodies, schools, teachers and even pupils themselves and their parents.

The call for evidence provided many possible avenues for investigation, but six themes featured in some form in almost every response:

- **Conflation of the various components of Computing within the label 'ICT'** Students are not always aware which of Computer Science, Information Technology or digital literacy they are studying at any point – if indeed all three components are being taught at all – so a negative experience of digital literacy within ICT can sometimes put students off pursuing Computer Science or lead to a misunderstanding of what Computer Science 'is'.
- **A shortage of specialist teachers, and problems with availability and access to Continuous Professional Development that improves subject knowledge and understanding**
- **Implementation of the curriculum in schools and in particular the 'boring' nature of ICT in England** – often focusing on skills in using particular office software, and being overburdened by documenting students' work through screenshots in order to meet assessment requirements
- **League tables** The incentive for schools to achieve a good league table position can result in negative side-effects. Schools are incentivised to offer qualifications that are deemed to be equivalent to several GCSEs but which focus strongly on office skills and coursework. Schools are discouraged from risk-taking and so enter students for 'safe' ICT courses, rather than 'difficult' Computing qualifications.
- **Lack of understanding of Computer Science and Information Technology by senior management in schools** Computer Science is seldom recognised as a subject distinct from Information Technology and is rarely taught at all, leading to fewer specialist teachers being recruited and the status of the subject being reduced.
- **The 'image' of Computer Science** Some students are interested in and excited by Computer Science. For others it is seen as boring, geeky or difficult. There is also a significant gender bias.

These themes provided a framework for the rest of the project in terms of research commissioned, further soundings taken and conclusions drawn. The themes are reflected in the structure of this report, which is described in more detail below.

1.2.3 Research commissioned

Prompted by the results of the call for evidence and further discussions at stakeholder meetings, research was commissioned in the following areas:

- An analysis of available data on the training and deployment of 'specialist' Computer Science teachers, and a supplementary piece of research on job advertisements for Computer Science, both conducted by Professor John Howson (incorporated into chapter 7)
- A review of the Computer Science and Information Technology curricula of other countries, conducted by the National Foundation for Education Research (NFER) (incorporated into chapter 4)
- Surveys of existing Continuing Professional Development (CPD) courses in Computer Science and Information Technology (incorporated into chapter 7)
- Surveys of existing Enhancement and Enrichment opportunities in Computer Science (incorporated into chapter 4)
- Purchase and analysis of HESA data on HE student attrition from Computing degrees (see chapter 6)
- Purchase and analysis of UCAS data on applications to study Computing subjects at degree level (see chapter 6)

Further details of these can be found in the relevant sections of the report.

The Different Natures of Computer Science, Information Technology and digital literacy

A major theme arising from responses to our call for evidence was the problem of terminology in this area, and in particular the perils of conflating 'ICT' with Computer Science. This chapter therefore establishes working definitions and explores how problems can arise from confusing Computer Science, Information Technology and digital literacy. It also describes the role of Computer Science as an 'underpinning' subject and the way it relates to other disciplines.

2.1 Terminological issues

The issue of terminology was immediately identified by the Advisory Group as being a potential barrier to making progress in investigating this area, and a source of many problems in itself. It was well-known – and borne out in the responses to the call for evidence – that there are a wide range of terms in use, and that they are used in different ways to mean different things by different communities. For example, industry often refers to 'IT' (Information Technology), teachers following the National Curriculum in England use the phrase 'ICT' (Information and Communications Technology), teachers in Scotland refer to 'Computing Science', and academe prefers either 'Computer Science(s)', 'Computing' or even 'Informatics'. A parent or student may describe a subject as 'Computer Studies' or just 'Computers'. In the context of education and skills, these terms could refer to anything from being able to use a mouse, building a computer from hardware components, writing new software, or understanding the abstract underpinning principles of a computer.

It should be noted that 'ICT' is an unusually problematic term because it is commonly used to mean many different things. Among them are:

1. The (current, English, Welsh and Northern Ireland) National Curriculum subject called ICT (a combination of digital literacy, Information Technology and Computer Science).

2. The use of generic information technologies to support teaching and learning (interactive whiteboards, Virtual Learning Environments, class response systems, websites to distribute and submit homework, etc.).

3. The use of specific computer technologies to support particular aspects of a subject (for example, weather stations in geography, MIDI instruments in music, etc.).

4. The use of technologies to support teachers' administrative processes, and the school's management information systems, including registration, record keeping, finance, reporting, communicating, etc.

5. The physical infrastructure of a school's computer systems: the networks, printers and so on.

These multiple overlapping meanings present a significant barrier to communication. In this document we have therefore avoided the term 'ICT' entirely, except when speaking of the current provision as a National Curriculum subject or referring to existing qualifications.

The focus of this report is exclusively on the first meaning above, namely Computer Science and Information Technology as subjects in their own right, and on digital literacy as a core skill. The various applications of information technologies to support teaching and learning throughout a school (2 – 5) are important, of course, but these uses have been covered elsewhere[7], and are outside the scope of this report.

Terminological issues in this area and attempts at solving them are nothing new, or indeed restricted to the UK. Chapter 4 highlights the terms some other countries use in their educational settings, demonstrating that the problem exists on a global scale, and has no simple solution. Appendix J charts key developments in the UK, including the changing use of terminology.

Whatever the origins, at present we have a situation where industry, academe and teachers lack a consistent language within which to communicate business needs, careers advice, and curriculum content. The impact of this is a major theme of this report.

7 The second meaning of ICT above is referred to in the Royal Society 2011 *Brain waves module 2: neuroscience: implications for education and lifelong learning.* London: Royal Society. (See www.royalsociety.org/policy/projects/brain-waves/education-lifelong-learning)

2.2 Definitions of terms used in this report

Given the confusion between stakeholders described above, it is important to define what we mean when we use the terms 'Computer Science', 'Information Technology' and 'digital literacy' in this report.

The Computing community is necessarily a 'broad church', and it has proved impossible to define terms to everyone's satisfaction. Nevertheless, in order for this report to be written it was necessary to construct working definitions and some clear suggestions for how to describe the various components of this landscape.

In some ways, the distinction we draw between digital literacy at one end of the spectrum and Computer Science at the other parallels the existence of terms such as 'numeracy' and 'functional maths' alongside mathematics, or 'scientific literacy' alongside science. The difficulties of finding words that reflect the need for a 'curriculum for all' alongside a 'curriculum for future specialists' and the need to understand whether the two overlap are by no means limited to Information Technology and Computer Science.

This is not the first time that terminology has been called into question; a rich history of terminological change is described in the timeline of developments in Computing education given in Appendix J.

Definitions of terms used in this report

Computer Science should be interpreted as referring to the scientific discipline of Computer Science, covering principles such as algorithms, data structures, programming, systems architecture, design, problem solving etc.

Information Technology should be understood to mean the assembly, deployment, and configuration of digital systems to meet user needs for particular purposes. We elaborate this definition in Chapter 2, section 2.5.

Often we use the phrase Computer Science and Information Technology to indicate the union of the two, as this report reflects issues in both areas. We avoid using the term 'ICT', except when referring to existing curricula or qualifications that are labelled as such. We elaborate on this definition in Chapter 2, section 2.4.

Digital literacy should be understood to mean the basic skill or ability to use a computer confidently, safely and effectively, including: the ability to use office software such as word processors, email and presentation software, the ability to create and edit images, audio and video, and the ability to use a web browser and internet search engines. These are the skills that teachers of other subjects at secondary school should be able to assume that their pupils have, as an analogue of being able to read and write. We elaborate on this definition in Chapter 2, section 2.6.

Inevitably there will be topics that test the extent to which the three areas above can be effectively disaggregated – there will always be some blurring at the boundaries. Nevertheless, we maintain that it is useful to make these distinctions as an aid to effective communication between stakeholders.

2.3 Problems arising from conflating Computer Science, Information Technology and digital literacy

Our suggested definitions above draw the distinction between two separate subjects – Computer Science and Information Technology, along with the basic skill of digital literacy. Conflation of these areas is at the heart of the problem that this report explores. The English National Curriculum currently combines all of these into one subject known as ICT (see Chapter 4), and this leads to many of the problems in England described in later chapters. It is notable that the existing ICT and Computing A-levels have different purposes and target audiences, and the labelling of ICT in the current English National Curriculum to cover the whole spectrum is therefore misleading to students.

One obvious effect of this conflation is on student progression when making subject choices. Participants at our stakeholder events explained that students frequently associate their (often negative) experience of digital literacy within the heading of 'ICT' at school with the discipline of Computer Science, and are put off studying either subject post-16. Those that do study towards the existing A-levels in ICT or Computer Science may subsequently choose the wrong university course on the basis of terminological problems and then leave their course – this phenomenon is explored further in Chapter 6.

Conclusion

Industry, academe and teachers lack a consistent language within which to communicate business needs, careers advice and curriculum content to key policy stakeholders including Government. Existing terminology gives rise to considerable confusion which can effect young people's subject choices and lead to poor policy-making

Recommendation 1

The term ICT as a brand should be reviewed and the possibility considered of disaggregating this into clearly defined areas such as digital literacy, Information Technology and Computer Science. There is an analogy here with how English is structured at school, with reading and writing (basic literacy), English Language (how the language works) and English Literature (how it is used).

The term 'ICT' should no longer be used as it has attracted too many negative connotations.

To underline our distinction between Information Technology and Computer Science we explore below the 'nature' of these subjects.

2.4 The Nature of Computer Science

It is the firm belief of the Advisory Group to this project that Computer Science is a rigorous subject discipline, in the same way that Mathematics or Physics are. The 'Computing at School' group[8] characterises a 'discipline' as a subject that has[9]:

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

Computer Science is a discipline with all of these characteristics[10]. It encompasses foundational principles (such as the theory of computation) and widely applicable ideas and concepts (such as the use of relational models to capture structure in data). It incorporates techniques and methods for solving problems and advancing knowledge (such as abstraction and logical reasoning), and a distinct way of thinking (computational thinking) and working that sets it apart from other disciplines. It has longevity (most of the ideas and concepts that were current 50 or more years ago are still applicable today), and every core principle can be taught or illustrated without relying on the use of a specific technology.

Concepts include:

- **Programs:** these 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. This abstraction is the key to controlling the enormous complexity of real programs (e.g. a web browser), which consists of dozens of layers of such abstractions.
- **Algorithms:** re-usable procedures (often a sequence of steps) for getting something done. For example, plan the shortest delivery route for a lorry, 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 (twos-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.
- **Architecture:** this 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.
- **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 of such a collection.

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8 The Computing at School Working Group (CAS) is a grass roots organisation that aims to promote the teaching of Computing at school. CAS is a collaborative partner with the BCS through the BCS Academy of Computing, and has formal support from other industry partners. See computingatschool.org.uk

9 UK Computing Research Committee 2009 *Computing at school: the state of the nation*. (See www.computingatschool.org.uk/data/uploads/CAS_UKCRC_report.pdf)

10 We are by no means the first to state that Computer Science is a discipline. This has been asserted at least since 1989, for instance in "Computing is a discipline", Communications of the ACM (January 1989, Vol 32:1, pp9-23), available from cs.gmu.edu/cne/pjd/GP/CompDisc.pdf

Alongside these concepts are a set of Computer Science 'methods' or ways of thinking, including:

- Modelling: representing chosen aspects of a real-world situation in a computer.
- 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.
- Designing, writing, testing, explaining, and debugging programs.

These ways of thinking have much in common with other sciences and mathematics.

Moreover, Computer Science is an 'underpinning' subject, in the sense that its concepts are useful to many other science and engineering disciplines, particularly physics, and in some cases they are relied upon to such an extent that they can be considered to be part of that subject too. For example, algorithms are sometimes considered to be an element of discrete mathematics, and the logical and rigorous approach of Computer Science has much in common with mathematics in general[11]. Indeed, the use of digital technologies in the teaching of mathematics (given the overlap in areas such as algorithms, and the need for technology to teach mathematical modelling in particular) is the subject of a report from the Joint Mathematical Council of the UK released in November 2011[12].

Establishing territorial boundaries between subjects is problematic, and in common with other fundamental disciplines, Computer Science can sometimes suffer from being assumed to be primarily a 'tool' for other sciences rather than a subject in its own right. It is both of these, and in particular it is a science and an engineering discipline. However most STEM initiatives do not explicitly refer to Computer Science as a STEM discipline.

2.5 The Nature of Information Technology

Information Technology is the application of computer systems and the use of pre-existing software to meet user needs. It is the assembly, deployment and configuration of digital systems to meet user needs for specific purposes. Information Technology involves:

- Using software for storing and manipulating data (sorting, searching and reordering), file systems (naming, categorising and organising), and the effective application of databases and spreadsheets for particular tasks.
- Creating and presenting information within a variety of contexts with a sense of audience, fitness for purpose and drafting and redrafting as key considerations.
- Designing and configuring systems for others to use including spreadsheets, databases, web-based interfaces such as quizzes, forum, wiki and profile pages.
- Project planning and management including the identification of need, writing specifications, designing and creating products, evaluating their effectiveness and so identifying the further development to meets the needs of the user.
- Security, safety, and etiquette online, in particular when using email, forums, virtual worlds and social networks.
- The social, economic, ethical, moral, legal and political issues raised by the pervasive use of technology in the home, at work and for leisure.

Technology has evolved rapidly in recent years with the emergence of multimedia computers, the internet and worldwide web, mobile Computing and web 2.0 applications, and will continue to evolve in the future. Despite these changes, the critical elements of Information Technology as a subject will remain:

- handling and communicating information,
- designing and creating resources,
- evaluating and sensing fitness for purpose, and
- being aware of the implications of the pervasive use of technology in society.

11 For a discussion of the merits and drawbacks of an 'across the curriculum' approach to ICT and Computing see §4.6.

12 Joint Mathematical Council 2011 *Digital technologies and mathematics education*. (See www.ncetm.org.uk/files/9793653/JMC_Digital_Technologies_Report_2011.pdf)

2.6 The nature of digital literacy

Digital literacy is the analogue of being able to read and write – a fundamental skill which it is necessary to possess in order to access all subjects across the curriculum, including Computer Science and Information Technology. Digital literacy is not a 'subject' in itself – neither are reading and writing – but is an essential skill for all in the modern age.

Digital literacy is the ability to use computer systems confidently and effectively, including:

- 'Office' applications such as word processing, presentations and spreadsheets
- The use of the Internet, including browsing, searching and creating content for the Web and communication and collaboration via e-mail, social networks, collaborative workspace and discussion forums
- Creative applications such as digital photography, video editing, audio editing.

We intend "digital literacy" to connote those skills that (say) a history teacher can assume his / her students have, just as s/he assumes they can spell (literacy) and do simple mental arithmetic (numeracy). Higher level information handling skills are part of Information Technology.

Digital literacy does need to be taught: young people have usually acquired some knowledge of computer systems, but their knowledge is patchy. The idea that teaching this is unnecessary because of the sheer ubiquity of technology that surrounds young people as they are growing up – the 'digital native' – should be treated with great caution.

In terms of delivery, digital literacy can be treated much like literacy and numeracy are dealt with at school:

- Discrete lessons and teaching embedded within the broader curriculum throughout primary education and in the early part of secondary education.
- Opportunities for pupils to apply and develop these skills through authentic, purposeful and collaborative projects in most or all subject areas throughout primary and secondary education.

Whilst digital literacy skills can be taught and assessed using online systems, at the pupil's own pace, teacher-led lessons and project work allow the teacher to focus on developing pupils' knowledge and understanding of the systems pupils use, and provide opportunity for collaborative work.

Conclusion

Information Technology and Computer Science are distinct subjects, with different purposes, although they have areas of synergy. Computer Science is an academic discipline, in the same way that mathematics and physics are.

Digital literacy is a core skill for accessing subjects across the curriculum, including Computer Science and Information Technology themselves.

2.7 The nature of the Computing community

The terminological issues described above, the existence of two distinct subjects across the academic/vocational divide and their 'underpinning' nature are all reflected in the ways in which the Computing community has formed into a range of subject associations, learned societies, professional bodies and others. The result of this is a diverse community, but one which has chosen to unite on the issue of school education for the purposes of this report, under the auspices of the Royal Society.

Bodies working in this area include:

- BCS – the chartered institute for IT
- Computing at School – a 'grass roots' organisation of teachers of Computer Science and ICT
- CPHC – the Council of Professors and Heads of Computing, representing academic computer scientists
- e-skills UK – the sector skills council for Business and Information Technology
- Intellect – the trade association for the UK hi-tech industry
- ITTE – the Association for Information Technology in Teacher Education
- Naace – the subject association for ICT
- National Computing Centre – representing the corporate IT sector
- NESTA – the National Endowment for Science, Technology and the Arts
- UKCRC – the UK Computing Research Committee, an organisation of leading Computing researchers from academe and industry
- UKIE – the Association for UK Interactive Entertainment, which is leading on the follow up to NESTA's Next Gen report

Many institutes and societies associated with other science and engineering subjects such as the Royal Society of Chemistry, the Institute of Physics and the Society of Biology have their origins in a community of many small organisations, and to some extent the process of subject division and recombination is a natural part of the evolution of a discipline. Computer Science and Information Technology are subjects that have only emerged in the last 60 years; whatever ways the bodies above choose to develop in the next century, it is acknowledged by the Advisory Group for this report that retaining some forum for these bodies to work more closely together would be useful.

Contrasting somewhat with the references to the number of separate bodies working in this area, it is notable that although Naace is identified as the subject teaching association for ICT there does not appear to be an analogue for Computer Science. The community clearly feels that distinguishing between Computer Science and Information Technology is helpful, and formally establishing a separate home for Computer Science teachers would help to set them on an equal footing.

Conclusion

A broad range of professional bodies, subject associations, academies and learned societies have an interest in this area, arising from the underpinning nature of Computer Science and the all-pervading nature of Information Technology in the modern world. Meeting the challenges of this report is a shared responsibility, and coordination between these bodies will be essential to provide a clear voice to government and to carry forward the recommendations in this report.

Recommendation 11

The Computing community should establish a lasting UK Forum for joint working and coordination between the many Computing bodies, in order to progress the recommendations within this report. The Forum should provide regular progress reports on the implementation of the recommendations.

2.8 Gender issues

A gender imbalance in the study of Computer Science is both perceived and real. In 2011, for instance, across the UK only 302 girls took Computing A-level (7.5% of the total entry), compared to 3,700 boys (92.5% of the total entry).[13]

Exploration of A-level entry trends (see table 2.1) shows that the percentage of female entries to Computing A-level has continued to fall and has consistently been much lower than the percentage of female entries to ICT A-level. The latter actually rose during 2001–2011 and has consistently been similar to the percentage of female entries to mathematics A-level.

The low level of female entry to Computing A-level is even more severe than that observed in physics, where girls traditionally account for around 20% of all A-level entries. Similarly, while more boys take A-level mathematics and chemistry, the distribution of entries by gender in both these subjects is more even.

2.9 The relationship between Computer Science and Information Technology

Between them, digital literacy, Information Technology and Computer Science span the traditional academic-vocational divide, and form a broad spectrum of knowledge and skills ranging from the most abstract aspects of Computer Science to the most software-specific skills of digital literacy.

All parts of this spectrum are important in a modern society, from office skills to specialised programming (see Chapter 3). It is therefore important to take a holistic approach to discussing the teaching of Information Technology and Computer Science in schools to ensure that the full diversity of relevant knowledge and skills in this area is accounted for. The Royal Society was keen to ensure from the outset that this project was not limited to niche interests or guided towards a narrow view of education.

However, the Royal Society's decision that this report should cover both Information Technology and Computer Science should not be interpreted as a call for a similar approach in policy decisions. On the contrary, it is essential that government departments distinguish between Information Technology and Computer Science when considering curricula, funding, specialist teachers and many other issues described in later chapters. Continued blurring will lead to poor policy-making.

Table 2.1 Comparison of percentages of entries to Computing and ICT A-levels with entries to selected science A-levels across the UK by gender (2002–2011)

	2002		2003		2004		2005		2006		2007		2008		2009		2010		2011	
	%M	%F	%M	%F	%M	%F	%M	%F	%M	%F	%M	%F	%M	%F	%M	%F	%M	%F	%M	%F
Computing	86	14	87	13	88	12	89	11	90	10	90	10	91	9	90	10	91	9	92	8
ICT	65	35	66	34	65	35	65	35	64	36	63	37	62	38	61	39	62	38	61	39
Mathematics	63	37	63	37	61	39	62	38	61	39	60	40	60	40	59	41	59	41	60	40
Physics	77	23	77	23	78	22	78	22	78	22	78	22	78	22	78	22	78	22	79	21
Chemistry	49	51	48	52	49	51	51	49	51	49	50	50	51	49	52	48	52	48	53	47

Source: JCQ
Note: Data for ICT in 2002 and 2003 come from Interboard Statistics (supplied by Dr Jim Sinclair, Director, JCQ, personal communication, 24 October 2011).

13 Source: JCQ (see www.jcq.org.uk, accessed 21 October 2011).

Making the case for digital literacy, Computer Science and Information Technology

UK global competitiveness in the IT sector, and in many other sectors that rely on IT skills, is dependent upon a home-grown, reliable and growing supply of highly skilled graduates with significant deep knowledge in Computing disciplines, and with the skills to operate in multidisciplinary and fast changing environments in industry and research[14].

The trends in the numbers of young people studying for Information Technology and/or Computer Science qualifications are a source of concern to the community (see Chapter 5). To assess whether this concern is justified we explore in this chapter the economic and educational cases for Computer Science, Information Technology and digital literacy.

3.1 The 'economic' case for digital literacy, Computer Science and Information Technology

Although we argue in this report that it is important to distinguish between digital literacy, Computer Science and Information Technology when making education policy decisions, in this section we consider the 'economic' case for the latter two together, as existing data makes any other approach problematic. To evaluate these contributions we look to descriptions of the value of what is usually referred to as 'the IT industry'. A number of reports confirm that digital literacy, Information Technology and Computer Science can contribute significantly to the future wealth and health of the UK economy, and that the IT sector is a significant part of economic activity in the UK.

3.1.1 The economic case for digital literacy

The significance of education in this whole area extends beyond the IT industry, even if the skills being used are more at the level of digital literacy. In a submission to Lord Carter and the Digital Britain report in 2009, e-skills UK and Skillset estimated that 22m people in the UK now use technology in the workplace, with the proportion having nearly doubled to 77% over the previous 20 years[15].

In terms of 'basic ICT skills' (defined by the CBI as familiarity with word processing, spreadsheets, file management etc.), relatively few employers are dissatisfied with school/college leavers' abilities – some 88% of respondents to the 2011 CBI education and skills survey[16] reported that they were satisfied or very satisfied in this regard – the highest satisfaction level of the skill areas investigated. However, the Royal Academy of Engineering's 2009 report *ICT for the UK's Future* found that "the UK has lost or is in danger of losing core IT skills underpinning business competitiveness. Development and maintenance of such skills are essential to the creation of a strong cadre of technicians to keep the 'virtual pipes' working for the UK economy"[17].

According to PriceWaterhouseCoopers, there are 9.2 million people in the UK who are 'digitally excluded' – 15% of the population. It goes on to say that if digital exclusion were fully addressed, the results would be increased educational attainment, better access to jobs and skills, household savings through online shopping, and increased access to health and other public services online, resulting in cost savings to government and benefits to the individuals. 'The Economic Case for Digital Inclusion' quantified the potential economic benefits that could result from getting everyone in the UK online as in excess of £22 billion[18].

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14 Council of Professors and Heads of Computing 2008 *The decline in computing graduates: a threat to the knowledge economy and global competitiveness*. (See www.cphc.ac.uk/docs/cphc-computinggraduates-june08.pdf)

15 DCMS & DBIS 2009 *Digital Britain: final report.* Norwich: The Stationery Office. (See www.official-documents.gov.uk/document/cm76/7650/7650.pdf)

16 CBI 2011 *Education and skills survey 2011*. London: CBI. (See www.cbi.org.uk/media/1051530/cbi__edi_education___skills_survey_2011.pdf)

17 Royal Academy of Engineering 2009 *ICT for the UK's future*. London: Royal Academy of Engineering. (See www.raeng.org.uk/news/publications/list/reports/ICT_for_the_UKs_Future.pdf)

18 PriceWaterhouseCoopers 2009 *The economic case for digital inclusion*. London: PriceWaterhouseCoopers. (See www.raceonline2012.org/sites/default/files/resources/pwc_report.pdf)

3.1.2 Impact of Computer Science and Information Technology on the UK economy as a whole

The economic impact of a discipline may be quantified by looking at the numbers of related jobs as well as their contribution to the UK's gross value-added (GVA)[19].

In 2008, the Technology Insights report by e-skills UK placed the total figure for IT jobs at 1.07 million, but with a prediction that this would rise to 1.23 million by 2016[20]. The 2011 report noted that one in twenty people employed in the UK worked in the IT and Telecoms workforce (1.5 million people) and that this comprised around 863,000 in the IT and Telecoms industry itself and a further 674,000 working as IT or Telecoms professionals in other industries. The report also places the combined contribution of the UK IT and Telecoms industry at £81bn, or 9% of the UK economy[21]. The Royal Academy of Engineering uses ONS data to report that the UK IT industry produces an annual GVA of £30.6bn, forming 3% of the total UK economy in 2004[22].

Apart from the significant number of jobs that are IT related and IT intensive, advances in Computer Science and Information Technology have in turn led to advances in science and engineering that are valuable both to society and the economy as a whole. These advances require scientists and engineers in different fields to become more familiar with computational thinking (see box for examples). It is reasonable to hypothesise that providing a basic grounding in Computer Science at school will be valuable for a wide variety of future scientists and engineers. Advances in most major societal challenges require significant Computer Science skills and input.

19 GVA measures the contribution to the economy of each individual producer, industry or sector in the United Kingdom. GVA is used in the estimation of Gross Domestic Product (GDP). GDP is a key indicator of the state of the whole economy. The link between GVA and GDP can be defined as: GVA (at current basic prices; available by industry only) plus taxes on products (available at whole economy level only) less subsidies on products (available at whole economy level only) equals GDP (at current market prices; available at whole economy level only). (Taken from www.statistics.gov.uk/cci/nugget.asp?id=254).

20 *E-skills 2008 IT & Telecoms insight report*. (See www.e-skills.com/research/research-publications/insights-reports-and-videos/insights-2008)

21 E-skills 2011 *Technology insights 2011 UK*. (See www.e-skills.com/gamesreport).

22 Royal Academy of Engineering 2009 *ICT for the UK's future*. London: Royal Academy of Engineering.

The following examples illustrate advances in science, engineering and technology that have required scientists and engineers in a variety of fields to develop a greater aptitude for computational thinking, and the extent to which Computing is now all-pervading.

The Human Genome Project was successful because of advances in computer controlled robotics and data analysis techniques[23]. "From the beginning, laboratory automation has been recognised 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 challenges[24]. As a result CERN is now a leading developer of a global Computing infrastructure called the Grid spanning 50 countries. According to CERN "The infrastructure built by integrating thousands of computers and storage systems in hundreds of data centres worldwide enables a collaborative Computer Science environment on a scale never seen before."[25]

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."[26]

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.[27]

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.[28]

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.[29]

23 www.lbl.gov/Science-Articles/Archive/human-genome-mapping-sequencing.html

24 CERN 2008 *Data analysis*. (See http://public.web.cern.ch/public/en/Research/DataAnalysis-en.html)

25 CERN 2011 *Worldwide LHC computing grid*. (See http://lcg.web.cern.ch/lcg/public/default.htm)

26 Met Office 2011 *Climate modelling*. (See www.metoffice.gov.uk/climate-change/guide/science/modelling)

27 Roberts, F 2004 *Science careers: computational and mathematical epidemiology*. Washington: AAAS.

28 Airbus 2011 *Fly-by-wire*. (See www.airbus.com/innovation/proven-concepts/in-design/fly-by-wire)

29 Wilson, R 2011 *Ten million lines in 29 months – model-driven development on the Chevy Volt*. (See www.eetimes.com/discussion/-include/4215057/Ten-million-lines-in-29-months--model-driven-development-on-the-Chevy-Volt)
Brooke, L 2011 Computer code an increasingly precious E.V. commodity. (See www.nytimes.com/2011/01/23/automobiles/23SPIES.html)

However, data from the Higher Education Statistics Agency (HESA) from 2009/10 suggest that 14.7% of Computer Science graduates (as defined by HESA) are unemployed 6 months after completing their degree, the highest rate of unemployment among graduates of any subject, and significantly above the 9.1% average across all degrees[30]. Philip Hargrave, Chair of the ICT Knowledge Transfer Network has recently written to the Chief Executive of HESA to highlight the issue of overly-broad categorisation and to request that a more detailed analysis be undertaken. Further support for our decision to treat this information with suspicion can be found in a NESTA report which found that there are many university courses purporting to provide specialist training for the video games and visual effects industries, but that 'a strengthened accreditation system for such courses would highlight their industry relevance'[31]. It should also be noted that large numbers of entry-level jobs have been lost through the demise of graduate training schemes and off-shoring of entry level jobs which means that industry is making higher demands of the skills from graduates they wish to employ. Finally, we observe that the measure of employability is based on an individual's status six months after graduation, which is hardly a reflection of long-term value, particularly in a recession.

There is potentially a powerful link between Computing and entrepreneurial activity. The two most successful recent start-ups in the Computing and business world – Facebook and Google – were led by people who had been writing software at university.

The Cabinet Office estimates that cyber attacks cost the UK economy £27 billion per year, and this figure is growing rapidly. There is currently a shortage of Computer Science experts who understand how to combat cyber-crime in both the UK and the US[32].

3.1.3 Impact on the relevant sectors

Figures from the ONS Labour Force Survey 2010 show that 1.5 million people are emplyed in the IT and Telecoms workforce – 598,000 in the IT industry itself, 264,000 in the Telecoms industry and 674,000 as IT and Telecoms professionals in other sectors[33]. NESTA reports that global sales relating to the UK video games industry alone in 2008 amounted to £2 billion[34]. More recently, a Council for Industry and Higher Education (CIHE) report claims that the creative[35], digital and IT industries in the UK employ over 2.5 million people and contribute £102 billion in GVA, and that the worldwide IT industry is now worth $3 trillion[36]. It is often noted that there is a trend for IT jobs to be offshored to low cost economies. However, there are some data to suggest that at the same time more highly skilled jobs are created. For example, 70,000 computer programming jobs were offshored in the US between 1999 and 2003. Over the same period 115,000 more highly paid and highly skilled computer software engineering jobs were created in the US[37]. Offshoring lower skilled jobs has reduced costs, permitting companies to invest more in Research and Development, which has been focused in those countries with the most advanced education systems.

30 HESA 2011 *Destinations of leavers from higher education*. Cheltenham: HESA.

31 NESTA 2011 *Next gen: transforming the UK into the world's leading talent hub for the video games and visual effects industries.* London: NESTA. (See www.nesta.org.uk/library/documents/NextGenv32.pdf)

32 Cabinet Office 2011 *The cost of cyber crime.* Guildford: Detica.

33 E-skills 2011 *Technology insights 2011 UK*. (See www.e-skills.com/gamesreport).

34 NESTA 2011 *Next gen: transforming the UK into the world's leading talent hub for the video games and visual effects industries.* London: NESTA.

35 DCMS data shows that Software, Electronic Publishing and Digital & Entertainment media (Computer Games) remains the largest of the 'creative' industries contributing 44% of Creative industries GVA, 33% of total Creative employment and 45% of Creative businesses.

36 Council for Industry & Higher Education 2010 *The Fuse*. London: CIHE. (See www.cihe.co.uk/cihe-task-force-urges-far-reaching-changes-to-ensure-uk-is-a-leader-in-the-creative-digital-and-information-technology-industries)

37 Dash, S 2005 *The economic implications of outsourcing*. (See www.ssrn.com/abstract=779005).

The Royal Academy of Engineering report *ICT for the UK's Future* recommended that many more 14 – 19 year olds should be motivated to pursue careers in ICT and allied trades, advocating the development of appropriate qualifications in the implementation, upgrading, installation and support of complex IT systems. This description matches our formulation of 'Information Technology' in chapter 2[38].

A further proxy for the value of Computing skills to employers is the extent to which industry itself invests in on-the-job training courses in this area, such as apprenticeships and other vocational qualifications. In collaboration with STEMNET, BT has recently launched an IT Ambassador programme to provide eMentoring for young people, provide industry contacts for teachers and support development of resources to help teachers bring the subject to life. Some IT and software firms offer their own qualifications, which underlines the importance which industry places on developing skills.

3.1.4 Economic value to the individual based on salary returns

Any sector will need a supply of people with appropriate knowledge and skills, and the potential value to employers (and therefore the economy) of people with the relevant skills can also be measured by wage premiums – the extra remuneration an individual can expect to receive for holding a degree in Computer Science per se, beyond the premium for simply holding a degree. A PriceWaterhouseCoopers report claims that people with good ICT skills (as PWC defines them) earn between 3% and 10% more than people without such skills[39].

However, the picture here is complicated by the fact that the IT industry does not restrict its recruitment to Computer Science and Information Technology graduates – the ACCU, a membership organisation for programmers, told us that 'pupils who are potential [software] developers would do just as well to study a maths, science or engineering degree rather than aiming exclusively for a computer science degree… studying [computer science] is not necessarily the default option for anyone interested in software'.

Assessing the value to the individual of a degree in Computer Science or Information Technology is therefore not without its pitfalls. Further analysis in this area is needed.

3.2 The educational case for digital literacy, Computer Science and Information Technology

The 'need' for individuals who have studied a specific subject should not be defined solely by the demands of industry; businesses rise and fall, and their requirements change – it is therefore appropriate to consider whether a need for digital literacy, Computer Science and Information Technology education exists in a sense that is not purely utilitarian.

3.2.1 The educational case for digital literacy

In terms of the more basic skills, it is clear that being 'digitally literate' is fundamental to participation in modern society – even elements of the democratic process are based online now, such as 'ePetitions'. One submission to the call for evidence developed the 'literacy' analogy further, noting that 'being able to find and process information [using ICT] is an extremely useful life skill – it enables people to access all other areas of knowledge'. Research also points to a lack of digital literacy skills being linked to social exclusion[40].

There is also an increasing need for young people to learn to be safe and lawful when using information technology. A respondent to an e-skills UK survey of employers put it this way:

"It is easier to get "mugged" online than it is in real life and this is probably because most of us are taught for example where it is sensible to go after dark and who to talk to, but fewer people are aware of how to avoid some of the online traps that are out there."

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38 Royal Academy of Engineering 2009 *ICT for the UK's future*. London: Royal Academy of Engineering.

39 PriceWaterhouseCoopers 2009 *The economic case for digital inclusion*. London: PriceWaterhouseCoopers. (See www.raceonline2012.org/sites/default/files/resources/pwc_report.pdf)

40 PriceWaterhouseCoopers 2009 *The economic case for digital inclusion*. London: PriceWaterhouseCoopers. "Evidence from a range of sources points to a strong correlation between digital exclusion and social exclusion although the direction of causation is less clear8. We estimate that of the 10.2 million adults who have never used the internet, 4.0 million (9% of the UK population) also suffer severe social exclusion." (See www.raceonline2012.org/sites/default/files/resources/pwc_report.pdf)

3.2.2 The educational case for Computer Science

Perhaps most significantly, members of our Advisory Group and attendees at stakeholder meetings described how learning Computer Science developed young people into 'technology designers and creators' rather than merely 'technology users' – a philosophy of creativity and expression rather than mere productivity. Correspondents also pointed to the 'empowering' nature of understanding how a computer works and being able to create new systems as well as use those designed by others.

There is also clearly a stimulating intellectual element to Computer Science education. In their submission to our call for evidence, Naace told us that 'Computing… provides a degree of systematic thinking, attention to detail… that allows a higher order contribution to society, and a proper understanding of what has become a fundamental aspect of modern life.' The Computing at School group went further, by saying that 'Computing leads to deep enquiry, such as what it means to think, and new insights into life itself… Not only is Computing extraordinarily useful, but it is also intensely creative, and suffused with both visceral ("it works!") and intellectual ("that is so beautiful") excitement'.

We may summarise the educational arguments for Computer Science thus:

- **Computation is a fundamental part of our world.** We teach every school child elementary physics, although only a small percentage will become physicists, because they live in a physical world and some understanding of how that world works is essential for them to engage fully with it. As with physics, so with Computer Science: we want our children to understand and play an active role in the digital world that surrounds them, not to be passive consumers of opaque and mysterious technology. A sound understanding of Computer Science concepts enables them to get the best from the systems they use, and to solve problems when things go wrong. Citizens able to think in computational terms are able to understand and rationally debate issues involving computation, such as software patents, identity theft, genetic engineering, and electronic voting systems for elections.
- **Computer Science develops key thinking skills** of logical reasoning, modelling, abstraction, and problem-solving. For example, like Mathematics or Latin, Computer Science requires care and precision. Unlike those subjects the consequence of a lack of precision is immediately obvious: programming teaches respect for accuracy and attention to detail. The consequence of a lack of precision is that the program fails – the student gets immediate feedback. Similarly, the idea of breaking down a problem into sub-problems that can be solved separately takes a very concrete form in Computer Science, in which sub-systems interact through carefully-defined interfaces.
- **Creation and Creativity:** The Computer Science student has unprecedented freedom over what, and how, to create. Programming is the quintessential craft: the principles of quality, workmanship, fitness for purpose, and considerations of project management (time, quality and cost), are all learned here in their purest form. At the same time the student has the opportunity to make their ideas real and thus to appreciate how such ideas could be improved.
- **Computational thinking is invading every other discipline[41,42].** It is a commonplace observation that computers are a pervasive tool in other disciplines, but of late it has been suggested that computational thinking is changing the disciplines themselves. Computational thinking is the process of recognising aspects of computation in the world that surrounds us, and applying tools and techniques from Computer Science to understand and reason about both natural and artificial systems and processes.

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41 Wing, J 2006 Computational thinking. *Communications of the ACM, Vol. 49, No 3*.

42 National Academy of Engineering 2010 *Report of a workshop on the scope and nature of computational thinking*. Washington: National Academy of Engineering. (See http://books.nap.edu/openbook.php?record_id=12840&page=1)

3.2.3 The educational case for Information Technology

As with Computer Science, the importance of Information Technology is not defined merely by the needs of employers. Our definition of Information Technology extends beyond basic skills, and there are also compelling 'educational' arguments for this higher level of ability. Naace told us that 'ICT and Computing empower their students to think and act independently, making efficient and effective use of the technology available... ICT supports the creative expression of individuals through many media, and provides a diverse, global audience for the fruits of such creativity.' The Welsh National Curriculum for ICT states that 'ICT contributes to learners' personal and social education by providing opportunities to work in contexts that allow learners to make decisions based on the values that underpin society, helping them become active and informed global citizens. They begin to identify and question bias in sources of information and become increasingly aware of the social, ethical and moral effects of ICT in the wider world'[43].

Information Technology – at all levels – can be considered to be an 'empowering' subject in the sense that it can underpin creative expression, meticulous design and realisation, effective analysis and use of information and safe and secure social participation.

3.3 Digital literacy, Computer Science and Information Technology in Schools

Digital literacy, Computer Science and Information Technology may be important in both economic and educational senses, but this alone does not justify the need for specific subjects to be taught in state-funded schools. Indeed, it could be argued that if there is a business need for a particular skill then it should be businesses that invest in providing it once the individual reaches the world of work, rather than during schooling. In a crowded curriculum schools are faced with difficult choices – without increasing the length of the school day, a decision to teach one subject will be at the expense of another, and without increasing a school's budget the decision will be to decrease resource elsewhere. A report that recommends teaching a particular subject or topic should consider the 'zero sum' nature of this situation carefully before reaching its conclusion.

The basis of the current review of the National Curriculum in England is to identify the 'core' knowledge that students need and to leave subjects outside this core to a teacher or a school's discretion[44]. At the time of writing, programmes of study for Mathematics, Science, English and Physical Education are being developed within 'phase 1' of the review, with consideration of other possible subjects being undertaken in early 2012.

At present, Computer Science occupies a similar space to psychology, geology, economics and law in 5 – 19 education; the subject exists as Computing (Science) at A-level and equivalent, but is not currently a distinct pre-16 subject in the curriculum, though some qualifications are starting to move it in this direction[45]. Why should this change? Similar arguments about the economic importance of economics and law to the UK could potentially be constructed, as could wage returns to the individual.

The argument hinges on the role of Computer Science as an 'underpinning' discipline that supports other sciences, the need to signal its national economic importance, and the extent to which the study of Computer Science develops higher thinking and analytical skills. In the case of Information Technology, the argument rests on pervasiveness of applications in the modern world, the enhanced capacity for creativity and expression, and the notion that without preparing young people for this at the school level we will be doing the next generation a great disservice.

43 DCELLS 2008 *Information and communication technology in the national curriculum for Wales*. Cardiff: Welsh Assembly Government.

44 Publicly-funded schools in England achieving 'Academy' status are to be granted flexibility to deviate from the National Curriculum, so long as a 'broad balanced' curriculum is provided – see www.education.gov.uk/schools/teachingandlearning/curriculum/a0061710/review-of-the-national-curriculum-in-england-frequently-asked-questions

45 A GCSE in Computing has recently been piloted in England – see section 5.3

Based on the economic and educational arguments above, it is our conclusion that:

- Computer Science is sufficiently important and foundational that it should be recognised as a high status subject in schools, like mathematics, physics or history.
- 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 both Information Technology and Computer Science) from primary school age onwards, and by age 14 should be able to choose to study towards a recognised qualification in these areas
- Pupils should be exposed to, and should have the option to take further, issues such as understanding of the internet and the design of web-based systems, the application of computers in society, business, science and engineering, computer programming, data organisation and the design of computers, and the underlying principles of computing.

As presented above this is largely a philosophical conclusion, based around what should be the case on the basis of the arguments in this chapter; practical options for curriculum reform arising from this are explored in Chapter 4.

Conclusions:

- Digital literacy, Computer Science and Information Technology make a significant impact on the UK economy and will continue to do so in the future.
- A compelling 'business' and 'educational' case exists for digital literacy, Information Technology and Computer Science.
- Computer Science is sufficiently important and foundational that it should be recognised as a high status subject in schools, like mathematics, physics or history.
- 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 both Information Technology and Computer Science) from primary school age onwards, and by age 14 should be able to choose to study towards a recognised qualification in these areas.
- Pupils should be exposed to, and should have the option to take further, issues such as understanding of the internet and the design of web-based systems, the application of computers in society, business, science and engineering, computer programming, data organisation and the design of computers, and the underlying principles of computing.

The School Curriculum

Having established that Information Technology and Computer Science are both nationally 'important', we now turn to the school context and the curriculum in particular.

4.1 Current National Curricula in the UK

In this section we explore the status quo in terms of the curriculum in England, Wales, Scotland and Northern Ireland. In each case we consider (i) the 'intended' curriculum – i.e. what is prescribed in official documents, and (ii) perceptions of the 'implemented' curriculum – i.e. what is actually taught in schools. The issue of terminology is prominent here (see Chapter 2).

For a view of 'how we got here' in the sense of curriculum reform and terminological change please see Appendix J.

From the table overleaf it is clear that there is considerable curriculum variation even within the UK, both in terms of labels used and whether the subject is distributed across the curriculum or taught separately. Reflections on the curriculum in England were particularly numerous and troubling.

We focus our attention particularly on England for the rest of this section; during this project a review of the National Curriculum for England has been announced, which makes recommendations in this area particularly timely (see Chapter 4, section 4.7). Scotland has already been through this process recently and is now working on new qualifications to complement the new curriculum, which raises its own issues (see Chapter 5).

Respondents to our call for evidence noted that in some cases ICT was being well taught, and that the current National Curriculum in England gave sufficient scope for teachers with specialist knowledge and enthusiasm to teach the necessary concepts up to Key Stage 3 (despite the label merging the two subjects –Information Technology and Computer Science). However, there was concern expressed by many respondents, and participants in our stakeholder meetings, that the current curriculum was written in such a way as to allow non-specialists to teach most of it, and that there was therefore little incentive for school leaders to recruit specialist teachers, particularly given that supply is known to be an issue (see Chapter 7). A 2009 thematic report from Ofsted[46] noted that 'students were spending considerable time demonstrating proficiency in what they could already do in order to meet the assessment criteria, rather than being introduced to new and more challenging material and skills... Teachers gave too much emphasis to teaching students to use particular software applications rather than helping them to acquire genuinely transferable skills.' – i.e. it is the digital literacy elements that are being emphasised rather than Computer Science and Information Technology.

Clearly any reform of the curriculum needs to take into account that there is a shortage of specialist teachers of Information Technology and Computer Science at the moment (see Chapter 7). Any changes must also be supported by sufficient CPD to support existing teachers.

Conclusion

The current National Curriculum in England lumps together a range of aspects of Computing including Computer Science, Information Technology and digital literacy under the heading 'ICT'. A consequence is that Computer Science is often forgotten or ignored within the heading of ICT, resulting in teaching being biased towards 'how to use office software' rather than the knowledge that will form a foundation for the rest of a pupil's life. This has led to many people holding a very negative view of ICT, to the extent that terminological reform and careful disaggregation is required.

46 *The importance of ICT* report – www.ofsted.gov.uk/resources/importance-of-ict-information-and-communication-technology-primary-and-secondary-schools-20052008

	England	Scotland
Labels used	Information and Communication Technology (ICT)	(i) ICT to enhance learning (ii) Computing science
Context within curriculum structure	ICT is currently one of twelve core subjects – a review is in progress	The Curriculum for Excellence for ages 3 to 15 is described in terms of 'Experiences and outcomes', in eight broad curricular areas, divided into organisers'[47]. Within the 'Technologies' curriculum area, there are six organisers, two of which are 'ICT to enhance learning' and 'Computing science'.
Ages taught	Compulsory in KS 1 – 4 (age 5 – 16)	An entitlement for all learners
Description – the 'intended' curriculum	The majority of the ICT curriculum relates to learning about how to use and share information, with relatively few references to Computer Science concepts. However, at Key Stage 1 (age 5 – 7), students are expected to learn 'how to plan and give instructions to make things happen' (for example, programming a floor turtle, placing instructions in the right order). During Key Stage 2 (age 7 – 11), this is expanded to 'how to create, test, improve and refine sequences of instructions to make things happen and to monitor events and respond to them (for example, monitoring changes in temperature, detecting light levels and turning on a light). The Programme of Study at KS3 (age 11 – 14) includes (as one component among many) 'Use ICT to make things happen by planning, testing and modifying a sequence of instructions, recognising where a group of instructions needs repeating, and automating frequently used processes by constructing efficient procedures that are fit for purpose'. This matches part of the description of 'Computer Science' in chapter 2, albeit without mentioning the word itself. The focus here is on programming, although Computer Science is much broader than this.	(i) 'ICT to enhance learning' is seen as cross-curricular, and the responsibility of all teachers. It is mainly skills-based, in the manner of 'digital literacy' in our definitions given in Chapter 2. (ii) 'Computing Science' includes 'building digital solutions', 'knowledge and understanding of the components of a computer' and 'designing and implementing a game, animation or other application' at third level (i.e. the broad general education during the first 2 – 3 years of secondary school – age 12 – 15). These are considered an entitlement for all learners. There are other 'Computing Science' experiences and outcomes at 4th level (an optional extension for more able learners aged 12 – 15), which are optional (for learners and schools), and include security software, emerging technologies, basic principles of a programming or control technology, and creating animations.
Description – the 'implemented' curriculum	The overwhelming concern from respondents to our call for evidence and our stakeholder meetings was that there was a separation between the intended curriculum in England as described by official documents and what is actually taught in schools. The vast majority pointed to an undesirable 'flexibility' in the current curriculum, with the result that Computer Science elements described above are not being taught in practice. Some felt that the curriculum was simply too broad to be implementable. NAACE told us that 'The National Curriculum for ICT has the strength of permitting much and prescribing little'. NAACE went on to say that 'The position of Computing within the ICT curriculum up to and including KS3 is more positive, with much innovative, engaging work taking place using now common tools such as Bee Bots, Roamers, Logo, Scratch, Game Maker and Lego.'	The Curriculum for Excellence is being rolled out during 2012 – 15, and we reserve judgement on whether the implementation will match the aims outlined above. SQA is developing new qualifications for upper secondary, to reflect and build upon the Curriculum for Excellence, with first qualifications in 2014 (current S1 pupils). However, although the third level Computer Science outcomes are deemed to be an entitlement, consultation with teachers in Scotland indicates that some schools are not replacing their Computing teachers when they retire – this presents a risk to delivering on this entitlement. Consequently, there is a risk that the issues reported in England – where a flexible curriculum is interpreted in a narrow way when there is a lack of knowledgeable teachers – may start to arise in Scotland. Careful monitoring of this situation as the Curriculum for Excellence is rolled out would be advisable.

47 SQA 2010 *Curriculum for excellence: technologies: experiences and outcomes*. (See www.ltscotland.org.uk/Images/technologies_experiences_outcomes_tcm4-539894.pdf)

48 External qualifications are the main means of assessing attainment in Key Stage 4 rather than curriculum documents.

49 DCELLS 2008 *Skills framework for 3 to 19-year-olds in Wales*. Cardiff: Welsh Assembly Government.

Wales	Northern Ireland
Information and Communication Technology (ICT)	Information and Communication Technology (ICT)
ICT is one of twelve core subjects	ICT in Northern Ireland is identified as one of the three statutory, cross curricular skills, along with Communication and Using Mathematics (also see section 4.6 for discussion of a distributed approach to ICT).
Compulsory throughout Key Stages 2 – 3 (ages 7 –14)[48].	Compulsory cross-curriculum element for years 1 to 12 (ages 4/5 – 15/16)
Revised programmes of study and attainment targets for ICT came into effect during 2008 – 09, superseding the previous National Curriculum for 'Information Technology'. Key Stage 2 refers to skills that correspond with our own definition of Information Technology, such as 'use an increasing range of ICT tools and resources to find, process and communicate relevant information'. At Key Stage 3 children are expected to consider social, economic, ethical and moral issues raised by the impact and use of ICT, and produce and use databases to analyse data and follow lines of enquiry (e.g. simple and complex queries – searches/sorts) Programming does not feature in the Key Stage 2 – 3 National Curriculum in Wales. To help schools deliver the revised curriculum, a non-statutory 'Skills Framework for 3 to 19-year-olds in Wales' has also been developed[49]. This framework defines the range of skills that learners aged 3 – 19 should develop, and provides guidance about continuity and progression in developing thinking, communication, number and ICT across the curriculum. In September 2010 the Welsh Government introduced an entitlement for all learners in Key Stage 4 to develop and apply their ICT skills and, where appropriate, to have those skills recognised by an accredited qualification.	Teachers are encouraged to provide pupils with opportunities to acquire, develop, understand, demonstrate and apply ICT concepts and processes appropriately in a variety of meaningful contexts across the curriculum. "Using ICT" is assessed and reported on using levels of progression which are set out under headings described as the 5 "E"s – Explore, Express, Exchange, Evaluate and Exhibit. However, there do not appear to be any references to Computing concepts such as programming. Currently an ICT accreditation scheme is available for schools to use on a voluntary basis however it is planned that the scheme will become compulsory in 2013. The scheme is based on the teacher assessment of pupils' skills using ICT at the end of key stage 1, 2 and 3. Teachers are encouraged to ensure that these skills are developed each year as pupils progress and that they should base their evidence of pupils' competence on work undertaken across the Areas of Learning or subject specialisms. Pupils are required to demonstrate their level of competence of Using ICT by carrying out tasks set in a variety of subject contexts that provide opportunities to cover the breadth of the 5 "E"s. At key stage 3 the curriculum is defined across Areas of Learning (The Arts, English and Irish, Environment and Society, Mathematics, Modern Languages, Physical Education, Science and Technology, Religious Education) and within these the statutory requirements for each subject there are statements on learning outcomes for ICT. It should be noted that there is no subject requirement for ICT in the planned curriculum at key stage 3. At key stage 4 the curriculum is defined by the Areas of Learning and schools are required to ensure that pupils complete a minimum of one course (GCSE) in each of the areas. ICT is not included in any of these areas as a course however schools are required to ensure that pupils have opportunities to continue to develop their skills in Using ICT as a cross curricular theme.
We received very few comments on the implementation of the National Curriculum in Wales. Like England, there is variability in how much time students actually get on ICT at KS3 and KS4 and how much of this includes anything that relates to Computer Science. This may depend on a school's subject leadership and expected local employment outcomes for its students.	The Northern Ireland Curriculum has been in place in schools for five years with two years of training and support for school leaders prior to that. The use of ICT in primary schools is progressing well as evidenced in comments from recent inspection reports: "Information and communication technology is used very effectively to support teaching and learning across the curriculum. Effective use is made of a range of ICT, including interactive games, websites and programmable devices to support learning and teaching in English and mathematics." Although post primary schools have not been encouraged to retain ICT as a separate subject at key stage 3 most schools have found time in the curriculum and continue to offer it at least in the first two years. At key stage 4 the majority of schools offer ICT as a GCSE subject and in some cases they have made it compulsory that all pupils participate.

4.3 International Comparisons

The National Curriculum in England is currently being reviewed by the Department for Education, and it is known that the process has involved looking at the curricula of successful countries and regions (in terms of PISA and TIMSS results[50]). International comparisons are therefore highly relevant to education policy at present, albeit with the caveat that many other factors contribute to the educational success of a country beyond its intended curriculum, and that a simple transplant of one element is unlikely to have the desired effect[51].

As part of our project, the National Foundation for Educational Research (NFER) was commissioned to undertake desk research into the school curricula of Singapore, Japan, Finland, Canada (Ontario), and USA (Massachusetts). The aim was to investigate (i) whether other countries encountered the same terminological problems as we do in the UK, and how their school curriculum accounts for this, and (ii) whether and at what ages various components of Computer Science and Information Technology are taught.

It should be noted that the focus of this research was strictly the intended curriculum of these countries, rather than the implemented curriculum. As discussed above, the situation in England demonstrates the scope for divergence between intention and implementation.

The countries above were chosen for the extent to which their curricula are already influencing policy in England – Singapore and Finland in particular are often looked to as examples of 'high performing countries' in terms of PISA and TIMMS results. Ontario and Massachusetts were chosen for their reputation in developing innovative curricula, and Japan was selected as an example of a country whose economy is known to depend heavily on high technology.

Other countries and regions were considered but not explored for various reasons, including pragmatic issues such as availability of curriculum documents written in English (Hong Kong, Austria and Russia), and potential challenges that countries may face in providing their students with the access to computers (India – where it is acknowledged that computer access and connectivity present a serious barrier to delivering their curriculum aims).

The research comprised an initial web search and interpretation of curriculum documents available online, followed by validation of NFER's interpretation by contacts in each country[52].

Alongside NFER's research, use was made of the Royal Society's membership of the ALLEA network of scientific academies in Europe[53]. Contacts were asked to provide information on their country's National Curriculum with respect to Information Technology and Computer Science; responses were received from Serbia, Montenegro, Italy and Finland.

The main findings overall were as follows:

- The comparator countries vary considerably in how (or indeed, if at all) the subjects equivalent to Information Technology and Computer Science are represented in their curricula. In most of them, Information Technology is integrated with other learning during the earlier years of education, being used as a tool across the curriculum. Where Information Technology and/or Computer Science are represented as discrete subjects, this tends to arise at the later stages of schooling. In some cases these are compulsory, and in others they are optional.

- A wide range of labels is used to describe Information Technology and Computer Science, in some cases with this label changing between the upper primary/lower secondary phases. These include 'Technics and informatics' (Montenegro),

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50 Trends in International Mathematics and Science Study (TIMSS) – http://nces.ed.gov/timss - and the OECD Programme for International Student Assessment (PISA) - www.pisa.oecd.org – provide information on the relative educational performance of countries. ICT is not assessed as part of these surveys, but a country's overall 'ranking' relative to others has been a subject of recent political attention.

51 Oates, T 2010 *Could do better: using international comparisons to refine the National Curriculum in England*. Cambridge: Cambridge Assessment.

52 Usually education ministry contacts or similar

53 ALLEA is a Federation of 53 National Academies of Sciences and Humanities in 40 European countries – see www.allea.org/Pages/ALL/4/731.bGFuZz1FTkc.html

'Technology Literacy' (Massachusetts), 'Computer and Information Sciences' (Serbia), and 'Computer Technology' (Ontario). It is notable that the phrase 'Information and Communication Technology' does not appear in the curricula of the countries studied, although it is known that some other countries use this term.

- There is also considerable variation in the ages at which Information Technology or Computer Science are first taught (see below)
- The use of Information Technology (and safe and secure use of ICT in particular) is included in the curriculum more commonly than the technical aspects of Computer Science such as programming
- Where Computer Science features in a curriculum it tends to include programming – in some cases specific languages are identified, while in others there is flexibility ('industry standard')

An illustration of the ages at which the broad areas of Information Technology and Computer Science are introduced is given in the table below. In cases where the starting age for Information Technology is quite high it should not be inferred that students do not use computers before this age – merely that it is not specified in the curriculum.

Full details are available in NFER's report[56]. Highlights from specific countries are as follows:

- In Japan Information Technology education is textbook-based. One of the 'Information' textbooks (used from age 10) covers the themes of: the information society and the computer; the mechanism of the computer and its function; modelling of problems and the use of computers; storage and management of information and databases; and progress of information technology and impact on society. However, there is no mention of networks and systems management in the Japanese system.
- Massachusetts is unusual in specifying keyboarding skills – the standards for 11 – 14 year olds indicate that students should be able to type 25 – 30 words per minute with fewer than 5 errors. On the more technical side, students at ages 14 – 18 are expected to identify properties of devices and understand addressing schemas (e.g. Internet protocol (IP) addresses, Dynamic Host Configuration Protocol (DHCP) and Domain Name System (DNS).

Country/region	**Information Technology** (use of software packages, word processing, spreadsheets, presentations)	**Computing** (Using formulae in spreadsheets, understanding what a 'program' is and suggesting improvements, later adapting and constructing programs, understanding and/or constructing networks, systems management)	**Computing** (Programming specifically, although in some cases may refer to floor turtles[54])
Finland[55]	9	14-16	?
Italy	14	14	?
Japan	10-12	12	12
Massachusetts	6	12	14
Montenegro	11	14	15
Ontario	6	14	15
Serbia	7	15	13
Singapore	12	16	16

54 'Floor turtles' are educational robots that can be provided with sequences of movement instructions

55 Finland has no national curriculum for ICT; these are the ages at which school might tend to introduce the skills, through their optional courses

56 Available from royalsociety.org/education/policy

- Singapore's post-secondary Higher 2 curriculum for Computing (age 16+) covers five modules: the development of computer solutions; programming concepts; algorithm and design; data management; and computer systems.

- Ontario provides a wide range of optional courses, broadly split into 'technological education' and 'Computer studies'. Students studying 'Computer Engineering and Technology' at age 16 upwards are expected to design, install, configure, test and troubleshoot networks. Those studying Computer Technology at the same age will have experience of planning, installing and managing a computer network. Under the 'Computer Studies' stream students develop a solid foundation in software development, algorithms and data structures, programme correctness and efficiency, and professional and ethical responsibility.

From this small-scale study it is obvious that there is considerable variation in the extent to which Computer Science and Information Technology are part of a country's National Curriculum – some have almost no references, and others include Computer Science concepts from an early age. We also learn that terminology problems are not unique to the UK. There appears to be no single model to point to, or evidence to suggest that there is a right or wrong approach.

4.4 Reforming the curriculum: international comparisons

Several other countries have encountered exactly the same issues as those highlighted in this report, and are actively reforming their high school curricula to increase the emphasis on computer science as a discipline. For example:

- United States. The *Computer Science Teachers Association*[57] in association with over 80 universities, has developed a new national Advance Placement course in *Computer Science Principles*[58]. This course is just one aspect of a major alliance of employers, professional societies and others, called *Computing in the Core*[59], aimed at reinvigorating the high-school curriculum with Computing content. A key report was the CSTA's report *Running on empty: the crisis in K-12 Computer Science education*[60].

- Israel undertook a major review of Computing at school in the 1990s, and now has the most rigorous Computer Science high school program in the world. One of the key papers is *A model for high school computer science education: the four key elements that make it*[61]. The new curriculum has been in place since 1995, and is taken by 10,000 – 20,000 students.

- New Zealand. Following two influential reports in 2008 (Grinsey et al[62], Carrel et al[63]), New Zealand has revamped its school curriculum in Digital Technologies, and from 2011 has an explicit strand entitled "Programming and computer science". The course designers are now shifting their focus from making the case for Computer Science at school to the challenge of implementation: materials, teacher training, and so on. All seven major Computer Science departments have been involved in this course redesign, and in supporting teacher training.

- Germany. In 2008 Germany adopted new high-school standards that clearly distinguish ICT from Computing education. The key curricula documents are in German, but an English-language overview is

57 www.csta.acm.org

58 www.csprinciples.org

59 www.computinginthecore.org

60 Association for Computing Machinery & Computer Science Teachers Association 2010 *Running on empty: the crisis in K-12 computer science education*. (See www.acm.org/runningonempty/fullreport.pdf)

61 Hazzan, O, Gal-Ezer, J & Blum, L 2008 *A model for high school computer science education: The four key elements that make it* 39th Technical Symposium on Computer Science Education, SIGCSE Bulletin, vol. 40(1), pp. 281–285. ACM: New York.

62 Grinsey, G & Phillipps, M 2008 *Evaluation of technology achievement standards for use in New Zealand secondary school computing education.* Wellington: NZCS.

63 Carrel, T, Gough-Jones, V & Fahy, K 2008 *The future of Computer Science and Digital Technologies in New Zealand secondary schools: Issues of 21st teaching and learning, senior courses and suitable assessments* (See http://dtg.tki.org.nz)

given in *Bridging ICT and CS: educational standards for computer science in lower secondary education*[64] (Brinda et al).

- India offers high-school education in Computer Science. For example the Council for Indian Certificate Examinations (an awarding body) offers Computer Science exams for age 15[65] and 17[66]. The International GCSE in Computer Science and International Baccalaureate are gaining popularity in India, and a group of academics is working on a new Computer Science curriculum for schools[67].

- South Korea. The existing high school curriculum[68] in South Korea already includes some computer science (including object-oriented programming, simple algorithms and logic circuits). A new draft curriculum has been proposed for introduction in 2013 (approximately), with less emphasis on programming and more on fundamental concepts of computer science.

All of these countries have recognised the need to offer Computer Science as a subject discipline to their high school students, and have reformed their curricula to do so, or are in the process of reform.

Conclusion

There is considerable variation in national curricula for Information Technology and Computer Science in terms of content taught, ages introduced and labels used. No single model of best practice exists in the UK or internationally. A number of other countries have considered this issue in the last decade and are taking steps to put in place a new curriculum for Computer Science.

4.5 Anecdotal evidence submitted to the Royal Society relating to the school experience

A number of school pupils and parents were motivated to submit personal responses and anecdotes to the Society's call for evidence. Alaia (aged 14) told us that:

"We all know how to use WORD, EXCEL, POWERPOINT, CAD, etc., we even sometimes have to instruct our teachers on how to perform something new as they do not seem to keep up with the continual changes in ICT… [We] are bored in ICT, it's not that it is not an important subject, ICT is vital in today's world, but you are teaching us things we already know and unless we need to specialise there is no need to teach us beyond Year 7 where we conquer most office applications if we haven't already done so by the end of primary school."

This can be interpreted either as reflecting the inadequacies of the current National Curriculum for ICT in England in terms of its scope for minimalist interpretation, or as an example of the effects of relying on teachers with low subject knowledge to deliver the programme of study. Both of these clearly affect pupil perception of ICT, and potentially of Computer Science too.

Several students who responded to the call for evidence felt that their ability to use a computer was better than their teacher's. This matches Ofsted's comment in a recent thematic report that 'Sometimes pupils' ICT capability was so good that it outstripped their teachers' subject knowledge and, as a result, their good progress was not sustained. In such circumstances, higher-attaining pupils often underachieved'[69]. This issue relates closely to the supply of specialist teachers (see Chapter 7).

64 Brinda, T, Puhlmann, H & Schulte, C 2009 Bridging ICT and CS – Educational Standards for Computer Science in Lower Secondary Education. ACM SIGCSE Bulletin, Vol. 41, Issue 3.

65 CISCE 2011 *ICSE (class X) computer science syllabus year 2012*. (See www.cisce.org/ICSE%20SYLLABUSES%202012%20FINAL%20CRC/18.ICSE%20Computer%20Science%201.pdf)

66 CISCE 2011 *ICSE (class XII) computer science syllabus year 2012*. (See www.cisce.org/ISC%20Syllabus%202012/26%20ISC%20Computer%20Science%20Scope.pdf)

67 Iyer, S, Baru, M, Chitta, V, Khan, F, & Vishwanathan, U 2010 *Model Computer Science Curriculum for Schools*. Mumbai: Indian Institute of Technology.

68 National Curriculum Information Center 2011 *High school curriculum: South Korea*. See http://ncic.kice.re.kr/nation.dwn.ogf.inventoryList.do)

69 Ofsted 2009 *The importance of ICT: information technology and communication technology in primary and secondary schools, 2005/2008*. London: Ofsted.

Case study:
Queen Elizabeth School, Kirkby Lonsdale

Despite the nature of the current ICT curriculum, there are examples across the country of schools that are bucking the trend and tackling the problems described in this report. One of these is Queen Elizabeth School, an 11-18 mixed comprehensive in the small market town of Kirkby Lonsdale, Cumbria.

There are five specialist ICT teachers (including two Computer Science graduates) at Queen Elizabeth School. After a fall in numbers in around 2001 interest in Computing at A-level is now growing across the school. Roger Davies, Director of IT, reports that two factors have been key: developing a curriculum in the lower school that introduces pupils to Computing early and, more recently, offering the new GCSE in Computing (see § 5.3).

"Many young children, when probed, are curious about the technology they take for granted. They want to know how Google finds so many hits so quickly, and how it ranks them. How an email gets to its correct destination, how predictive text works and so on. In recent years, activities from Computer Science Inside, cs4fn (see §4.12) and others have made these concepts very accessible to young children, particularly when mixed with explorations in programming. If programming conjures up visions of blank faces staring at incomprehensible code it is time to rethink. Over the last six years, we have developed projects that introduce coding in enjoyable and engaging ways. Scratch, BYOB, the modelling tool StarLogoTNG and others have been used at Key Stage 3 (11-14 years old). They all use visual languages, thus avoiding the problem of unforgiving syntax and allowing children to focus on the structure and sequence of their commands. Other projects, for example writing html or using RoboMind introduce the rigour of text based coding at a later stage, whilst GameMaker allows Year 9 children to design their own computer games – a fusion of creativity and computation. These wonderful free tools have given us the opportunity to plant the Computing flag within Key Stage 3 ICT."

The school has itself identified the need to distinguish between Computer Science and other subjects:
"Renaming the department 'Computing and ICT' helps make clear the distinction between our emerging discipline and digital literacy. It is still a work in progress, but when a class descends into silence, so absorbed in a challenge that you can almost hear their collective brains ticking, you know you're on to a winner.

It is not just about programming, it is more fundamental. It is about logic, abstraction and problem solving. Children who engage in these tasks are developing thinking skills that transfer to many other areas. Above all, the projects are fun because of their capacity to stretch pupils and make them tenacious thinkers. There is something very special about the moment 'it works!'."

Case study (continued)

At Key Stage 4 (14 – 16) the school offers the vocational level 2 OCR Nationals ICT qualification. Although this is a popular qualification, the school also wanted to offer a course that would appeal to the technically savvy and intellectually curious:

"Previous ICT GCSEs had, for many, proved boring and demotivating. They focused largely on 'office' skills; in the words of one pupil "Teaching the boring bits of my Mum's job". Not so the new Computing GCSE. Although less than two years old, it is proving a hit with those who study it. Again there are lots of free resources that offer the next step up for pupils. As it becomes established we can provide, for the first time, a clear progression route to A-level Computing.

In the past, identifying students who might wish to study Computing happened through lunchtime clubs. These are still important and we currently run a Year 7 Computing club, making such activities distinct from other ICT work. Currently they are experimenting with Kodu, a free, three dimensional, visual game coding environment. Older Computing students help run the club. Others work as informal testers of new projects or resources. Our sixth form Computing students have a particularly valuable role".

Roger Davies teaches the A-level course but also oversees the management of the IT infrastructure. As such, the in-house technical support team is focused on providing for the needs of the students. A wide range of programming tools are available across the network. In the Computing suites, imaginative ways have been found for students to explore operating systems, network protocols and system tools.

"Whilst this could provide potential for misuse, there have never been any such incidents. The students understand that their rights entail responsibilities and act accordingly. Indeed, they help police the network, letting the technical staff know of any flaws they discover. This is a responsibility they value and it has meant we can provide a relatively open resource (albeit closely monitored) and thus avoid many of the frustrations inherent in locked down systems. The support of other teachers, principally through the Computing At School (CAS) working group has also spurred on developments. We hope to work with other geographically dispersed schools in the region to form a local CAS hub. The simple aims are to educate, engage and encourage one another".

Case study:
Langley Grammar School, Slough

Langley Grammar School (LGS) is a mixed selective school on the Slough and West London boarder with around 1000 students. It has been a Maths and Computing specialist school since 2004 and is a member of the Leading Edge network with a commitment to supporting schools in the local area.

The Digital Schoolhouse (DSH) is a transition project established to offer Years 5 and 6 pupils from local primary schools the opportunity to visit LGS for a day of free specialist teaching in a dedicated ICT and Computing environment. The project's coordinator, Mark Dorling, is a primary trained teacher with secondary ICT and Computing teaching, and industry experience.

In response to the proposed changes to the National Curriculum in the 2009 Rose Report and to feedback received from primary and secondary schools on transitional and curriculum challenges; the DSH started to teach ICT skills discretely within a creative curriculum, and to focus on the teaching of the different aspects of Computing.

The aim of DSH lessons is to accelerate pupils' learning of new skills and concepts with a focus on how they are deployed in secondary education, the world of work and business. Once consolidation of the key skills and concepts has taken place, a typical DSH lesson will develop the learning to focus on the expected outcomes for that age group, and introduce pupils to concepts and principles from KS3 and even KS4. This accelerated learning is achieved by challenging pupils' perceptions and their expectations when working in an ICT suite, with Computing concepts being taught (wherever possible) without the use of computers and related to pupils existing 'real world' understanding.

The experience in the DSH confirms that KS2 pupils are often far more capable than the existing ICT curriculum allows for; this experience has been shared with Computing at School (CAS) during the development of the KS3 and KS4 *A Curriculum for Computing* document.

All new lessons developed in the DSH are now in alignment with the CAS *A Curriculum for Computing* document. A number of subject departments have collaborated with the DSH to develop KS2 lessons, the English department to teach creative writing using Scratch, the MFL department to teach French using Probots, the Maths department to teach algebra using Scratch to make a calculator, and the ICT department to develop a Computing lesson based on how the internet and search engines work.

A number of collaboration projects utilizing the expertise of industry, Universities and educational visitor centres provided 'real life' scenarios to engage and stimulate pupils. For example, the DSH collaborated with Royal Holloway, University of London to develop database projects based Science and Literacy, with Hampton Court Palace to use their maze as a scenario to teach Logic using Scratch, and Philosophy for Children (Philosophy of Computing) through consultation with Dialogueworks. The DSH is currently developing a lesson on Human Computer Interaction based on mobile phones in collaboration with Blackberry and Queen Mary, University of London.

Case study (continued)

Visiting class teachers are also provided with CPD opportunities through team teaching and gaining confidence to use lesson resources from the DSH website. The project regularly receives excellent feedback from both staff and pupils; teachers feel more confident to deliver similar lessons in school, and use their next DSH booking to experience a different Computing lesson.

The DSH also regularly supports the wider education community through lecturing at Brunel University (Education Department), running twilight workshops for experienced teachers, chairing a cluster group of local schools running events such as programming competitions, and articles in various educational publications about creative ways of teaching Computing concepts and innovative teaching pedagogy; this is helping to raise the profile of Computing in local primary schools.

There has also been a significant impact within LGS by the DSH project. The ICT department is fortunate to have two Computing specialists and an Advanced Skills Teacher in ICT who have benefited from a pedagogy and subject knowledge exchange. Teaching materials from the DSH have been adapted for use in lessons and extra-curricular activities in KS3. This has helped ensure a good uptake into GCSE Computing in KS4 and a growing enthusiasm for Computing amongst students and Senior Management.

4.6 ICT across the curriculum?

The phrase 'ICT across curriculum' can mean two quite different things in a school context:

a) Using information and communication technology to enhance learning in, say, history.

b) Embedding the teaching of ICT skills in other curriculum subjects – e.g. Excel skills are learnt through subjects such as business studies and mathematics.

These are not the same, but they are very frequently conflated. In our opinion, the former is a given, and is not the focus of this report. The latter is the approach taken through the ICT curriculum in Northern Ireland, and many international examples of this exist.

The call for evidence and stakeholder meetings provoked a mixed response to this approach – some saw this as an efficient way of building the ICT curriculum into the school day, but others were highly sceptical of the idea that many different teachers throughout the school could between them have sufficient subject knowledge to avoid a tick-box approach. Naace notes that ICT as currently constructed can be delivered in a solely distributed way, but also cautions that there are many potential problems with this method and few examples of success.

To extend the analogy of 'literacy' to basic digital literacy skills, an approach that may satisfy these concerns is to ensure that young people are taught how to use computers in Key Stage 1 and 2, much as they are taught to read and write, but with a subsequent emphasis on extending this skill in new contexts through other subjects or cross-subject projects rather than teaching discretely.

Computer Science, on the other hand, is a largely 'concept'-driven subject and is therefore more suited to specialisation in secondary school than either being taught across the curriculum or being made compulsory throughout schooling.

4.7 The 2011–12 National Curriculum Review in England

During the project the Royal Society submitted evidence to the Department for Education to inform the 2011–12 review of the National Curriculum in England. Our submission[70] highlighted terminological problems in this area (see Chapter 2) and the 'flexibility' of the current curriculum, and suggested that many pupils were turning away from studying either Computing or ICT at GCSE and A-level on the basis of an impoverished experience delivered by non-specialist teachers. Longitudinal studies would be needed to firmly establish a causal link between a negative school experience and deciding not to take the subject at A-level, but the weight of opinions

70 See Appendix E.

expressed in our call for evidence leads us to believe that this is the case.

Our submission also indicated that a body of 'essential knowledge' across the Information Technology and Computer Science landscape exists and could be included in a new National Curriculum in place of the existing entitlement, and suggested that a statutory component linked to this could help ensure that the shortage of specialist teachers will not dissuade schools from striving to teach these important subjects.

Chapter 3 describes the nature of both Computer Science and Information Technology, and identifies underlying concepts associated with both that do not change over time. Work has been undertaken by the 'Computing At School' group – a grass roots organisation supported by the BCS – to develop a Programme of Study for Computing.[71]

It is important to appreciate the difference between 'statutory' and 'non-statutory' subjects in the context of this review. A statutory subject must be taught by every school (other than Academies) to children at the relevant ages, although a school can choose to deliver a programme of study in a cross-curricular way. Some schools take this approach with the existing ICT curriculum (which is a statutory subject). However, there are also non-statutory subjects which a school has no legal requirement to teach but for which a programme of study exists and can be used.

The political context for the current review is a move towards fewer subjects being statutory and a need for the curriculum to be specified in such a way as to not require updating on a short timescale. English, Mathematics, the Sciences and PE will be statutory in the new National Curriculum and their content is being considered as 'phase 1' of the review; the government is expected to consider in 2012 what other subjects should have a statutory component.

The intention is that the National Curriculum will specify a much smaller amount of school time than at present, with schools granted flexibility to teach beyond the (slimmer) National Curriculum in the additional time available. That is, if a subject is not statutory it does not necessarily mean that it will not be taught – schools will simply have the ability to decide.

We have already said that the term 'ICT' should no longer be used, irrespective of whether another phrase is used in its place. Secondly, we have already stated the importance of distinguishing between digital literacy, Information Technology and Computer Science when making policy decisions. With this in mind 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.

Pupils should be exposed to, and should have the option to take further, issues such as understanding of the internet and the design of web-based systems, the application of computers in society, business, science and engineering, computer programming, data organisation and the design of computers, and the underlying principles of computing.

This approach ensures that pupils are equipped with the basic skills they need at an early age and are not bored by over-rehearsal of them. It provides a route for specialisation and maintains a separation between basic level skills and the rigorous subject of Computer Science from Year 1 to post-16.

71 See www.bcs.org/content/conWebDoc/33107, accessed 24 October 2011.

The government has made it clear that National Curriculum content must be phrased in such a way as to not require regular updating, and we believe that it is possible to achieve this with Computer Science given the existence of stable concepts in this subject which do not change over time (unlike the corresponding hardware and software). However, it is also clear that a smaller number of subjects than at present are likely to be statutory, and we believe that the current focus on science, mathematics and English is logical. For these reasons we advocate the model described above, on the basis that Computer Science will still be chosen to be taught in schools (despite being non-statutory) if the statutory curriculum occupies a smaller part of the school day than at present.

Our preference accords with the remarks made by David Willetts MP in September 2011 when launching a pilot scheme for a new school curriculum: "There's going to be a live pilot over two terms in schools of a programme that will transform the IT curriculum away from computer literacy, which we believe many young people can do earlier, towards instead how they develop software and computational principles; how they can create their own programs".[72]

Whatever approach is chosen through the National Curriculum review, we reiterate at this point that successful implementation will depend heavily on the supply, training and development of the teachers that will be delivering the curriculum. This issue is explored in Chapter 7.

The new tranche of Academies – which have the freedom to diverge from the National Curriculum – are advised to note our recommendations when constructing their own curricula.

Conclusion

The Department for Education should remedy the current situation, where good schools are dis-incentivised from teaching Computer Science, by reforming the current ICT curriculum in England by establishing clearly-defined sets of learning experiences for ages 5 – 14 across the range of Computing aspects, e.g. digital literacy (the analogue to being able to read and write), Information Technology, and Computer Science.

These should be constructed to be implementable in a variety of ways, including a cross-curricular approach at primary and early secondary school. Schools may prefer not to impose a timetable or separately staff these elements at this age, but the existence of separately-defined learning experiences will ensure that each strand is always properly developed – unlike at present.

A timetable distinction should then be in place from the age of 14, allowing pupils to make a well-informed choice to study for recognised qualifications in Information Technology and/or Computer Science.

Given the lack of specialist teachers, we recommend that only the teaching of digital literacy is made statutory at this point. However, the long term aim should be to move to a situation where there are sufficient specialist teachers to enable all young people to study Information Technology and Computer Science at school. Accordingly, the Government should put in place an action plan to achieve this.

The national schools inspectorates should monitor the implementation of this change to ensure that the problems of the current curriculum are not replicated.

This approach aims to ensure that pupils are equipped with the basic skills they need at an early age and are not subjected to over-rehearsal of them. It provides a route for specialisation at the age of 14, and maintains a separation between basic level skills and the rigorous discipline of Computer Science. It also mirrors the existing science curriculum – with minimal distinction between strands at the early ages and greater differentiation at secondary school.

72 www.ft.com/cms/s/0/ee58426a-df9a-11e0-845a-00144feabdc0.html#axzz1iOVIrKc0

4.8 Computing in primary schools

Our definition of Computer Science and the corresponding description of the concepts involved (see Chapter 2) may at first glance appear to suggest that the content would only be suitable at secondary level and above. This is not the case, and we have received many examples that show how Computer Science concepts can be introduced from a very young age. The list below illustrates some common approaches, to demonstrate that Computer Science is not the preserve of universities or secondary schools:

- In the Early Years Foundation Stage, children can benefit from direct experience of programming ideas, albeit using relatively simple control interfaces to programmable toys, such as the Bee Bot, a small bee-like robot: early years practitioners guide children's play with these, encouraging them to create progressively more complex sequences of instructions to travel to particular points or follow a route.

- Many primary schools use visual programming environments such as Scratch or Kodu to create complex animations, interactive simulations and games.

- Primary school pupils can explore encryption ideas through coding and decoding secret messages.

- The idea of flow charts can be introduced in the context of interactive adventure stories, where decision points lead to different chapters.

- Whilst all primary pupils learn to use e-mail, pupils might also learn something of how e-mail works, and whilst the skills of creating web pages or other online content are commonplace, some teachers will develop children's understanding of the relationship between the Internet and the Web and of the HTML behind the page.

- Computer Science education does not necessarily involve computers. A good example is the book *Computer Science Unplugged*[73]. Specifically aimed at primary-aged children, and extensively classroom-tested, it covers topics such as binary numbers, image representation, text compression, searching algorithms, minimal spanning trees and finite state automata, all of which are core Computer Science topics.

The Digital Schoolhouse Project is a UK-based example of what can be achieved in primary schools (see Langley Grammar School case study).

4.9 Computing in secondary schools

Again, to illustrate the concept we envisage, the list below describes how learning about Computing may continue in secondary school:

- At Key Stage 3 (ages 11 – 14), pupils can be encouraged to work in a more sophisticated creative environment. Although this will still be child-friendly and graphical (eg through Scratch), and still employed for the creation of models and games, it can emphasise the core Computer Science concepts of variables, loops, conditional statements and subroutines. This will help pupils make a well-informed decision about studying Information Technology or Computer Science at Key Stage 4 (14 – 16).

- At Key Stage 4 (ages 14 – 16), students can choose to study towards a level 2 qualification (such as a GCSE) which will introduce concepts of problem-solving and abstraction, and introduce formal programming through an appropriate language (such as Python).

4.10 Non-formal learning

This chapter has so far concentrated mainly on the formal school curriculum. Learning does not only take place within the context of the National Curriculum and wider school curriculum however, nor even the school itself. Non-formal learning encompasses a wide range of activities that might take place inside or outside of school, and research is only just starting to untangle the benefits of different approaches.

The following sections discuss non-formal learning as a supplement to the curriculum; it should be noted that such learning can only support what is already on offer in schools. Without teachers willing to engage, implement, encourage and organise these are unlikely to be successful.

73 Bell, T 2010 *Computer science unplugged*. Huazhong: Huazhong University Press

4.11 What are the benefits of non-formal learning?

While there is little research available about specific effects of non-formal learning in Computer Science and Information Technology, some general impressions can be gained by looking at the literature on science and engineering non-formal learning in general. Even so, evidence for non-formal learning raising aspirations, changing attitudes, increasing knowledge and skills, or impacting attainment and progress is patchy.

If non-formal learning activities are undertaken voluntarily by students, then there is likely to be the potential to influence attitudes towards a subject (albeit within a self-selecting group). Non-formal learning opportunities may have an immediate impact on a participant, such as enjoying a mathematical challenge that is not encountered in solving 'known' problems (Feng 2010a)[74]; they might also have far longer-term effects, affecting career choice later in life[75]. There is some evidence to suggest that 'out of school hours' learning (which includes non-formal learning) correlated with better progress in mathematics at age 11 (Sylva et al. 2008); but a recent OECD report suggested that countries which perform highly in PISA rankings spend the majority of time learning science during regular formal lessons (OECD Education at a glance 2011)[76]. Nevertheless, access to a rich variety of non-formal learning opportunities should complement and enhance the benefits of good quality classroom teaching.

From the initial call for evidence, respondents stated that those students who wanted to study Computer Science tended to have an interest in technology outside of school. Regardless of what is or is not taught in school, there will always be some students exploring the subject with computers in their own time, and these individuals are likely to be motivated by factors including the desire to learn how to program, curiosity, and the intellectual challenge afforded by creative problem solving. However, there is a need to provide this 'spark' if it is not already there, and the influence of peer groups, parental opinions, societal and media views can also play a part in encouraging an interest in Computer Science.

4.12 Enhancement and Enrichment activities in Information Technology and Computer Science

STEMNET characterises Enhancement and Enrichment (E&E) activities as those that offer schools the opportunity to deliver exciting and inspiring activities to the classroom[77]; E&E activities can therefore be thought of as a subset of non-formal learning, and in practice, such activities can range from a show performed in a classroom to individual industrial placements or site visits.

Prompted by submissions to our initial call for evidence, our small survey (N=114) of school and college teachers in the UK included questions on E&E opportunities in Information Technology and Computer Science. Despite the lack of published research about non-formal learning, respondents were clearly able to identify a range of creative programmes and activities they believed benefited students, both directly and through enhancing teacher capabilities to deliver non-formal learning (see Appendix J). These ranged from ambassadors schemes and animation competitions, to programming software and after-school clubs, and include examples such as the project 'cs4fn' (computer science for fun)[78] created by Queen Mary University of London, comprising a print and online magazine together with live shows that aim to demonstrate how Computer Science pervades all aspects of life, and The Raspberry Pi Foundation[79] which is in the process of producing a very low cost ($25) computer to help teach computer programming to young people.

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74 Feng, W Y 2010 Students' experience of mathematics enrichment. Proceedings of the British Society for Research into Learning Mathematics (BSRLM), Volume 30, No. 1.

75 A survey of scientists for the Royal Society report Taking a Leading Role, showed that one-fifth of respondents claimed their career choice was influenced by a role model.

76 OECD 2011 *Education at a glance*. Paris: OECD (See www.oecd.org/dataoecd/61/2/48631582.pdf)

77 www.stemnet.org.uk/content/enhancement-and-enrichment accessed 23 August 2011

78 www.cs4fn.org accessed 04 October 2011

79 www.raspberrypi.org accessed 04 October 2011

Respondents also pointed to various barriers to accessing E&E, including budgets, the 'rarely cover' policy[80], and the general administrative burden (risk assessment, form filling etc), which limit the extent to which out of school activities are undertaken. These issues are not unique to Computer Science and Information Technology, however, and would require attention on a broader scale.

Mirroring the issues described in chapter 7 with respect to CPD, a problem identified in recent years in the wider science, mathematics and engineering community was the need for a national picture of E&E opportunities and a centralised list of what is available. This led to the creation in 2008 of the STEM Directories[81] as an online database of activities in science, technology, engineering and mathematics. Teachers may search this database by subject; an 'ICT/Digital' category exists and includes many of the examples referred to above. However, more effective promotion of the STEM Directories to ICT teachers is needed.

4.13 Are some E&E activities 'better' than others?

During the project, there have been calls by universities and industry for guidance as to what they can do to help. Several respondents to the survey suggested that they would like to have more links with industry, for example local companies 'adopting' schools with the aim of offering industrial visits, work experience and opportunities for students to see the application of Information Technology and Computer Science in real-life situations. Enhancing links with universities was also thought to be beneficial, as these institutions are more likely to have the expertise to offer E&E opportunities.

To help ensure cohesion across STEM initiatives, and to help improve the quality and impact of any E&E provision, the DCSF STEM Cohesion Programme published evaluation guidance in 2008[82] and 2009[83], based on evaluation procedures in use in DCSF and DIUS, and with input from various organisations active in the field of science and mathematics education. Individual evaluations of different types of schemes and activities demonstrate a range of – usually short-term – benefits, for example an evaluation of the British Science Association's CREST Awards Scheme showed that students who participated in CREST had improved positive attitudes and aspirations towards SET subjects a year after taking part in the scheme[84].

The second of the DCSF STEM Cohesion Programme reports[85] acknowledged the need for collating and investigating the range of individual evaluations across all types of E&E activities and initiatives. Mapping all activities on a similar framework would allow a clearer picture of impact across the whole E&E landscape to be developed, and also gaps in provision to be identified (Grant, 2005)[86]. Those projects that are attempting to do this are ongoing; early results highlight the complexity of the E&E landscape, and the influence of contextual factors (for example the type of school attended) on students' perceptions of activities in which they participate.

When assessing the effectiveness of E&E activities, one key factor that should be considered is the type of impact the particular activity is expected to achieve: what is the goal of the enrichment and who is the intended audience (Feng 2010b)[87]? In most cases there will be a trade-off between the quality of individual students' interactions with a particular activity, and the number of students that can be reached via a particular scheme. This is illustrated by comparing activities such as an intensive summer school that allows thirty students to interact with like-minded individuals over

80 In an effort to ensure that non-contact time is preserved, teachers are expected now to provide cover for other colleagues lessons only rarely – in practice the interpretation of this policy can mean that teachers are prevented from attending CPD events. See Science and Mathematics education 5-14, §5.10 for further discussion royalsociety.org/education/policy/state-of-nation/5-14

81 www.stemdirectories.org.uk

82 DCSF 2008 *STEM cohesion programme – evaluation guidance*. (See www.nationalstemcentre.org.uk/res/documents/page/STEM_eval_guidance.pdf)

83 National STEM Centre 2009 *Does it work? Better evaluation: better STEM*. York: National STEM Centre.

84 Grant, L 2007 *CREST awards evaluation*. Liverpool: University of Liverpool.

85 DCSF 2008 *STEM cohesion programme – evaluation guidance*. (See www.nationalstemcentre.org.uk/res/documents/page/STEM_eval_guidance.pdf)

86 Grant L 2005 *Comparative evaluation of science communication activities and their impacts*. (See www.lauragrantassociates.co.uk/ReportsAndResources.aspx)

several weeks, with an activity such as a UK-wide competition where thousands of students take part on an individual basis through a written challenge (Feng 2010a)[88].

One aim of the Understanding Participation rates in post-16 Mathematics and Physics (UPMAP) project[89] is to investigate the factors (including E&E activities) that promote participation in physics at university level; this may have strong implications for E&E activities in general. As part of the project, physics undergraduates were surveyed to find out why they chose to study science – and particularly physics – at university. Results suggested that the key influencing factor was the students' relationship with a significant adult associated with physics, such as a teacher, family member, or other type of role model, rather than 'interventions' such as E&E activities alone (Rodd et al. 2011)[90].

Therefore giving students access to Computer Science and IT professionals, or allowing them to build relationships with other students or teachers interested in the subject, might provide a bigger impact than an individual-based competition. Relationship-building schemes, however, are more costly to run and can usually only operate on a smaller scale. Questions need to be asked as to whether a potential E&E provider wants to bring Computer Science to the attention of many, or to prompt those who already have a spark of interest to become a Computer Science professional.

There is no one-size-fits-all solution, and more research – on a long-term basis – is desperately needed in this area in order to focus future investment. One model worth considering is after-school clubs. After-school clubs can introduce students to inspiring ideas within Computer Science in much greater depth, fostering an inclination to continue with further study in the subject, without placing inordinate demands on teachers' resources. They are not without their issues – for example they can sometimes unintentionally turn into Gifted and Talented clubs (Feng 2010) – but there is the potential to build good relationships with other motivated students, teachers and professionals, and to give students access to the types of creative learning opportunity, including practical building of development boards and programming of simple software, which inspired the current Computing professionals of today.

Conclusion

There are many successful Computer Science enhancement and enrichment (E&E) activities in existence but there is lack of understanding in schools of what opportunities are available; rather than introducing further new schemes the existing activities need to be augmented, with better coordination between them to avoid fragmentation.

Many out-of-school STEM clubs exist and have been shown to be effective. With sufficient support these could be extended to complement a Computer Science curriculum, thereby raising awareness of the subject and inclination towards further study.

Recommendation 9

The UK Forum (see recommendation 11 in Chapter 2) should put in place a framework to support non-formal learning in Computer Science and to support teachers. Considerations include after-school clubs, school speakers and mentoring for teachers in developing their subject knowledge. Bodies such as STEMNET will have a role to play in implementing this.

To inform the focus of investment in non-formal learning in Computing, the UK Forum should also look at establishing a rigorous evidence base for the effectiveness and value of various Computer Science E&E activities. Affordability will also be a relevant consideration.

87 Feng W, Y, 2010 The development of a framework for understanding mathematics enrichment in the UK. *Proceedings (Mathematics Education Research at the University of Cyprus and the University of Cambridge: A Symposium).*

88 As above.

89 www.ioe.ac.uk/study/departments/cpat/4814.html accessed 4 October 2011

90 Rodd, M, Reiss, M & Mujtaba, T 2011 *Undergraduates' stories about why they are studying physics: implications for policy.* London: Institute of Education.

Qualifications

One of the initial motivators for this project was the sharp declines in numbers completing GCSE and A-level courses titled or categorised as in ICT and Computing. However, the range of qualifications available across the UK in these subjects is much more extensive.

This chapter explores this complexity and assesses trends in numbers taking examinations for these qualifications. Inevitably, the usage of terminology here is consistent with that of the actual titles of past and present qualifications as well as the manner in which they have been classified by different stakeholders. The new terminology advocated by this report is only used where it appears appropriate to do so.

5.1 Breadth and complexity of existing qualifications

In responding to our call for evidence, e-skills UK, the Sector Council for Business and Information Technology, told us that:

"The IT/Computing qualifications system needs radical simplification in order to be better understood by students and employers. It needs to include a clear distinction between IT literacy as a key skill for all students (regardless of subject choices) and IT /Computing as a subject discipline (which supports progression into higher education and/or employment)."

"At the moment, there is an unwieldy catalogue of often poorly understood qualifications which are mostly variations on IT literacy. This does not help young people who may ultimately pursue an IT career (because neither universities nor employers value them in terms of progression), nor does it provide evidence of IT literacy in a way that is recognised by employers. A simplification of the catalogue itself is needed as well as clearer articulation and progression in qualifications rather than the current disjointed approach (e.g. different timescales and developers for GCSEs and A-levels.)"

Certainly, there is a plethora of qualifications on offer. In its Government-funded investigation of the science, technology, engineering and mathematics qualifications available in the FE and Skills sector in England,[91] published during the period of our call for evidence, the Royal Academy of Engineering established the numbers of qualifications available. The Academy identified 'technology' qualifications (those which 'contain learning outcomes that are of a "technical" or "technology-application/use nature"') and distinguished these from 'technology-related' qualifications in which technology 'features in many learning objectives (and/or the qualification provides a degree of learning that will aid progression in STEM)'.

The Royal Academy of Engineering classified the following as 'technology' qualifications:

- IT/ICT practitioner qualifications;
- Electronics/systems and control;
- Music technology;
- Production technology and technical theatre (light; sound; media);
- 3-D design;
- CAD/CAM;
- Interactive media;
- Design and technology GCSEs and GCEs;
- IT/ICT GCSEs and GCEs.

Qualifications the Academy classified as 'technology-related' included IT/ICT user qualifications (as everyone needs these) and general Art & Design (a necessary precursor to studying, for instance, 3-D/industrial design).

In all, the Academy classified some 339 'technology' qualifications[92] and 532 'technology-related' qualifications across all recognised levels of learning that were taken in 2009/10 (see table 5.1). In addition, the Academy also determined a significant number of technology/engineering qualifications and much

91 Royal Academy of Engineering 2010 *Research project: FE and skills STEM data*. London: Royal Academy of Engineering. (See www.thedataservice.org.uk/NR/rdonlyres/FA3B05C3-2914-4983-A1FD-0CD2B4C4B35C/0/FESTEMDatareport271010.pdf)

92 Technology was taken to include: IT/ICT practitioner qualifications; electronics/ systems and control; music technology; production technology and technical theatre (light; sound; media); 3-D design; CAD/CAM; interactive media; design and technology GCSEs and GCEs; IT/ICT GCSEs and GCEs.

Table 5.1 Number of different qualifications taken in the FE and skills sector in England by QCF/NVQ level and STEM classification in 2009/10[a]

	Entry level	Level 1	Level 2 (GCSE equivalent)	Level 3 (A-level equivalent)	Level 4 and above	No level assigned
Technology	2	27	80	178	51	1
Technology-related	39	132	165	142	12	42
Technology/Engineering	2	22	68	151	46	0
Technology/Engineering related	0	3	5	3	1	0
Technology related/ Engineering related	0	3	4	3	0	1
Technology or Engineering with Mathematics related	0	0	0	0	0	0
Science/technology/ engineering	0	0	2	5	0	0

a All data refer to qualifications taken by learners funded by the Skills Funding Agency or Young People's Learning Agency.

Notes
1. A qualification is classified as distinct if it has a unique reference number in the National Database of Accredited Qualifications (now the Register of Regulated Qualifications) and/or the Learning Aim Database qualification database.

2. Data cover all age groups in 'FE colleges', independent providers, third sector providers and employers.

Source: Royal Academy of Engineering.

smaller numbers of technology/engineering-related and technology related/engineering related qualifications.

One very salient indication of the extent to which Computer Science has gradually drifted out of the English curriculum is the number of qualifications in ICT at Key Stage 4, compared with only a single pilot of a GCSE qualification specifically in Computing (see section 5.3).

While information on the numbers of enrolments and completions give some idea of the relative popularity of these different qualifications,[93] it is, however, more difficult to ascertain their value from such data. Notably, for instance, in a follow-up report published in July 2011, the Royal Academy of Engineering was able to show that there is a huge geographical spread in the distribution of – and achievement in – Level 3 technology qualifications across England, indicating how the growth of qualifications in this area may reflect a response to the needs of local employers, which of course may be similar in different parts of the country.

Even so, e-Skills UK may well be justified in asserting that such an enormous array of qualifications makes it very hard for employers to appreciate their individual value.

Conclusion

The range of ICT and Computing-related qualifications at Level 2 in England, Wales, and Northern Ireland is overly diverse and confusing to potential end users. Many of these qualifications do not appear to provide what employers and HE are looking for; others lack the currency of GCSEs and A-levels.

The progression routes (e.g. from level 2 to level 3, or to employment or HE) are poorly defined.

93 Op. cit., note 1, see, in particular, pp. 35–45.

Recommendation 7
In order to redress the imbalance between academic and vocational qualifications in this area – and to ensure that all qualifications are of value to those who take them – the Department for Education should encourage Awarding Organisations to review their current provision and develop Key Stage 4 qualifications in Computer Science in consultation with the UK Forum (see recommendation 11 in Chapter 2), universities and employers.

Awarding Organisations across the UK should review and revise the titles and content of all new and existing qualifications in this area to match the disaggregation described in this report (e.g. Computer Science and Information Technology).

5.2 Perceptions of the quality of existing ICT qualifications

Research undertaken by e-skills UK has shown that students' experience of Information Technology at Key Stage 4 is the biggest single factor in the dramatic drop in uptake of Information Technology-related education beyond that level[94]. Further, too many Information Technology-related 14 – 19 qualifications are neither valued by employers nor by higher education institutions. They therefore add little value to the people taking them.

Responses to our call for evidence highlighted restrictions on assessment of coursework as being a source of frustration to teachers and students undertaking ICT qualifications. Some teachers complained that the only permissible format for submitting coursework to the awarding body was on A4 paper, with annotated screen shots of the student's work. It is surprising that assessment of a subject such as Information Technology is not enhanced by modern technology. Teachers also referred to the sheer quantity of time spent documenting a piece of work with screenshots being a disincentive for students. Providing documentation may be important in industry and project management, but the current balance between time spent fulfilling this requirement for assessment purposes and learning new material was felt by respondents to be unjustified.

Conclusion
Assessment methods that rely on taking screenshots to document coursework (rather than take advantage of more modern submission and marking methods) are a contributor to the negative perceptions of ICT.

Recommendation 8
The UK Forum (see recommendation 11) should advise Awarding Organisations on appropriate assessment methods for qualifications in digital literacy, Information Technology and Computer Science.

5.3 A new GCSE in Computing

A new GCSE in Computing has been developed by OCR, working together with the Computing at School Group (CAS), Microsoft, and Cambridge and Birmingham universities. Around 100 centres participated in a pilot from September 2010 and it was rolled out nationally from September 2011. This development is to be welcomed, but the timing of this report means that it is too early to provide meaningful information on take up and progression.[95]

The GCSE focuses on the following areas and is aimed to attract all students, but especially 'problem-solvers', through covering:

- Underlying theory;
- Task style programming (not projects);
- Research and practical investigation beyond the basic theory.

94 Wolf, A 2011 *Review of vocational education – the Wolf report*. London: Department for Education. (See www.education.gov.uk/publications/eOrderingDownload/The%20Wolf%20Report.pdf)

98 OCR 2010 *GCSE in computing*. (See www.ocr.org.uk/qualifications/type/gcse_2010/ict_tec/Computing/documents/index.aspx)

It was introduced by OCR for two reasons:
(i) In order to resolve concerns about the prior knowledge of students embarking on A-level Computing courses. When the OCR A-level in Computing specification was last revised in 2008, OCR had to assume no prior knowledge of Computer Science, recognising the limitations of what was being provided within ICT at Key Stage 4.

(ii) It was felt that there would be a market for the qualification in terms of introducing Key Stage 4 students to Computing proper and so help them to develop an interest in this area, or consider other more appropriate options rather than solely ICT.

5.4 Barriers to the pursuit of existing Computing qualifications at Level 2

Looking ahead, the future success of OCR's new Computing GCSE seems uncertain. As the Wolf report points out, 'the DfE did, and does retain, one enormously powerful lever over how institutions behave: the performance measures which determine institutions' position in league tables. At present, these apply most forcefully to primary schools and to 11–16 education, and their impact on how schools operate is demonstrably enormous'.[96]

Whatever the educational and economic merits of Computer Science as a school subject, there are a number of potential disincentives for head teachers to introduce Computer Science qualifications:

- Computer Science is a rigorous academic subject, and qualifications (e.g. GCSE) will be demanding, so high grades may be difficult to achieve.
- Computer Science qualifications are not included within the English Baccalaureate. (Until recently there were no Key Stage 4 qualifications in Computing; OCR introduced a GCSE in 2010 (details above))
- There is no programme of study for Computer Science and no recognition at national level, and so other subjects are prioritised.
- Delivery is compromised by a lack of specialist teachers (see Chapter 7).

The status quo presents head teachers with significant disincentives to offering a Computer Science curriculum to their students, especially given that many will be starting from a near-zero base.

5.5 Popularity of existing Level 2 ICT and Computing qualifications in different educational contexts

In this section we look at the available data on the popularity of Level 2 (GCSE and equivalent) and Level 3 (A-level and equivalent) ICT and Computing qualifications, examining changes in the numbers of students recorded as completing final examinations in these subjects. These figures may, of course, differ from the numbers who first began courses in pursuit of these qualifications.

It is important to note that much of the data that are available refer to participation in academic qualifications (particularly GCSEs and A-levels), which have historically attracted particular interest. Further, it is very hard to find data that are fully inclusive of the academic and vocational qualifications available and representative, too, of qualifications taken across different educational sectors.

For this section, we use a combination of overlapping, possibly trend-indicative data published by Cambridge Assessment (covering participation among schools in England) and the Joint Council for Qualifications[97] (providing a wider UK perspective).

5.5.1 Schools in England

National Pupil Database extracts on existing Level 2 ICT and Computing qualifications analysed by Cambridge Assessment in recent years illustrate a shifting landscape where qualifications have come and gone within very short time-spans – as a direct impact of Government reforms (table 5.2).[98] This has had an inevitable impact on the popularity of individual qualifications (although it may be harder to determine precise cause and effect relationships in their differential fortunes).

96 Op. cit., note 5.

97 The Joint Council for Qualifications (JCQ) consists of AQA, City & Guilds, CCEA, Edexcel, OCR, SQA and WJEC, the seven largest providers of qualifications in the UK, offering GCSE, GCE, Scottish Highers, Entry Level, Vocational and vocationally-related qualifications.

98 Cambridge Assessment 2011 *ICT and computing qualifications taken in schools in England 2007-2010*. Cambridge: Cambridge Assessment.

What has changed is the qualifications that students are being entered for. There has recently been an upsurge in new 'vocational' ICT qualifications, in particular the OCR National in ICT, which increased by an order of magnitude between 2007 and 2008, and again between 2008 and 2010. In 2010 the OCR National in ICT accounted for more than a third of all entries to Level 2 ICT and Computing courses taken in schools by students at the end of Key Stage 4. There has been dramatic growth in the popularity of the BTEC First Diploma and First Certificate, too, though in contrast with entries to the OCR National qualifications, in 2010 the numbers of entries to these qualifications accounted for 5% of all entries to all such qualifications.

The growth of OCR Nationals can in part be attributed to their previous 'equivalence' to more than one GCSE for school league table purposes, despite the perception that they may be easier to achieve. This phenomenon is referred to in Alison Wolf's review of vocational qualifications[99] and has been criticised by the current government; the government has recently consulted on changes to performance tables, including a policy move to 'counting one subject as "one"'[100].

In contrast, it can be calculated from table 5.2 that the numbers of entries to the full GCSE in ICT fell by almost half (47%) between 2007 and 2010.

Overall, table 5.2 shows that the number of 15 year olds taking Level 2 ICT and Computing qualifications declined by 1.5% between 2007 and 2010. The true extent of this decline is, however, best appreciated when looked at in the context of changes in school rolls.

Decreasing birth rates in England during the 1990s led, since 2005, to falls in the numbers of 11–15 year old secondary school students (figure 5.3). The 5% fall in the population of these students between 2005 and 2011 is similar to the 4% fall recorded in the total number of 15 year olds in England between 2005 and 2009[101]. Both figures are considerably higher than the falls seen in the percentages taking Level 2 ICT and Computing qualifications. This indicates that the decrease in numbers taking qualifications fell by a lesser extent than might have been expected from the fall in the school roll.

99 Cambridge Assessment 2011 ICT and computing qualifications taken in schools in England 2007-2010. Cambridge: Cambridge Assessment.

100 www.education.gov.uk/16to19/qualificationsandlearning/a00192510/performance-table-reform-and-transparency-will-raise-standards-and-end-perverse-incentives

101 Data from the Office for National Statistics, May 2010.

Table 5.2 Level 2 ICT and Computing qualifications taken in schools in England by students at the end of Key Stage 4, normally aged 15 at the start of the academic year in which the qualifications were taken (2007–2010)[a]

Level	Qualification	Entries			
		2007	2008	2009	2010
1/2	GCSE Full Course in ICT	78,414	65,211	53,082	41,315
	GCSE Short Course in ICT	77,870	64,019	45,158	30,992
	GCSE Short Course in Digital Communications Studies	0	53	251	100
	Vocational GCSE Double Award in Applied ICT	26,470	14,481	7,856	4,936
	IGCSE in ICT[b]	0	0	0	323
2	Functional Skills[c]	0	944	5,613	9,511
	Key Skills[c]	6,320	5,835	3,711	3,139
	GNVQ in Applied ICT[d]	48,704	0	0	0
	NVQs[e]	35	50	35	52
	VRQs[f]	2,310	3,908	3,819	4,443
	BTEC First for ICT practitioners[g]	1,393	9,674	13,986	17,775
	OCR National in ICT[h]	5,022	60,648	118,081	126,853
	BCS[i]	5,184	7,453	5,580	4,396
	Award/Certificate/Diploma in Digital Applications	68,774	114,228	82,550	71,316
	Principal Learning (Diploma)	0	0	0	662
	Other	148	193	160	0
All		320,644	346,697	350,345	315,813

a Entry level qualifications have not been included in this table. Likewise, Level 3 qualifications taken by pupils at the end of Key Stage 4 have been excluded.

b IGCSEs received accreditation from Ofqual, the national regulator, in 2009.

c Functional Skills and Key Skills are in computer appreciation/introduction.

d GNVQs were withdrawn after 2007.

e NVQs at Levels 1 to 2 can be obtained in the following subjects: systems/network management, computer appreciation/introduction, computer hardware/firmware.

f VRQs at levels 1 to 2 can be obtained in the following subjects: computer appreciation/introduction; computer architecture/systems, systems/network management, telematics, computer help desk operations, software development, graphics software, multimedia, multimedia software, website development, word processing.

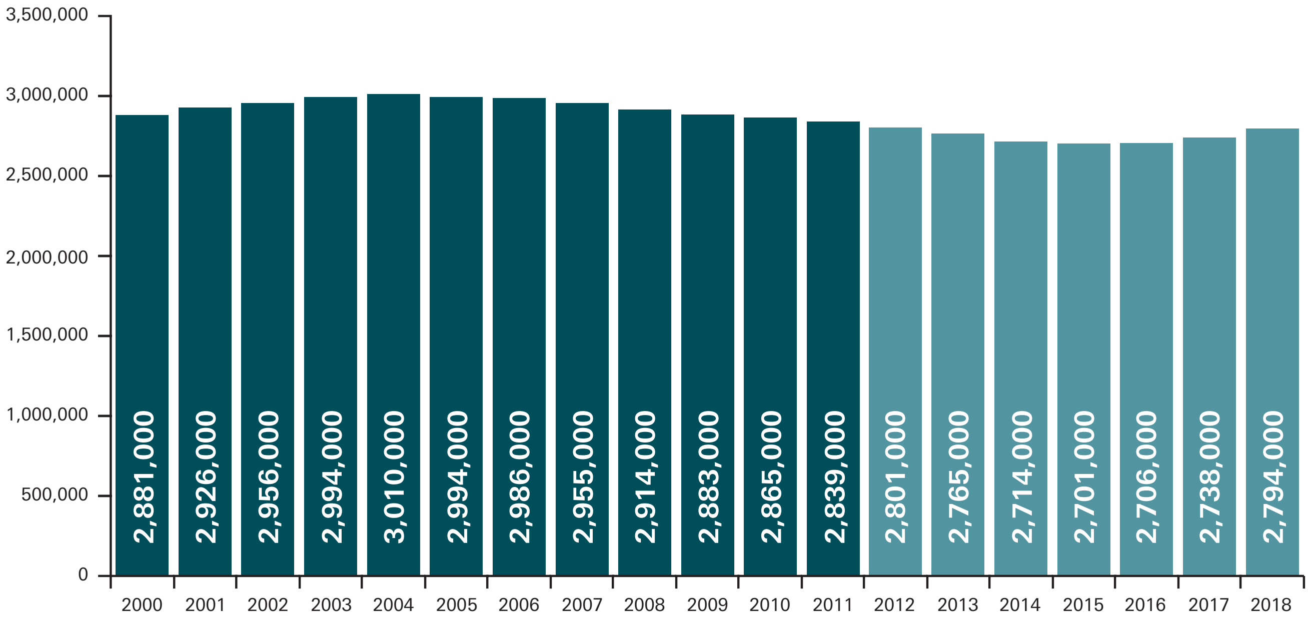
g BTEC First includes BTEC First Diploma and BTEC First Certificate.

h Level 2 OCR National in ICT includes First Award, Award, First Certificate and Certificate in ICT.

i Qualifications awarded by the British Computer Society.

Source: Cambridge Assessment 2011 (abridged).

Figure 5.3 Numbers of students aged up to and including 15 in state-funded secondary schools in England (January 2000–2011, actual; January 2012–2018, projected)[a]



a State-funded secondary schools include maintained secondary schools, secondary academies, secondary free schools and city technology colleges. Numbers are rounded to nearest thousand.

Source: Department for Education.[102]

Unfortunately the population data above are not directly compatible with the qualifications figures and can only be used to give a general impression of how these two factors vary with each other.

5.5.2 Participation in past and present Level 2 ICT and Computing qualifications across the UK [103]

Each August, the Joint Council for Qualifications publishes selected data on entries to public examinations (see jcq.org.uk). Figure 5.4 shows fluctuations in entries to certain Level 2 qualifications in ICT and Computing subjects taken by candidates of all ages across the UK during the past 11 years.

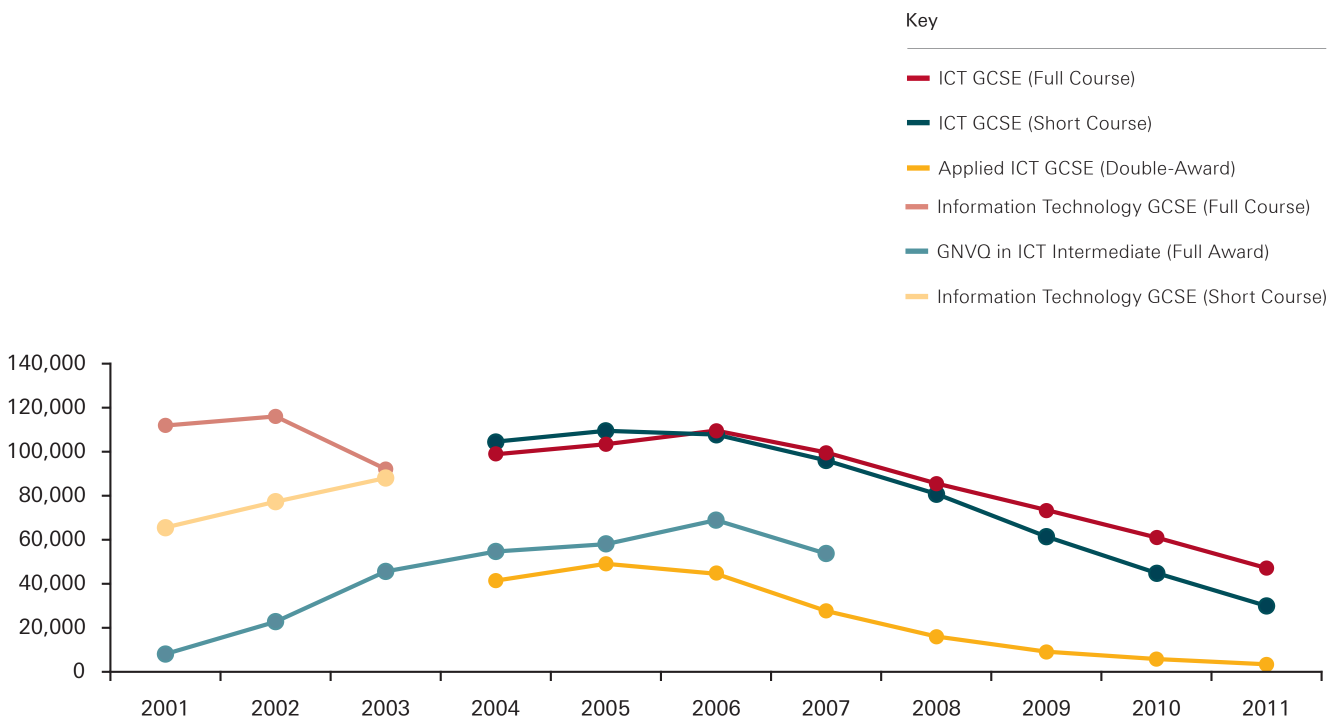
Figure 5.4 shows the move from Information Technology GCSE courses to Information and Communication Technology (ICT) GCSE courses, the rise and subsequent demise of the GNVQ in ICT and the introduction of the GCSE Double-Award course. Across this time-period, entries to all courses included in this analysis rose steadily from 2001 to a peak of 330,862 in 2006. Since then, the number of entries has decreased by 75%, to just over 80,000 in 2011.

Of course, the range of qualifications covered by the JCQ data is not inclusive of the full provision available.

102 Department for Education 2011 *National pupil projections: future trends in pupil numbers*. OSR, 12/2011.

103 Data are for candidates with the major awarding organisations that serve England, Wales and Northern Ireland.

Figure 5.4 Total number of GCSE entries in ICT and Computing subjects across England, Wales and Northern Ireland (2001–2011)



Source: JCQ.

5.6 Popularity of past and present Level 3 ICT and Computing qualifications in different educational contexts

In this section, we examine trends in entries to Level 3 academic and vocational qualifications taken by 16 – 18 year old students in schools in England. We have decided not to include any analysis of publicly available AS-level data. This is because, while AS-levels may prove to be significant in determining the award of a place on an undergraduate course in Computing or other disciplines:

(i) it is impossible to tell from these data how many of the entrants recorded may have been retaking their examinations (which could be multiple); and

(ii) many students decide not to 'cash in' their AS-levels and proceed directly to the second year of their A-level studies.

5.6.1 Schools and colleges in England

Cambridge Assessment data show that during 2007 – 2010 the five A-level qualifications available have, together, accounted for 60% or more of all Level 3 ICT and Computing qualifications taken within school and colleges (table 5.3). Yet, with the exception of the newly introduced Applied GCE A-level/AS-level combined, each has experienced a decrease in entries, and there has been a 14% overall decrease. Indeed, across all courses listed, entries have fallen 3%. Within this time-period, only BTEC National courses have prospered, with entries to these courses growing 77%.

Table 5.3 Level 3[104] ICT and Computing qualifications taken in schools and colleges in England by 16–18 year old students at the end of Key Stage 5 (2007–2010)

Qualification	Entries			
	2007	2008	2009	2010
GCE A level in ICT	10,968	9,726	9,208	9,133
GCE A level in Computer Studies/ Computing	4,683	4,203	3,993	3,606
Applied GCE Double Award in ICT	2,491	2,191	1,545	1,066
Applied GCE Single Award in ICT	10,083	11,583	11,641	10,445
Applied GCE A level / AS level combined in ICT	0	0	0	22
Key Skills	4,460	4,537	4,411	3,160
NVQs[a]	31	799	1,105	235
BTEC National for IT practitioners[b]	5,905	6,505	8,799	10,461
OCR National in ICT[c]	0	0	41	263
VRQs[d]	751	1,705	2,092	1,558
Principal Learning (Diploma)	0	0	0	4
BCS	0	0	0	11
IB component in Computer Studies/ Computing	0	0	0	33
IB component in ICT	0	0	0	65
Other	0	3	32	0
All	41,389	43,297	44,890	40,312

a NVQs at Level 3 can be obtained in: systems/network management, computer appreciation/introduction, computer hardware/firmware.

b BTEC National includes BTEC National Sward, BTEC National Certificate and BTEC National Diploma.

C Level 3 OCR National in ICT includes Certificate, Diploma and Extended Diploma in ICT.

d VRQs at Level 3 can be obtained in the following subjects: computer appreciation/introduction; computer architecture/ systems, systems/network management, telematics, computer help desk operations, software development, graphics software, multimedia, multimedia software, website development, word processing.

Source: Cambridge Assessment.

104 Qualifications at levels 1 and 2 taken by students aged 16 – 18 are included in the full extract (page 5).

5.6.2 Participation in past and present Level 3 ICT and Computing qualifications by candidates across the UK

Table 5.4 provides trend data in entries to ICT and Computing qualifications for the period 2001–2011, published by the JCQ. Across all the qualifications listed, entries have fallen 14%, from 32,388 to 27,840.

Table 5.4 shows that ever since the division of the original A-level Computing course into separate A-levels in Computing and ICT (in 2003/04), the subject as an 'academic' option has declined, although the A-level in ICT has consistently been the more popular of the two. This decline compares poorly with the recovery of other mainstream science and mathematics subjects, particularly given that during 2002–2010 there were year-on-year increases in both the cohort size and the total number of entries to all subjects, with the former falling 2.5% in 2011 (figure 5.5).

Similarly with the 'vocational' programmes, the switch from Advanced VCE qualifications in Information Technology to new Applied ICT qualifications has been followed by a steady decline in their popularity. Indeed, between 2007 and 2011, entries to these qualifications fell 21%.

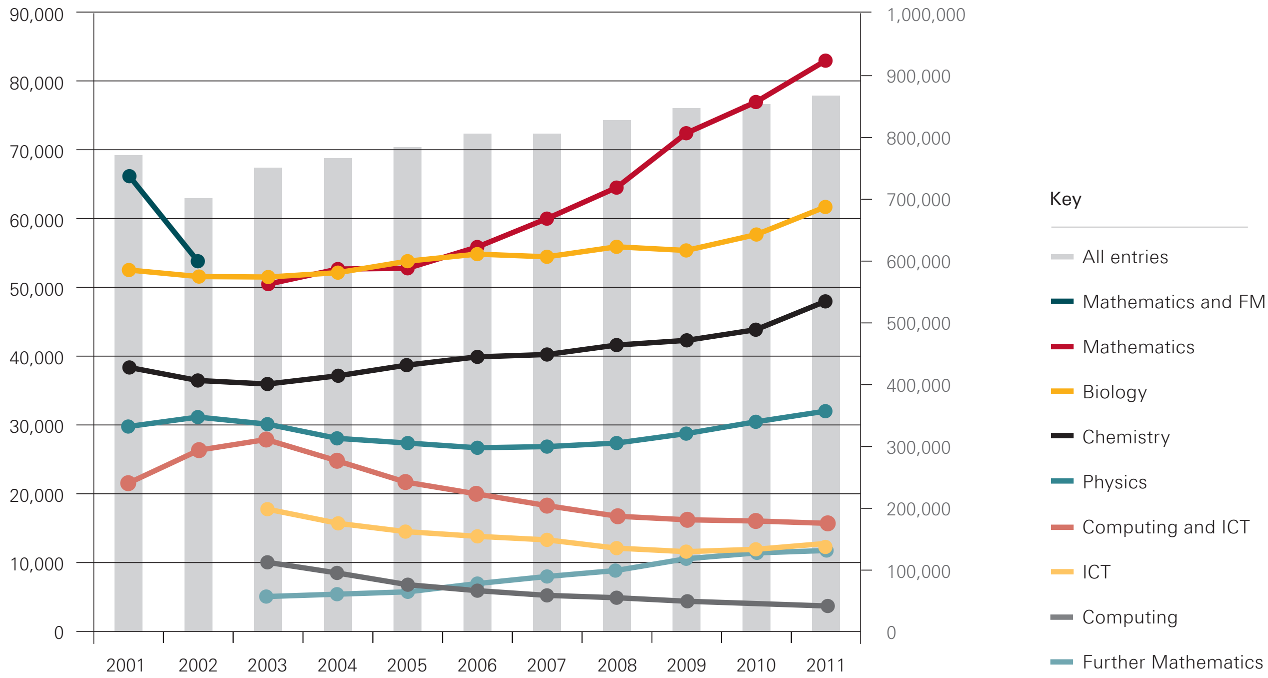
Table 5.4 Level 3 ICT and Computing qualifications taken across the UK by candidates of all ages (2001–2011)[a]

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
GCE A-level in Computing	21,744	26,780	28,175	0	0	0	0	0	0	0	0
GCE A-level in Computing	0	0	0	8,488	7,242	6,233	5,610	5,068	4,710	4,065	4,002
GCE A-level in ICT	0	0	0	16,106	14,883	14,208	13,360	12,277	11,948	12,186	11,960
GNVQ	9,483	0	0	0	0	0	0	0	0	0	0
AVCE in Information Technology	1,161	9,377	13,468	14,881	15,498	13,603	0	0	0	0	0
AVCE in Information Technology (Double Award)	0	7,150	9,034	8,222	6,933	6,113	0	0	0	0	0
Applied ICT GCE A-level (Single Award)	0	0	0	0	0	0	12,076	13,618	13,580	12,291	11,045
Applied ICT GCE A-level (Double Award)	0	0	0	0	0	0	3,051	2,609	1,835	1,328	833

a AS-level data and data on the new Diplomas (first publishedin 2011) have been excluded.

Source: JCQ.

Figure 5.5 Total number of UK GCE A-level entries in science and mathematics subjects (2001–2011)



Source: JCQ.

5.7 The differential popularity of vocational Level 2 and 3 ICT and Computing qualifications in England

As we have seen, and in confirmation of the advice of several respondents to our call for evidence, the declining trends in entries to GCSE and A-level qualifications have been offset, to an extent, by the number of people studying for vocational Level 2 or Level 3 qualifications in ICT or Computing.

Previous sections in this chapter have given some indication of the variety of vocational qualifications in ICT and Computing that are on offer. In particular, in addition to the better known BTEC and OCR qualifications may be added those of CLAIT, ECDL, DiDA, BCS qualifications, Key Skills, Functional Skills, NVQs, and VRQs.

5.8 Trends in entries to existing Scottish ICT and Computing qualifications

There are some clear differences in the structure of the curriculum and qualifications between Scotland and the rest of the UK. Table 5.5 outlines the structure of secondary education and the qualifications in Scotland. Standard Grade qualifications are broadly equivalent to GCSEs in the UK as the school 'exit' qualification. Standard Grades are typically taken at S3 and S4.

With respect to Intermediate courses, these were originally intended for students to progress to from their Standard Grades in S5 and S6. For instance, in recent years students gaining Credit level in Standard Grade examinations have generally progressed directly to Higher-level courses, while those gaining General level at Standard Grade have usually continued onto Intermediate 2 (since their introduction in 1999) in those subjects in S5, as a stepping stone to Higher-level courses[105]. Intermediate 1 and 2 qualifications have been increasingly utilised at S4 as they have been considered a better progression route in some subjects

105 Royal Society 2008 *Science and mathematics education, 14–19. A 'state of the nation' report on the participation and attainment of 14–19 year olds in science and mathematics in the UK, 1996–2007.* London: Royal Society. (See http://royalsociety.org/uploadedFiles/Royal_Society_Content/Influencing_Policy/Education/Reports/SNR2_-_full_report.pdf)

Table 5.5 Secondary education and the typical SQA qualifications taken

Stage	Age range	Typical qualifications
S1	12–13	
S2	13–14	
S3	14–15	Standard Grade
S4	15–16	Standard Grade
S5	16–17	Intermediate 1/2, Higher
S6	17–18	Higher/Advanced Higher

to Highers than Standard Grades. Highers hold a broad equivalence to A-levels in the UK as the 'gold standard' (Scottish Government 2008). Advanced Highers are additional to Highers and are usually studied at S6 by students with good attainment at Higher who choose not to leave school at the end of S5. Students with strong results in relevant Advanced Highers may be allowed direct entry into the second year of (four-year) first degree courses in Scotland.

One key difference between Scotland and the rest of the UK is the breadth and flexibility in the qualifications that students can take. It is very common for students to take five Highers or a combination of Intermediates and Highers in S5. Students may also take additional Highers along with Advanced Highers in S6, and the uptake is based to some extent on their achievement in Standard Grade and Intermediate courses. The data included in this chapter take account of this flexibility by including entries in Highers and Advanced Highers taken in previous academic years.

As a result of the newly introduced Curriculum for Excellence, S-grade, Intermediate 1 and 2, Higher and Advanced Higher will all be replaced in 2013 by new qualifications called Access 3, National 4, National 5, Higher and Advanced Higher. Computing and Information Systems courses will be replaced by a single suite of courses to be called 'Computing and Information Science'. The focus of these courses will be on developing software using a range of environments, including traditional programming languages, but also more modern development tools. These courses are partly developed and are still under consultation; draft documents for National 4, National 5 and Higher are available online[106].

With these considerations in mind, we now look at trends in ICT and Computing qualifications in Scotland. These include:

- Standard Grade Computing Studies (a mix of applications, computer systems hardware and programming, at approximately GCSE level)

- Intermediate 2, Highers and Advanced Highers in both 'Computing' and 'Information Systems'. These are broadly equivalent to GCSE, AS-level and A-level, respectively, and are now generally taken by students aged 16–17/18. 'Computing' includes programming, systems and a choice of Artificial Intelligence, networking or multimedia. 'Information Systems' is more ICT-related, but with a deeper theoretical approach than simply using applications.

Trends in numbers taking the existing qualifications are given in the table below. Given the shifts in popularity of these qualifications over time, and the fact that students can take these at different ages and stages, changes in the numbers recorded taking Standard Grade and Intermediate qualifications need to be treated with caution. To demonstrate, the fact that entries to Standard Grade Computing studies were 29% less in 2011 than in 2006 must be set against schools' decision to increasingly favour Intermediate qualifications.

106 SQA 2011 *Curriculum for excellence: computing and information science*. (See www.sqa.org.uk/sqa/45643.html)

Greater confidence may be placed in analysing the figures for Higher and Advanced Higher Computing entries. The numbers of entries to Higher Computing fell 10% overall between 2001 and 2011, and by 19% since 2004. In contrast, although numbers remain small, there has been a fourfold increase in the number of entries to Advanced Higher Computing, although as with Higher Computing, a 10% fall in entries has been recorded since 2005.

Table 5.6 Entries to Scottish Computing qualifications (2001–2011)

	Standard Grade Computing Studies	Intermediate 1 Computing Studies	Intermediate 2 Computing	Higher Computing	Advanced Higher Computing
2001	21,067	781	1,836	4,604	105
2002	22,114	832	2,180	4,480	439
2003	21,723	1,023	2,102	4,753	495
2004	18,849	1,488	2,153	5,090	512
2005	17,237	1,674	2,094	4,628	499
2006	16,508	1,552	2,742	4,356	450
2007	16,040	2,024	2,682	4,180	349
2008	15,383	2,403	2,865	4,256	366
2009	13,586	2,294	2,948	4,307	411
2010	12,390	1981	3,079	4,356	414
2011	11,659	1681	3,154	4,124	461

Source: SQA.

Uptake of Information Technology and Computer Science courses in Higher Education

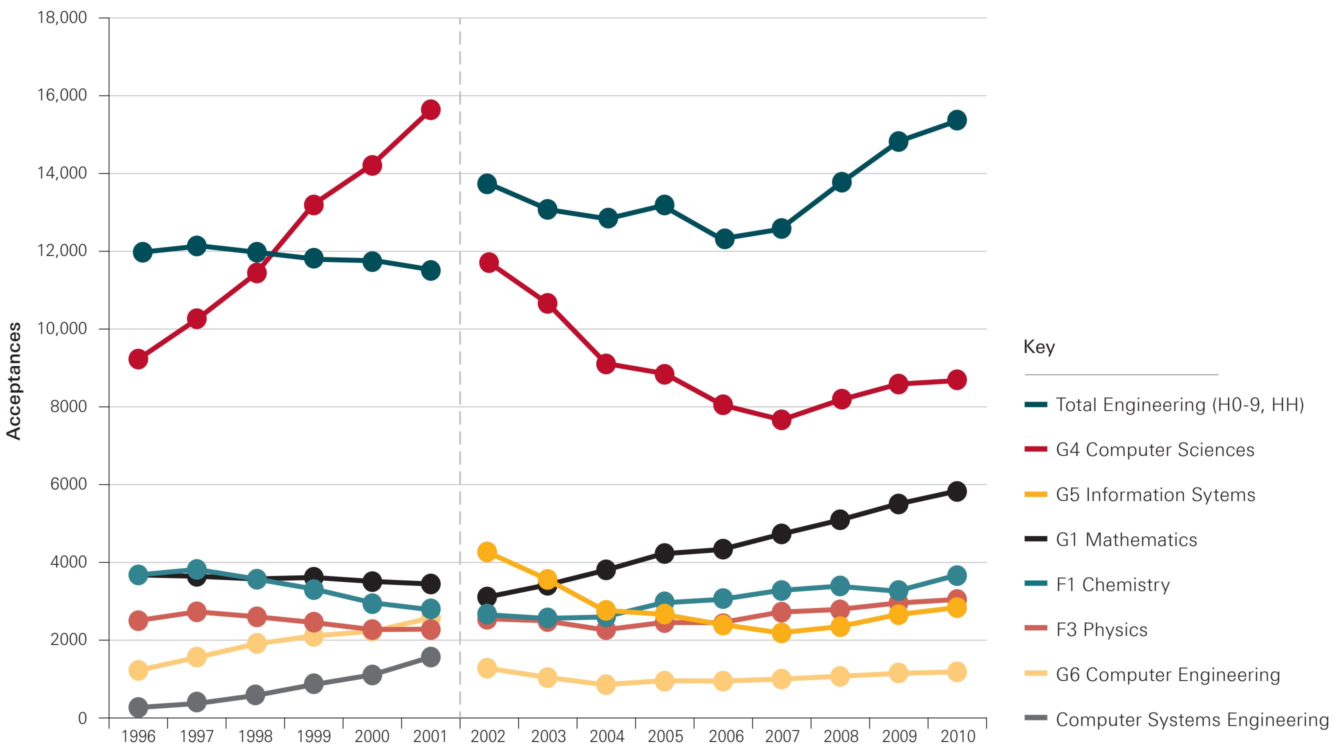
As we showed in Chapter 5, the numbers of people entering ICT and Computing GCSE, A-level, Scottish Highers and Advanced Highers have decreased in recent years, whereas there has been a significant increase in the numbers studying OCR Nationals and other vocational ICT qualifications. In this chapter, we assess trends in uptake of and rates of attrition from higher education courses in Information Technology and Computer Science.

6.1 Acceptances onto Information Technology and Computer Science Higher Education courses

Figure 6.1 shows the trends in the number of (UK-domiciled) acceptances to HE courses in the UK as defined by HESA. Owing to a change in the classification of courses, figures between 1996 and 2001 are not directly comparable with figures for 2002–2010. However, despite this discontinuity, it is clear that acceptances to Computer Science (G4) were increasing rapidly at the end of the last century but, even though numbers remain second highest after Engineering courses, are now declining. This contrasts with the picture in mathematics, where a significant increase in acceptances has been recorded over the last decade; and similarly, in chemistry, where the numbers of acceptances have stayed relatively stable. Figure A6.1 in Appendix G provides further information on applicant numbers showing how these are distributed among different groupings of higher education institutions.

One possible explanation for the dramatic change in applications to Computer Science is the 'dot-com' crash in 2001 – this event coincides with the start of the downturn in Figure 6.1.

Figure 6.1 Trend in Acceptances to HE courses by subject



Source: UCAS – UK-domiciled students only

Note: figures for 1996-2001 (SCAS catagories) are not comparable with 2002-2010 data (JACS, JACS2)

6.2 First year undergraduate 'drop out' rates from Computer Science

While figure 6.1 evidences that the numbers of acceptances onto Computer Science degree courses are consistently higher than in mathematics or chemistry, the Advisory Group for this project was concerned about anecdotal suggestions that Computer Science courses experience higher drop-out rates than other subjects.

In particular the Advisory Group was concerned about the extent to which Computer Science students 'drop out' in their first year – either transferring to another courses or leaving Higher Education all together – which it suspected to be unusually high in Computer Science as a result of students being ill-informed and confused by terminology about what a degree in Computer Science would entail.

To investigate this further, the Higher Education Statistics Agency (HESA) was commissioned to undertake an analysis of the subject of study[107] of first year home domiciled undergraduates aged 21 or under and compare this with their participation in Higher Education one year on. Four subjects were chosen for comparison – mathematical sciences, economics, physics and engineering & technology – two at a subject level ('Principal Subject') and two at a broad category heading ('Subject Area').

Three measures of attrition were considered, as follows:

A. The proportion of students starting a course with an element of subject X in year 1 but who are no longer in higher education the following year.

B. The proportion of students starting a course with an element of subject X in year 1 but who in the following year are:

- No longer in higher education;
- Are now at a different Higher Education institution and are no longer studying the subject; or
- Are at the same institution and are no longer studying the subject.

C. The proportion of students starting a course with an element of subject X in year 1 but who in the following year are:

- No longer in higher education;
- Are now at a different institution and are no longer studying the subject;
- Are at the same institution and are no longer studying the subject; or
- Are now at a different institution but are studying the same subject.

Accordingly, measure A provides the most basic measure of 'drop-out'. Measure B extends the definition to include transfers away from the subject (either within the same institution or elsewhere) and measure C extends this further to include those who stay in the subject but change institution.

6.2.1 Drop-out measure A (see table 6.1)

Table 6.1 presents data on the percentages of students across the range of comparator subjects selected who are not in Higher Education the following year. It shows that the basic drop-out from Computer Science subjects is higher than in mathematical sciences and physics, but is comparable to engineering and technology.

6.2.2 Drop-out measure B (see table 6.2)

Under this definition attrition from Computer Science subjects is observably higher than among the comparators. It is also noticeable that the attrition rate is higher for principal subjects within Computer Science. This indicates that there is some 'churn' within the subject area; for instance, students starting a course in Artificial Intelligence may then be transferring to an Information Systems course. Table 6.2 shows that the attrition rate is worryingly high in Information Systems, where across 2006/07–2008/09 the average drop-out rate was almost 30%, compared to 16% in mathematical sciences and 13% in Physics.

107 HESA records up to three subjects of joint study – the data has been produced on the basis of whether an individual is studying 'an element' of the relevant subject in either year. Thus, a student studying mathematics and music in the first year and then transferring solely to mathematics is not deemed to have left mathematics. Similarly, a student starting on a single honours course but then moving to a major-minor

Table 6.1 The proportion of students starting a course with an element of subject X in year 1 but who are no longer in higher education the following year

% students leave HE by subject (excl 'qualified')	2006/07	2007/08	2008/09	Multi-year rate	Multi-year totals
Mathematical sciences (subject area)	5.4%	5.5%	6.6%	5.9%	22,856
Engineering and technology (subject area)	9.3%	9.0%	9.0%	9.1%	47,085
Physics (F3)	5.3%	4.6%	5.1%	5.0%	9,707
Economics (L1)	4.2%	4.0%	4.1%	4.1%	20,158
Computer Science (subject area)	11.5%	11.2%	9.7%	10.8%	37,605
Computer Science (principal subject) (G4)	11.5%	10.9%	9.6%	10.7%	27,746
Computing Science (G400)	10.9%	10.8%	8.8%	10.2%	21,819
Information systems (principal subject) (G5)	12.0%	11.5%	9.8%	11.1%	7,517
Software engineering (principal subject) (G6)	10.9%	11.7%	10.2%	10.9%	3,148
Software engineering (G600)	8.9%	10.2%	9.9%	9.7%	2,378
Artificial Intelligence (principal subject) (G7)	6.2%	14.0%	7.4%	9.1%	398
Others in computing science (principal subject) (G92)	12.5%	22.2%	18.2%	17.2%	65
Computer Science (broad based) (principal subject) (G02)	na	40.0%	0.0%	12.5%	17

Source: HESA.

Table 6.2 The proportion of students starting a course with an element of subject X in year 1 but who have transferred out of Higher Education or away from the subject (either within the same institution or elsewhere)

%students no longer taking subject across institutions (excl 'qualified')	2006/07	2007/08	2008/09	Multi-year rate	Multi-year totals
Mathematical sciences (subject area)	15.7%	16.4%	15.8%	16.0%	22,856
Engineering and technology (subject area)	17.0%	16.1%	16.2%	16.4%	47,085
Physics (F3)	14.0%	12.0%	13.1%	13.0%	9,707
Economics (L1)	14.1%	13.7%	12.8%	13.5%	20,158
Computer Science (subject area)	20.5%	18.7%	17.4%	18.9%	37,605
Computer Science (principal subject) (G4)	23.5%	21.2%	20.1%	21.6%	27,746
Computing Science (G400)	25.3%	22.8%	21.7%	23.3%	21,819
Information systems (principal subject) (G5)	29.6%	33.6%	25.0%	29.4%	7,517
Software engineering (principal subject) (G6)	24.5%	28.7%	23.4%	25.5%	3,148
Software engineering (G600)	23.7%	29.2%	24.4%	25.8%	2,378
Artificial Intelligence (principal subject) (G7)	31.5%	38.8%	26.2%	32.2%	398
Others in computing science (principal subject) (G92)	87.5%	27.8%	54.5%	59.4%	65
Computer Science (broad based) (principal subject) (G02)	na	100.0%	9.1%	37.5%	17

Source: HESA.

Table 6.3 The proportion of students starting a course with an element of subject X in year 1 but who have left Higher Education or moved to a different institution and/or subject or stayed at the same institution and moved to a different subject

% students no longer taking subject within institutions (excl 'qualified')	2006/07	2007/08	2008/09	Multi-year rate	Multi-year totals
Mathematical sciences (subject area)	16.7%	17.3%	16.8%	16.9%	22,856
Engineering and technology (subject area)	18.5%	17.8%	17.7%	18.0%	47,085
Physics (F3)	14.5%	12.9%	13.6%	13.6%	9,707
Economics (L1)	14.7%	14.4%	13.4%	14.1%	20,158
Computer Science (subject area)	22.0%	20.1%	19.2%	20.4%	37,605
Computer Science (principal subject) (G4)	24.7%	22.2%	21.5%	22.8%	27,746
Computing Science (G400)	26.3%	23.7%	22.9%	24.3%	21,819
Information systems (principal subject) (G5)	30.2%	34.0%	25.7%	30.0%	7,517
Software engineering (principal subject) (G6)	25.1%	28.8%	23.6%	25.9%	3,148
Software engineering (G600)	24.5%	29.2%	24.8%	26.2%	2,378
Artificial Intelligence (principal subject) (G7)	31.5%	38.8%	26.2%	32.2%	398
Others in computing science (principal subject) (G92)	87.5%	27.8%	54.5%	59.4%	65
Computer Science (broad based) (principal subject) (G02)	na	100.0%	9.1%	37.5%	17

Source: HESA.

6.2.3 Drop-out measure C (see table 6.3)

As table 6.3 shows, measure C produces very similar results to measure B, indicating that the additional category of 'at a different institution but studying the same subject' is very small. This suggests that where students do transfer it tends to be as a result of subject choice rather than choice of university. (Figure A6.2 in the Appendix H provides a breakdown of measure C by institutional mission groups.)

Overall, the first year attrition in Computer Science is indeed higher than in other subjects, which gives some credence to the notion that undergraduates arrive with misguided expectations about what Computer Science 'is'.

6.3 What does Higher Education want from Computer Science entrants?

Although the downturn in numbers studying A-level Computing or ICT is a legitimate source of concern, the connection to participation in Higher Education requires separate analysis. Relatively few undergraduate degrees in Computer Science in England demand that entrants hold an A-level in Computer Science: indeed, many prefer applicants to have studied mathematics:

University of Cambridge:
"The primary qualifications we look for are in mathematics. A-level mathematics is essential. Further mathematics to AS or A-level is desirable, although we recognise that not all schools currently offer it.

There is often confusion over the value of the various computer-related A-levels when applying for CS at Cambridge. A-level ICT, IT and Computing are more vocational in nature and are generally considered less desirable than a physical science. Newer A-level Computer Science courses are more relevant but are not universally offered and so much of the material must be repeated by us in Part IA. As a general rule, we pay most attention to your mathematics qualifications. Specific first year options may also impose additional entry requirements[108].

Computer scientists need to enjoy problem–solving, and be able to think logically and beyond what they're taught. We don't require any qualifications in computer science or any prior knowledge of programming. However, since the subject has strong mathematical

108 See www.cscubed.org/entry accessed 2 September 2011.

groundings, it's essential to have Mathematics at A Level/IB Higher Level. Science subjects are also viewed favourably – often more so than subjects such as IT, which are more vocational in nature.[109]"

University of Bristol:
"Those A-Level students interested in applying for the Computer Science and Electronics degree programmes should note that Physics or Electronics A-Level are also required as well as Mathematics A-Level... A-Level Computer Science or ICT are not required for any of our courses.[110]"

University of York:
"Note that we do not specifically require or prefer Computing, or ICT, or anything similar, at any level, for any of our programmes. Computer Science/Studies or Computing or IT or ICT does not count as a mathematical subject within our requirements at A level, nor in place of a physical science at GCSE.[111]"

A preference for mathematics qualifications is not unsurprising given that Computer Science is a highly mathematical subject. The recent increases in uptake of Mathematics and Further Mathematics A-level are certainly to be welcomed and may well help combat the dwindling interest in Computer Science at university, but the luke-warm reception given to Computing A-level is more surprising, and will inevitably have an impact on the uptake of the qualification.

To quantify this effect we reviewed information and guidance provided by university departments on their websites covering entry to courses[112] in 2012/13 (see Appendix I).

All 160 of the Computer Science-related degree courses listed across 111 institutions could be studied without a Computing or Computer Science A-level[113]. All 19 of the Russell Group universities offering Computer Science courses saw mathematics and/or science A-levels as essential pre-requisites. Other findings include:

- 20 of the 160 courses, which equates to around 1 in 8, list a Computing or Computer Science A-level as a suitable alternative to other science, engineering and mathematics subjects, as part of the mandatory course requirements.
- 27 of the 160 computer-science-related courses expressly refer to Computing, Computer Science or IT A-levels as being a useful or desirable course requirement. This equates to around 16% of courses.
- 5 of the 111 institutions offering Computer Science related degrees expressly state that a Computing, Computer Science or IT A-level is not considered to be a useful alternative to other science, engineering and mathematics subjects. Almost half (54 out of 111 institutions) of the UK Universities offering a Computer Science degree specify mathematics or science A-levels as being essential or preferable prerequisites for entry to their courses.
- A further 11 institutions refer to Computing experience or Computing or ICT A-levels as being perhaps useful, but non-essential, and/or indicate that other science, engineering and mathematics subjects would be preferable:
  Cardiff University states: "Computing experience is not required" However, they also state that: "Applications from those offering alternative/vocational qualifications (eg Access, Vocational A-level) are welcome."

  Imperial College London states: "If you are ...worried that a lack of Computing experience will leave you at a disadvantage, don't be.... You do not need to have taken A-level Computing or ICT to do the degree. We look for people who are good at Maths and are excited by Computing."

  The University of Bath states: "We particularly value evidence of logical and analytical thinking, such as science subjects."

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109 See www.cam.ac.uk/admissions/undergraduate/courses/compsci accessed 2 September 2011

110 See www.cs.bris.ac.uk/admissions/ug/statement.html accessed 2 September 2011

111 See www.cs.york.ac.uk/admit/BritishQuals.html accessed 2 September 2011

112 Entry requirements were assessed only in terms of A-levels and/or UCAS points; Scottish universities all described these in addition to requirements for Highers or Advanced Highers, and many other universities described other acceptable entry routes.

113 Three Scottish universities – Strathclyde, Herriot-Watt and Glasgow – saw Computing A-level as a pre-requisite for fast track entry to the second year of the course.

The University of Bradford states: "Whilst many of our students coming in with A levels studied Computing, ICT, Mathematics and/or sciences, it is not essential to do so. We welcome applicants taking any combination of subjects for any of the courses."

The University of Birmingham states: "It is desirable, but not essential, to have some experience of writing computer programs, and requires at least one of either Maths, Physics or Computer Science or Psychology A-level."

The University of Dundee states: "For entry to Computing, competence in Mathematics is essential."

The University of Exeter states: "Mathematics underpins computer science and computer science opens up new areas of mathematics. This synergistic interplay makes a degree in Computer Science and Mathematics a natural combination."

The University of Huddersfield writes: "We do not require students to have prior Computing qualifications."

The University of Keele writes: "There are no specific subject requirements for entry to our Computing courses, and no previous experience of Computing or computer programming is assumed. The courses do not involve an advanced level of mathematics."

Oxford Brookes University writes: "Our course covers many topics you will not have seen before, even if you have already taken A-level Computer Studies or a course such as a BTEC Level 3 qualification in a Computing subject... Any previous experience you happen to have might help you to get started more comfortably."

- Only 3 out of 111 institutions expressly encourage previous Computer Science experience, whether gained through a Computing or ICT A-Level or otherwise:
  University College London states: "We are keen to admit students with an interest in subjects that relate to applications of computer technology."

  The University of Liverpool writes: "We give a one grade bonus for each mathematical subject (Mathematics, Further Mathematics, Pure Mathematics, Computing/Computer Science, and Physics) which may lead to lower offers."

  The University of Northampton states: "Previous experience of Computing is desirable."

  Queen Mary and Westfield College additionally states: "Vocational A-levels are acceptable."

In some sense then, the trend at A-level is unsurprising – if there is no 'pull' from Higher Education, then students may be inclined to keep their options broad by choosing what the Russell Group calls a 'facilitating subject'[114].

University admissions policies are complicated by the fact that admissions tutors must ensure that course places are filled – there is a 'chicken and egg' problem with subjects that are in decline, as if an individual university specifies the subject as an entrance requirement it may limit the number of applications it receives; on the other hand, where there exists a reasonable number of universities that do not list the subject as a prerequisite there is little incentive for students to choose it.

The rationale within the Higher Education sector for not focusing on A-level Computing as a prerequisite for Computer Science degrees at university level has been driven by serious concerns about the mismatch between the curriculum defined for A-level study by the various Awarding Organisations, and their relationship to first year university curricula. This mismatch resulted in many admissions tutors focusing more on candidates' mathematical ability than the skills and knowledge being developed through the A-level curriculum.

114 Russell Group 2011 *Informed choices*. London: Russell Group.

6.4 A new Computer Science A-level as a prerequisite for Computer Science degree courses?

A stakeholder meeting for representatives of Computer Science at HE was held in Leeds on 24 March 2011, during which there was considerable discussion as to whether (in an ideal world) universities would like to move to a position where an A-level (or equivalent) in Computer Science was a prerequisite for their undergraduate degree courses in the same subject. Some felt that this would allow them to dispense with much of the ground work in the first year and produce more highly-trained graduates by the end of their course.

For a Computer Science A-level to be a prerequisite for a Computer Science degree it was felt that a clear separation between Information Technology and Computer Science as disciplines would be needed to emphasise Computer Science as a credible academic discipline like physics and maths. Re-branding the A-level as 'Computer Science', rather than 'Computing', might also change the perception of the subject's academic qualities.

It was clear from the meeting that academics felt that a review of the A-level Computer Science curriculum would be needed for a qualification to become a prerequisite. Components that a new A-level curriculum should cover would need to include: computational thinking, programming and skills such as problem-solving, analytical thinking, evaluating, modelling and design. Creativity and innovation are also crucial to show the diversity of the subject. Intellectual rigour would need to be built into the curriculum content, but the way it is delivered and assessed should not discourage students from experiencing failure, which plays an important role in the development of knowledge. The prerequisite curriculum would also need to include content that shows the diversity of the subject through the history of Computing (and within that Computer Science) and its impact on society.

Several potential benefits of an A-level Computer Science prerequisite for Computer Science degrees were identified:

- an improved awareness among incoming students of what they will meet in a Computer Science degree. This could reduce the high attrition rates for Computer Science in HE[115];
- the removal of remedial work in the first year of study. This would reduce the burden curve students experience in the first year and allow them to move further and faster in Computer Science degree courses;
- higher quality graduates with better employability skills.

However, the current low numbers of young people studying Computer Science at A-level made some participants doubt that this could become a reality. Without more students studying A-level Computer Science, HE Computer Science provision across the UK could shrink because of a lack of applicants to courses. The perception of Computer Science among parents and wider society must also be addressed if more students are to be encouraged to study the subject post-16.

A barrier that would need to be overcome for an A-level prerequisite to come about is the diversity in the Computer Science sector in HE. University Computer Science departments have developed courses that cater for students with or without Computer Science qualifications. This can be expected to remain the status quo, allowing departments to maximise their student intake. This diversity will make it difficult for the HE Computer Science community to develop a common approach to a prerequisite – for the requirement to be an effective means of increasing the numbers studying Computer Science at A-level, all departments would have to subscribe to this policy.

The lack of uniformity across awarding organisations' different A-level specifications, and the range of post-16 qualifications (BTECs, IT Diploma, etc), are also barriers to the introduction of a prerequisite.

115 Yorke, M & Longden, B 2008 *The first-year experience of higher education in the UK*. York: Higher Education Academy.

Conclusion
Uptake of Computing A-level is hindered by a lack of demand from HE. Few HE departments appear to hold Computing A-level in high esteem and development of rigorous high-quality post-16 courses is required with the label Computer Science.

There is a follow-through effect in numbers studying Computer Science courses in HE, which suffers from a high first-year attrition rate – possibly as a result of students arriving without a clear understanding of what Computer Science is.

Recommendation 10
Awarding Organisations should consult with the UK Forum (see recommendation 11 in Chapter 2) and HE departments to develop rigorous Level 3 academic qualifications in Computer Science.

Resources and infrastructure

As the Coalition Government recently stated, 'Nothing is more important to the quality of a school system than the quality of its teachers'[116]. This chapter, which is largely based on research commissioned for this study[117], explores data on a school's most important resource – its teachers – and the extent to which they are supported by continuing professional development and hindered by school infrastructure.

7.1 Important issues to note when reading this chapter

1. Inevitably, the usage of terminology here is consistent with that used by the UK authorities. The new terminology advocated by this report (see Executive Summary) is only used where it appears appropriate to do so.

2. The lack of clear differentiation between Information Technology and Computer Science observed at the curriculum level (cf. Chapters 2 and 4) also affects official counts of ICT and Computing teachers. Where data are available, they exist for 'ICT' teachers in England, 'Computer science and information technology' (CSIT) teachers in Wales and 'Computing' teachers in Scotland. Since more precise information on the deployment of teachers that are categorised under these labels is generally lacking, we must assume that schools rely on them to teach current curricula in ICT and/or Computing.

3. This chapter only considers the teaching workforce at secondary level. This is because primary teachers across the UK are required to teach all subjects in the curriculum and data on the specialist subject backgrounds of primary teaching staff are either not collected or not publicly made available.

4. This chapter focuses to an extent on the qualifications of teachers because such information provides the most accessible measure of specialist subject teaching available. However, there are many in-service ICT and Computing teachers who have relevant industrial experience but no formal qualification(s) in these subjects – these people might otherwise be considered specialists if the data were available.

5. There is no universally agreed definition of what it means to be a subject 'specialist' teacher[118]. This is an important area for action given (i) the need for greater accuracy in establishing the numbers of subject specialist teachers and their deployment; (ii) the value of accurate counts in improving teacher supply modelling; and (iii) the need to bring renewed respect to the profession of teaching.

6. SCORE[119] has recently recommended to the Department for Education definitions of a subject specialist teacher in the sciences (biology, chemistry, physics)[120]. SCORE's definitions are principally based around recognising academic qualifications. However, in subjects such as Information Technology and Computer Science, which are strongly vocationally oriented, it is important to recognise that employment-based routes into teaching, such as the Graduate Teacher Programme, are just as valid and important in developing teachers of these subjects.

7. Nonetheless, academic routes have traditionally been the major conduit into teaching, and information on the numbers of teachers and on recruitment has been biased in this regard. It is important to realise that less of an emphasis has been placed on recruiting teachers through employment-based routes and in collecting data on the background qualifications and experience of those who enter the workforce through such routes.

7.2 Numbers of ICT/CSIT/Computing teachers across the UK

7.2.1 England

The latest available data on school staffing come from the inaugural Schools Workforce Census, conducted by the Department for Education in November 2010, which showed that there were some 18,400 ICT teachers in England.

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116 Department for Education 2011 *Training our next generation of outstanding teachers. An improvement strategy for discussion.* London: Department for Education.

117 Howson, J 2011 *The staffing of ICT/computing in UK schools*, available at royalsociety.org/education/policy

118 Royal Society 2007 *The UK's science and mathematics teaching workforce. A 'state of the nation' report*. London: Royal Society. (See http://royalsociety.org/uploadedFiles/Royal_Society_Content/Influencing_Policy/Education/Reports/SNR1_full_report.pdf).

119 Science Community Representing Education. (See www.score-education.org)

120 SCORE 2011 *Subject specialist teaching in the sciences: definitions, targets and data.* London: SCORE.

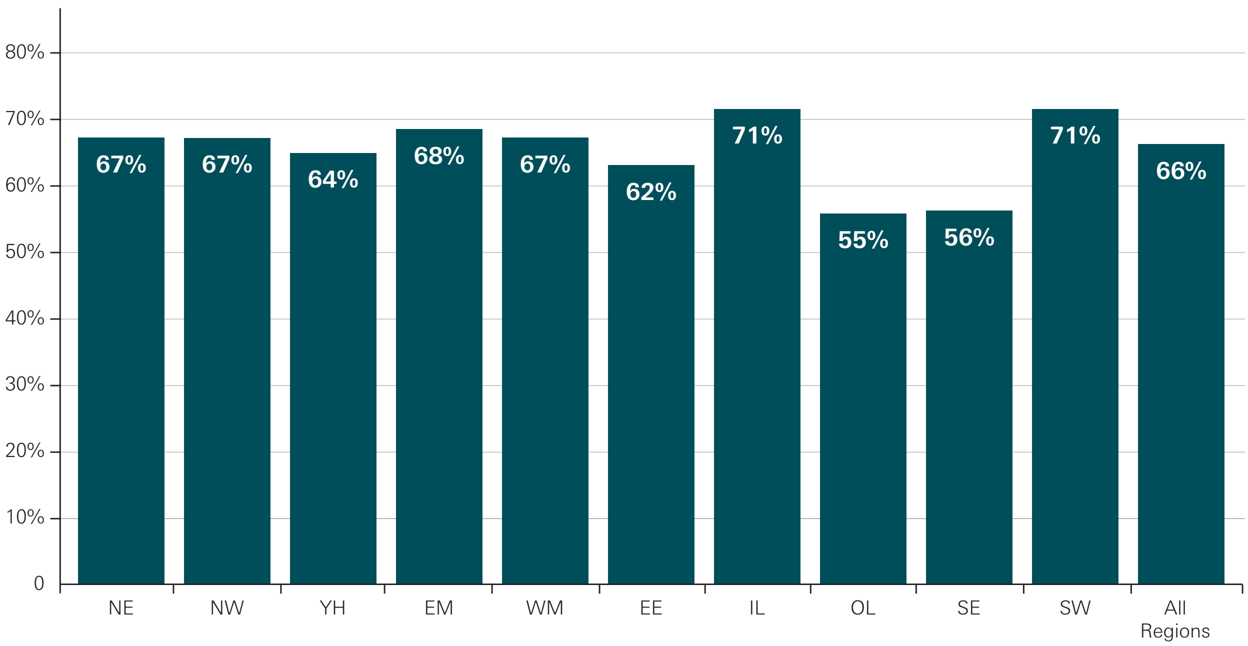
Of these 35% (6,440) were considered by the Department for Education to have a relevant qualification based upon the JACS codes used (G400-G700 plus G900[121]), while 65% (11,960) were not considered to have any relevant post A-level qualification. Twenty-five per cent (some 4,600) of the total number of ICT teachers possessed both relevant first degree and teacher training qualifications. A further 9.1% held a degree in a subject not included within the aforementioned JACS codes.

The number of ICT teachers in England that are regarded by the Department for Education as being specialists equates to an average of 1.5 per secondary school. This compares poorly with such equivalent levels of specialism seen in 'core' curriculum subjects. For instance, the census showed that 74% of those teaching mathematics and 69%, 73% and 88%, respectively, of those teaching physics, chemistry and biology had an appropriate post A-level qualification in the subject that they were teaching. However, the equivalent level of specialism among those teaching citizenship was 6%.

The comparatively low levels of specialism recorded among those teaching ICT and Citizenship by the Department for Education reflect the inevitable lag between the introduction of a new subject into the curriculum and the ability of schools to respond to this need. While schools are required to teach the subject, trained and qualified teachers are not immediately available, and unless or until new funds are made available or vacancies arise through staff turnover or redundancy, teachers of other subjects are required to provide cover.

Figure 7.1 shows the percentage of all in-service ICT teachers in England that are not categorised by the Department as 'qualified'[122], disaggregated by Government office region. It indicates that while the Midlands and north of England have high quantities of teachers that are not 'qualified' to teach ICT, Inner London (IL) borough and the South West (SW) have

Figure 7.1 Percentages of teachers teaching ICT not classified by the Department as 'qualified' in the subject, by Government office region (England, 2010)



Source: DfE School Workforce Census (2010)

121 These codes included degrees in computer science, information systems, software engineering, artificial intelligence and other mathematical and Computing degrees.

122 The DfE regards teachers to be 'qualified in the subject' if they have a relevant first degree and/or teacher training qualifications. The use of the word 'qualified' does not refer to Qualified Teacher Status.

the highest such percentages. Outer London (OL) boroughs and the South East (SE) have the lowest percentages of teachers that are not 'qualified' to teach ICT. It is unclear what is principally responsible for causing this pattern, but it may possibly be because there used to be more variable access to Higher Education for teachers who are now further into their careers.

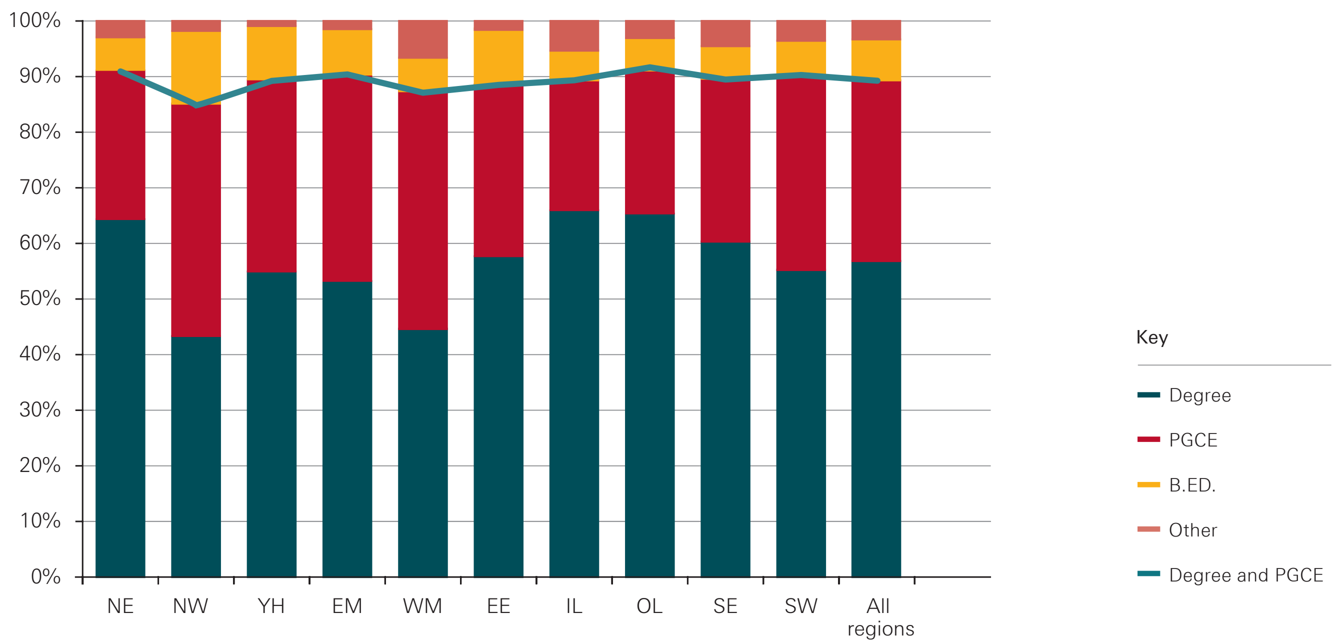
Figure 7.2 disaggregates the number of ICT teachers the Department categorises as being 'qualified' by Government office region. Amongst this number, secondary schools in outer London and the South East had the lowest percentages of ICT teachers who were not, under the Department's categorisation, considered as qualified to teach the subject.

Unfortunately, it is not possible to tell from the data in figure 6.2 what proportion of teachers in each region possess both a relevant degree and PGCE in ICT.

The School Workforce Census was unable to document data for all secondary schools in England[123]. But of the 2,452 schools providing information on ICT teachers, 93% had some 'unqualified' teachers, as designated by the Department, while 21% had no 'qualified' ICT teachers. A total of 76% of schools had teachers teaching ICT, of whom at least 50% were 'unqualified' according to the Department for Education.

Such an apparently high proportion of 'unqualified' teachers may help to explain Ofsted's finding that 'Sometimes pupils' ICT capability was so good that it outstripped their teachers' subject knowledge and, as a result, their good progress was not sustained. In such circumstances, higher-attaining pupils often underachieved'. Ofsted further reported that 'Teachers' subject knowledge was weakest in data logging, manipulating data and programming'[124].

Figure 7.2 Percentages of ICT teachers by Government office region regarded as qualified to teach the subject (England, 2010)



Source: DFE School Workforce Census (2010).

123 Department for Education 2011 Statistical first release: school workforce in England November 2010 (provisional) London: Department for Education.

124 Ofsted 2009 *The importance of ICT: information technology and communication technology in primary and secondary schools, 2005/2008*. London: Ofsted.

7.2.2 Wales

Data on the teaching workforce in Wales come from the register of teachers maintained by the General Teaching Council for Wales (GTCW). It is important to note that these data are self-reported and there may be some ambiguity as to whether teachers are reporting the subject they have been trained to teach, their current deployment or both.

The GTCW's data show that the number of its registered teachers trained to teach Computer science and information technology increased 24% from March 2009 to March 2011, rising from 286 to 355. The proportion of younger teachers (those aged less than 30) increased from 18% to 23% during this period, while the percentage of teachers in their forties declined from 29% to 26%. Almost two-thirds of these teachers are male.

7.2.3 Northern Ireland

Data on the teaching workforce in Northern Ireland come from the register of teachers maintained by the General Teaching Council for Northern Ireland (GTCNI). No subject-specific data for Northern Ireland are available as the GTCNI does not register teachers according to phase of subject specialism. It is undertaking a large scale review and development of its qualification data and will take some considerable time to complete this task[125].

7.2.4 Scotland

Data on the teaching workforce in Scotland come from the register of teachers maintained by the General Teaching Council for Scotland (GTCS) and from the Scottish Government. It is important to note that, as is the case for GTCW data, GTCS data are self-reported.

According to the GTCS, the numbers of Computing teachers registered in Scotland has increased over the past 3 years, from 771 in 2008/09 to 810 in 2010/11. However, in line with a reduction in training places, these figures include provisionally registered teachers (ie those who have not completed teacher training), whose numbers were reduced by 57% during this period, from 67 to 29.

In contrast, self-reported data collected by the Scottish Government's census indicates that between 2007 and 2010 the numbers of publicly funded secondary school teachers teaching Computing as their 'main subject taught' dropped from 788 to 702, not counting a further 346 teachers listed who were teaching Computing but not as the main subject taught[126].

During this same period, the average age of teachers of Computing increased from 44 to 45, amongst the highest average age of teachers in Scotland. By comparison the average age of physics teachers dropped from 44 to 43 between 2007 and 2010, and that of biology teachers also fell from 43 to 42 over the same period, while the average age of chemistry teachers remained steady at 44. The percentage of Computing teachers over the age of 55 increased from 14% to 20%. With teacher training places likely to continue to be restricted, the average age of Scotland's Computing teacher workforce looks set to increase further.

7.3 Deployment of specialist teachers

As indicated previously, records of numbers of teachers of different subjects do not necessarily shed light on their deployment.

Responses to the survey that was conducted for this study indicated that 'qualified' ICT/Computing teachers (ie those with a relevant degree) may have additional or other roles within schools. Some of these teachers were teaching mathematics; others were teaching other subjects or were senior staff (e.g. head teacher).

Similarly, and looking further afield, a recent report from the European Commission found that 'digital literacy is taught mainly by specialist teachers at secondary level but in approximately 50% of countries it is also taught by other specialist teachers such as mathematics or science teachers.'[127] Information Technology is not taught by specialist teachers in Ireland, France, Italy, the Netherlands, Sweden, Liechtenstein and Norway – even at secondary level. It is important to note, though, that in this report, the term 'specialist' is used to distinguish secondary subject teachers from 'generalist' primary teachers.

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125 Helen Jackson (Registration Manager, GTCNI), personal communication, 23 September 2011.

126 See www.scotland.gov.uk/Topics/Statistics/Browse/School-Education/teachersupplementarydata, table 3.9, accessed 13 September 2011.

127 Eurydice 2011 *Key data on learning and innovation through ICT at school in Europe 2011*. Brussels: EACEA.

7.4 Training of ICT/Computing teachers

Table 7.1 details the different initial teacher training routes available in the UK for aspiring secondary Computing/ICT teachers. Of these, a one year Postgraduate Certificate of Education (PGCE, or PGDE as an equivalent in Scotland) is the most common.

The majority of admissions to teacher training courses across England, Wales and Scotland are handled by the Graduate Teacher Training Registry (GTTR). Separate arrangements exist for Northern Ireland universities.

Figure 7.3 provides trend data on the numbers of trainees accepted for ICT/Computing courses in England (plotted against the left-hand y-axis), Wales and Scotland (plotted against the right-hand y-axis) during the past decade. It shows that the numbers of trainees accepted for courses in England grew steadily from 2000 to 2005, rising from 374 to 857 during this period, before falling back to 648 in 2008. Thereafter, following the onset of the recession, the numbers of acceptances increased in 2009, but declined again in 2010. A similar pattern is discernible in Wales, though the numbers are much

Table 7.1 ICT/Computing initial teacher training routes in the UK

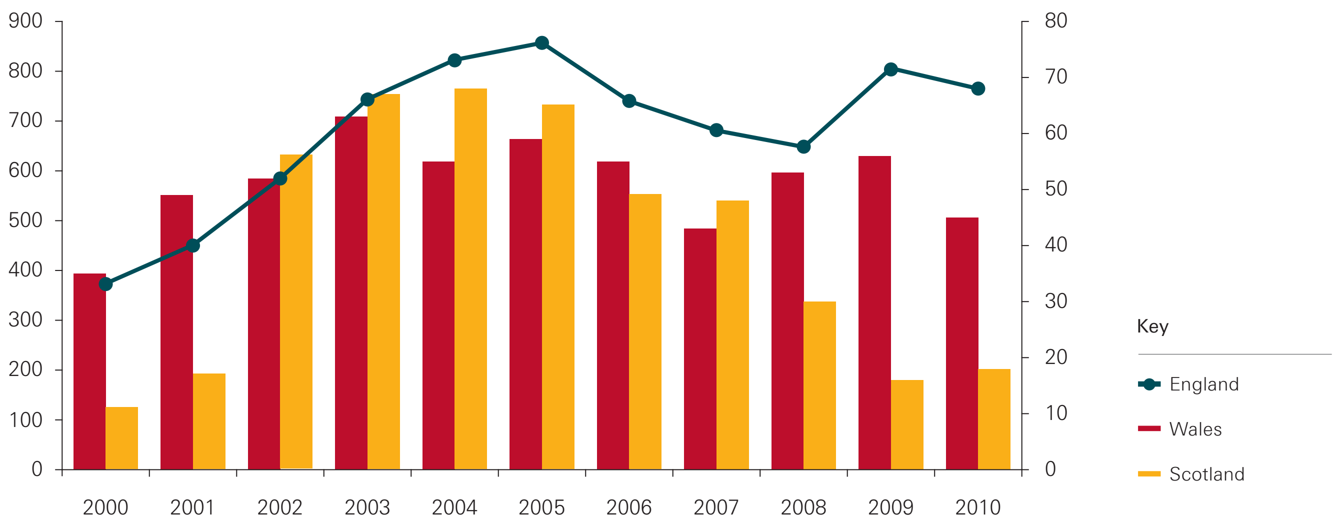
	Undergraduate	Postgraduate	Employment based[a]	Other[b]
England	✓ [c]	✓	✓	✓
Wales	✓ [c]	✓	✓	
Northern Ireland		✓		
Scotland		✓		

a Graduate and Registered teacher programmes. Only the former is available in Wales, but it is not known if any Computer science and information technology teachers have been trained through this route.

b Including fast track, overseas trained teacher schemes and Teach First.

c Three providers in England (Brighton, Edge Hill and Newman College and the University of Wales in Newport (UWIN)) offer undergraduate courses to train ICT teachers. Some courses are for Key Stage 2/3 teachers and the UWIN course is in conjunction with either mathematics or science.

Figure 7.3 Number of trainee teachers accepted through the GTTR for ICT/Computing courses in England, Wales and Scotland (2000-2010)



Source: GTTR.

smaller. In Scotland, the numbers of acceptances rose from 11 to 68 between 2000 and 2004, but decreased 72% thereafter, with the most recent falls being linked to swingeing cuts in places resulting from concerns over an oversupply of teachers.

Figure 7.4 illustrates that for all those prospective ICT/Computing teacher trainees that were accepted during 2000 – 2010, many more either failed to win a place or withdrew from courses. While in 2000 some 60% of applicants were successful, the acceptance rate fell to less than 50% in 2002 and, despite increasing numbers of applicants it did not reach this level again until 2007. In 2008, the level of acceptances once again exceeded 60%, but the recession and cuts in training places led to acceptances falling below 50% subsequently.

Of course, acceptances to a PGCE course do not equate to successful recruitment into the profession. A recent report by Professor Alan Smithers and Dr Pamela Robinson from Buckingham University's Centre for Education and Employment Research highlights ICT as the subject with the worst conversion rate from beginning a PGCE to classroom teaching , with 64.8% of PGCE starters going on to work in state schools. This should be compared against an average across all subjects of 72.8%, which in itself is quite low.[128]

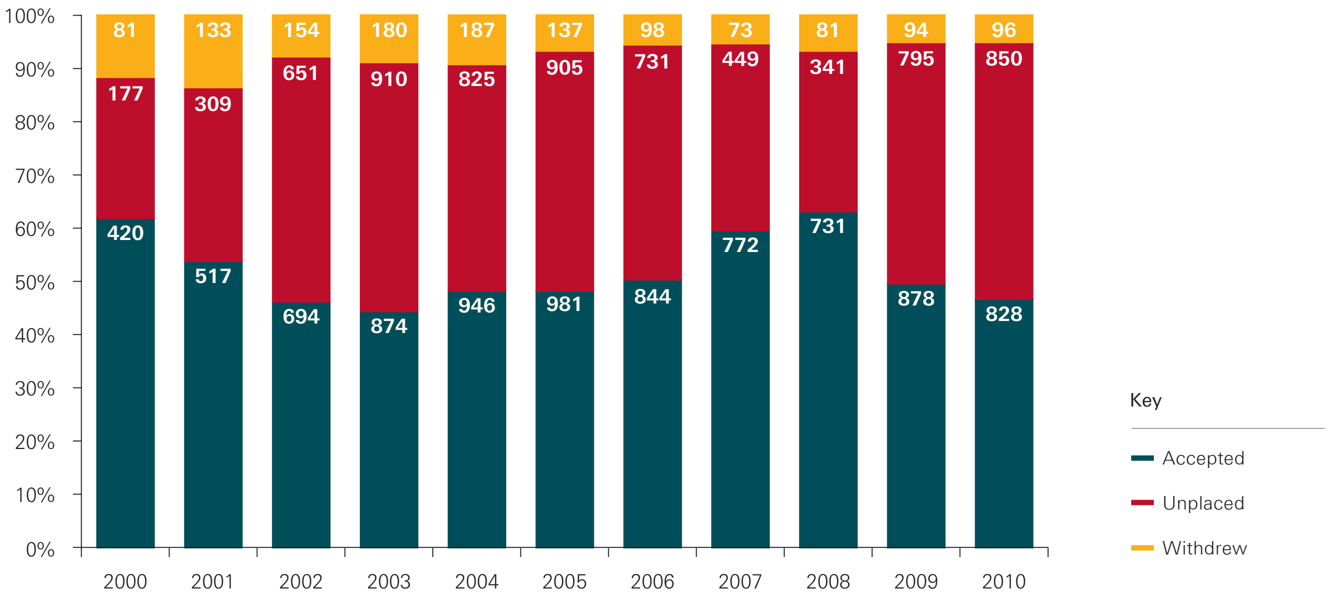
However, the picture provided by the GTTR is incomplete because it does not take account of employment-based routes into teaching.

7.4.1 Total recruitment to ICT ITT courses in England

Table 7.2 puts the GTTR acceptances data for 2005/06 – 2010/11 into the wider recruitment context. It is important to note that until 2009/10 there were no targets for employment-based courses and Teach First numbers were not disaggregated by subject.

Table 7.2 shows that unless recruitment through employment-based routes was sufficient to make up the shortfall, it is likely that up to and including 2008/09 the ITT recruitment targets would have been missed. And while, for 2009/10 and 2010/11, the only years for which complete data are available,

Figure 7.4 Percentages and numbers of applicants to ICT/Computing teacher training in England, Wales and Scotland accepted through the GTTR in 2010



Source: GTTR.

128 Smithers, A & Robinson, P 2011 *The good teacher training guide 2011* Buckingham: Centre for Education and Employment Research.

the targets have been exceeded, nothing is known of the background qualifications, or for that matter experience, of those entering ICT teacher training via employment-based routes.

The importance of work experience should not be underestimated. For instance, entry to the University of Exeter's PGCE course demands that in addition to a first degree (which may be in a wide range of subjects), candidates must have in addition 'substantial ICT subject knowledge and understanding either gained through degree studies, through further qualifications or through work experience'.[129]

We received additional data from Teach First, indicating that 58% of ICT recruits to the programme became career teachers during 2006 – 11 (see table 6.3).

Of the 68 applicants assessed for 2011 entry to Teach First by summer 2011, 31 had studied ICT/computer science as the main component of their degrees, the rest being considered eligible on the strength of their A-levels. In all 22 offers were made (21 to start in 2011 and 1 to start in 2012), nine of which were to individuals who had IT or Computer Science as the main component of their degree.[130] This suggests that less than a third (29%) of those offered places had degrees in the appropriate JACS codes.

Table 7.2 Total recruitment to ICT initial teacher training courses in England (2005/06-2010/11)[a]

	2005/06	2006/07	2007/08	2008/09	2009/10	Autumn term 2010/11[b]	2010/11
Higher education courses					955	984	
Employment-based routes					193	160	
Teach First						12	
Expected employment-based ITT						15	
Expected recruitment					1,148	1,171	
GTTR acceptances	857	740	681	649	806	765	
DfE target	1,100	1,040	985	1,195	1,115	1,035	805

a This table is a composite, being drawn from GTTR Annual Reports and the Department for Education's School Workforce Census.

b Number of places prior to 2008/09 include school centred ITT but excludes employment-based ITT routes (EBITT).

Source: GTTR and Department for Education.

Table 7.3 Recruitment into ICT teaching through the Teach First programme (2006-11)[a]

No. of ICT ITT recruits	53
No. currently completing the 2 year programme	24
No. still working for schools following completion of the 2 year programme	17
No. of teachers who left teaching following completion of the 2 year programme	7

a Data received from Teach First, 13 May 2011.

129 See www.education.exeter.ac.uk/course_information.php?sitscode=PGC1EDUSEC34

130 Information received from Teach First, 13 May 2011.

Concerns about future recruitment

The Government announced at the end of January 2011 that:

- the total number of secondary teacher training places would be cut in accordance with falling school rolls.
- the 'golden hello' – worth £2,500 for newly qualified ICT teachers who have completed their induction year and obtained a teaching post – would be abolished for entrants into teacher training from 2011/12 onwards in England.
- as of September 2012, 'in order to receive funding... anyone starting PGCE teacher training … will, in general, need to hold at least a second class first degree … or an equivalent…'.[131]

Clearly the effect of these changes will not be known for some time. However, given the information in table 7.2, it looks as if the combination of removing an incentive to attracting graduates into teaching training and, at the same time, tightening the entry requirements will make it harder to meet the new – and future – ICT teacher training targets. Indeed, in respect of the latter issue, degree class is a poor proxy for teaching aptitude,[132] and it is worth noting that in their latest Guide to ITT, Smithers & Robinson suggest that 12% of ICT teacher trainees did not hold a 2:2 and that only 49% of such trainees held a first or 2:1 degree, the lowest percentage of 'good' degrees for any secondary subject in the profiles. By comparison, 51% and 54.6%, respectively, of mathematics and science teacher trainees held 'good' degrees.[133]

7.4.2 Total recruitment to Computer science and information technology ITT courses in Wales

Table 7.4 details the total recruitment to Computer science and information technology (CSIT) initial teacher training courses in Wales, as recorded by the Higher Education Statistics Agency (HESA). The HESA records for 2008/09 are much higher than the figure of 56 recorded by the GTTR, indicating that a sizeable number of these students may not have ICT or Computing as a main subject. It appears that both main and subsidiary subjects are included within the total from 2007/08 onwards and this may account for the increase recorded after this point.

Table 7.4 First year CSIT students on ITT courses in Wales[a]

2004/05	50
2005/06	60
2006/07	60
2007/08 [b,c]	65
2008/09	80
2009/10	90

a Enrolments throughout the year.

b Prior to 2007/08 students were grouped according to subject of main specialism, where other subjects may be studied as additional specialisms. From 2007/08 the way in which the data are presented have changed. Students may be recorded under more than one subject.

C From 2007/08 students who are studying at the Open University and are funded by HEFCW will be included in the figures.

Source: HESA.

131 Gove, M 2011 *Teacher training places and financial incentive arrangements – 2011/12. Letter to Graham Holley, Chief Executive, TDA, 31 January 2011.* (See www.tda.gov.uk/~/media/resources/about/letter_from_michael_gove_to_tda_on_teacher_training_places.pdf)

132 Royal Society 2007 *The UK's science and mathematics teaching workforce. A 'state of the nation' report*. London: Royal Society. (See http://royalsociety.org/uploadedFiles/Royal_Society_Content/Influencing_Policy/Education/Reports/SNR1_full_report.pdf)

133 Op. cit., note 11.

Table 7.5 First year students on Computing initial teacher training courses in Scotland

2007	66
2008	57
2009	38
2010	29
2011	22
2009/10	90

Source: Sarah Gibb, GTCS (personal communication to John Howson, July 2011).

7.4.3 Total recruitment to Computing ITT in Scotland

The number of trainees has changed dramatically over the past decade. According to the GTTR figures, trainee numbers increased from 11 in 2000 (although not all Scottish Universities were in the GTTR Scheme at that time) to 68 in 2004, before falling to just 18 in 2010.

Curiously, for 2011, Computing is in a group of subjects with a target of 110 places across the subject group. The other subjects are Art, Classics, Drama, Modern Studies and Music.[134]

Figures provided by the General Teaching Council for Scotland (table 7.5) show a similar decline in the recorded number of teachers trained in Computing over recent years.

It is important to note that the GTCS figures are self-reported and will differ from those from other bodies such as the GTTR for that reason. Further, not all who qualify through GTTR either enter teaching in Scotland or teach in state schools where GTCS registration is required.

7.5 Recruitment difficulties of schools

As part of our investigation into teacher recruitment and deployment we conducted a survey of schools advertising ICT/Computing teacher vacancies in 2010–11, based on vacancy data collected through the Vactrack database maintained by Education Data Surveys at TSL Education Ltd. The survey was based on the 867 posts advertised across England, Wales and Scotland in this period. Of these posts, 767 were advertised by schools in England, 44 by schools in Wales and 56 by schools in Scotland. Across the sample, 107 schools advertising were in the independent sector.

In England and Wales, some 153 of the posts were for Heads of Department (2 on the Leadership Grade, 50 TLR1,[135] 58 TLR2 and 43 where the salary was unknown); 702 were advertisements for teachers (3 Advanced Skills Teacher posts, 34 with a TLR, and 665 main scale vacancies). Some 835 vacancies were for teachers of ICT solely. There were 73 ICT plus business studies vacancies, 23 for ICT with mathematics and a further 32 with ICT and a range of other subjects, half of which were in the design and technology field.

These figures represent a sharp fall in the number of posts advertised during previous years.

Table 7.6 Advertisements for teaching posts in ICT/Computing – England and Wales

	2008-09	2009-10	2010-2011[a]
Main scale teacher	1090	920	665
TLR teacher	155	92	34
Advanced Skills Teacher	21	14	3
Head of Department	323	267	153

a Until end of June 2011 (ie 10 months of the year).

Source: TSL Vactrack database.

134 Scottish Funding Council 2010 *Intake targets for the controlled subjects in higher education institutions for academic year 2010-11.* Edinburgh: Scottish Funding Council.

135 Teaching and Learning Responsibility payment.

In total, some 88 schools responded to the survey, either fully or in part. Of these, 78 were in England, 4 in Scotland and 6 in Wales. Four out of the 88 respondents were independent schools.

The response rate to the survey was some 10% overall. However, the response rate for classroom teacher posts was around 12%. Although not as high as might have been wished, the results were from schools across the country and probably offer a representative picture of recruitment in the state funded school sector in England and Wales.

The survey found that 82 schools made an appointment, but 6 were not able to do so, including one where the advertisement was too recent for an appointment to have been made.

Some 62 schools provided data on applications, with the average school making an appointment receiving 14.8 applications. Five of the schools that did not make an appointment averaged 6.4 applications. The sixth school had not yet made an appointment, but reported having received 70 applications. Schools generally reported receiving fewer applications for posts of responsibility, with the Head of Department vacancies attracting, 4, 5, 8, 14 and 16 applications, respectively, and the posts with TLR1s attached, 5, 6 and 19 applications. Schools in London reported the largest average number of applications (over 30 per school) helped by the 70 recorded by one school and 52 by another. Interestingly, schools in the East of England region had the lowest average of 7.6 applications. It is not clear whether this is due to a lack of sufficient teacher training courses in this region.

Amongst those appointed to teaching posts, 34 were newly qualified teachers who had just completed their training, another 34 were already qualified teachers who had already taught in a school, and 4 were listed as others, presumably including employment-based trainees and Teach First. Of those appointed, 40 had a PGCE but only 27 were reported as holding an ICT/Computing related degree.

Most teaching staff appointed were thought to be of the same level of qualification as existing teachers, although five schools thought their newly qualified teachers (NQTs) appointed were better qualified. This was balanced by seven schools who considered the NQTs they appointed were less well qualified in academic terms than the department as a whole.

The survey inquired whether newly qualified teachers were provided with the correct subject knowledge and appropriate level of skills during their training. Some 38 of the 71 who answered this question thought NQTs had both the subject knowledge and appropriate skills. However, 15 respondents thought NQTs were deficient in both areas, and a further 18 thought there were shortcomings in NQTs knowledge (6 replies) or skills (12 replies).

The picture overall in England from the survey is of schools facing little difficulty in making an appointment in ICT/Computing during 2010/11, with a mixture of newly qualified and existing teachers being appointed with qualification levels generally the same as those of existing department staff in the subject.

This picture contrasts rather with that presented by the School Workforce Census, which as we have seen indicates that there are many ‘unqualified’ teachers teaching ICT/Computing. It also differs from the 2007 TIMSS survey,[136] which found that in England some 47% of students were attending a school whose head teacher reported difficulties in recruiting ICT teachers, which is much higher than the European average of 29%. In Scotland, 23.5% of students were attending a school whose head teacher reported difficulties with recruiting ICT teachers.

Although these figures are striking, it should be noted that in both England and Scotland the figure was even higher for mathematics teachers and science teachers (61.8% and 57.2% for mathematics and science respectively in England, and around 34% for both in Scotland).

136 Teaching and Learning Responsibility payment.

Conclusion
There is a shortage of specialist teachers able to teach ICT and Computer Science.

Recommendation 2
The government should set targets for the number of Computer Science and Information Technology specialist teachers, and monitor recruitment against these targets in order to allow all schools to deliver a rigorous curriculum. This should include providing training bursaries to attract suitably qualified graduates into teaching – for which industry funding could be sought.

Education Scotland should ensure that the declared entitlement of all learners to third level outcomes in Computing Science is implemented in all schools for all learners using appropriately qualified teachers.

7.6 Teacher access to continuing professional development

A common theme that emerged from the call for evidence was the issue of availability and access to Continuing Professional Development (CPD).

7.6.1 The evidence

UNESCO hosted a summit on IT in education in June 2011. The report of the working group on professional development[137] made a number of recommendations for policy makers, including:

- Develop a minimum entitlement/requirement for professional development along a career-long continuum (pre-service, in-service and lifelong), which prepares and enables practitioners to develop and regularly update their expertise as education moves from traditional models, roles and practices to new and emerging ones.
- Ensure that at least 30% of funding for new educational initiatives is set aside for professional development.

A small-scale survey[138] of awareness of and participation in Computing and ICT professional development was undertaken as part of our project, attracting 114 responses from teachers and school leaders; findings included:

- **ICT/Computing teachers value the provision of quality CPD opportunities.** The ever-changing subject matter requires teachers to review and update their subject knowledge and skills on a regular basis.
- **The culture toward CPD varies within institutions.** Not all teachers are incentivised by their senior management to undertake CPD. Teachers' own desire to update their knowledge and skills is the main driver for CPD uptake. A national initiative to promote the importance of CPD for ICT/Computing teachers would help to develop a healthier culture toward CPD.
- **CPD events offer valuable networking opportunities.** By sharing ideas, experiences and discussing teaching issues participants gain self-esteem and confidence to try new approaches in their teaching of ICT/Computing.
- **Associated costs and 'rarely cover' policy** are the main obstacles to teachers taking up CPD opportunities. Teachers are reluctant to lose contact time with their classes by attending CPD activities scheduled during busy term-times. The geographical distribution of CPD events is a particularly off-putting for teachers working in rural areas. More local and regional provision of CPD would be welcomed, as would distance learning materials.
- **Teachers' CPD is vital to promoting more E&E opportunities** for young people in schools.
- **A coordinated national website/database of CPD opportunities** would ensure more teachers can identify appropriate courses and resources.

137 Twining, P, Albion, P & Knezek, D 2011 *Report from TWG3: teacher professional development. EDU summit on ICT in education.* Paris: UNESCO.

138 The size and dissemination of this survey is such that results should be treated as a 'taster' of opinions on this subject rather than interpreted as truly representative sample.

Of 80 respondents, 65 reported that they had never attended a CPD session on programming; a further 11 had attended only one such course.

Respondents pointed to a lack of CPD being available in the following areas:

- contexts – showing real-world applications of ICT (work shadowing), software development, hardware deployment;
- Computing and its principles – including programming workshops on Java, HTML5 and web-based programming;
- understanding computer hardware – a project in collaboration with Intel already aims to deliver this;
- incorporating new technologies – including workshops on new software (Flash, Photoshop etc) and building apps for mobile phones. As well as training teachers to be competent and confident in using these new technologies, these events should also cover the pedagogy to allow teachers to incorporate them effectively in their programmes of study;
- e-safety for teachers and teaching students.

For teachers in Scotland, additional provision linked to the role of ICT/Computing in delivering the aims of Curriculum for Excellence was a priority.

A 2010 report from BECTA also examined this issue, and produced a 'map' of the ICT CPD landscape in the UK by plotting both supply and demand[139]. The report encompassed the broader picture of ICT CPD, including that relating to use of technology in the classroom in general rather than our more narrow interest of CPD for ICT and Computing teachers, but many of the conclusions are relevant. The report notes that 'course content is overwhelmingly about skills and ICT in classrooms, i.e. on the curriculum application of the technology rather than the pedagogy' and describes the landscape as 'decentralised, informal and fragmented'. There was also 'limited rigour in evaluation of provision [which] increased the challenge of identifying relevant and challenging course content and effective ICT CPD models.'

BECTA recommended an entitlement to professional learning in this report, and suggested that consideration is given to personal CPD budgets for teachers, separate from a school's CPD budget, along with support for informal 'communities of practice'.

Similar issues relating to provision of and access to subject-specific CPD have existed in science and mathematics but are being addressed by the National Centre for Excellence in the Teaching of Mathematics (NCETM), the National Science Learning Centre (NSLC) and the Scottish Schools Education Research Centre (SSERC).

7.6.2 Current and future provision

In particular, BECTA suggested that 'the development of an overarching national online community of practice providing a one-stop shop for access to informal and formal CPD might be a useful way of harnessing increasingly fragmented individual endeavours'. One player currently is the Open University's Vital Professional Development programme, with a remit to enhance 'ICT Teaching', and which has funding support from the Department for Education. This programme covers the teaching of Information Technology and Computer Science as discrete subjects, as well as embracing the wider role of 'using ICT in the classroom' in the teaching of other subjects. Vital's website includes subject portals on Secondary IT run by e-skills UK and Primary ICT. Another increasingly significant player is Computing at School (CAS) which has 14 regional CPD hubs for Computing teachers based within HEIs and schools, runs 4 national conferences for Computing teachers per year and supports teachers in running twelve 6th Form conferences every year on Computing.

When considering how to make progress in this area it would be wise to consider the models already established for science and mathematics. The National Centre for Excellence in the Teaching of Mathematics (NCETM) was created in 2005 following a recommendation from the Advisory Committee on Mathematics Education (ACME) in 2002. Its equivalent in science is the National Science Learning Centre (NSLC, established in 2005) and its associated network of regional Science Learning Centres. The NCETM provides coordination of CPD opportunities and identify gaps in provision, whilst creating online communities of

139 BECTA 2010 *ICT CPD landscape: final report*. London: BECTA (See www.wlecentre.ac.uk/cms/files/becta/becta-ict-cpd-landscapereport.pdf)

practitioners and eSeminars for distance learning. The NSLC and its associated network of regional Science Learning Centres, plays a similar role but currently also provides CPD courses directly to teachers. There may be a case for better co-ordination between all organisations providing CPD in the subjects covered within this report and those connected to them.

Conclusion

There is a lack of support for CPD for Computing and Information Technology teachers that deepens subject knowledge and subject-specific pedagogy, particularly in Computer Science. This needs to be addressed – it is important that teachers have access to good quality CPD, particularly given the lack of specialists. This will be essential to support a new curriculum in schools.

Recommendation 3

The Government departments with responsibility for Education in the UK should seek industry support to extend existing funding in this area, and should ensure that there is coordination of CPD provision for Computer Science and Information Technology teachers that deepens subject knowledge and subject-specific pedagogy.

7.7 Student access to technology

The focus of this report is the teaching of Computer Science and Information Technology as subjects in themselves, not the number of computers in schools or the use of technology in pedagogy in general. Nevertheless, a chapter on resources would be incomplete without some reference to national expenditure on equipment and software, and the access that schools across the UK have to this technology.

A measure of hardware availability reported in the 2007 TIMMS survey is the number of students per computer. The average across Europe is 3.5 at primary level, with England and Scotland leading the way at 1.9 and 1.8 respectively. At secondary level, the European average stands at 1.4, and again England and Scotland are ahead of most European countries with 0.7 and 0.9 each[140]. Information from PISA 2009 indicates that in all the home nations there is very little variation in computer availability across the country.[141]

By these measures at least, the UK is outperforming its neighbours. However, anecdotal evidence in Scotland is that continual upgrading of operating systems and software by infrastructure providers often leads to obsolescence of hardware – so that the perceived high ratio of computers to pupils may be deceptive. Clearly there has been heavy investment in student access to technology in recent years, but this should not be confused with having improved Computer Science education.

140 TIMMS 2007, as reported in Eurydice report *Key data on learning.* This measure asks head teachers to report the number of students in the fourth and eighth grades and the total number of computers that could be used by them for educational purposes – it should not be inferred, for instance, that there are more computers than there are secondary school pupils in England and Scotland.

141 *Key data* page 76, based on PISA 2009 data.

7.8 Infrastructure issues

The issue of resource for teaching Information Technology and Computer Science extends beyond the sheer number of computers in a school; many respondents to our call for evidence referred to the issue of network security restrictions impeding legitimate teaching activities. As Naace put it: "In schools with particularly restrictive policies in place and where academic staff have little control over the computers used for subject teaching, teachers report difficulties in providing students with access to interpreters and compilers or installing software development environments."

This issue arises from the need for safe and secure operation of a school computer network, which is clearly an important priority for an organisation holding sensitive information on young people. Despite the legitimacy of security concerns, an analogy may be drawn between this and perception and overzealous implementation of 'health and safety' rules becoming a barrier to school field trips and practical science experiments. The latter was the subject of a 2011 House of Commons Select Committee inquiry[142], and the Secretary of State for Education spoke in 2011 of the need for reform in this area. A similar backlash against pedagogical restrictions in Computer Science and Information Technology may be apt in this instance.

Participants at a stakeholder meeting for teachers in Scotland in March 2011 were particularly vocal on this issue, and pointed to the fact that many schools in Scotland contracted out their network management to private companies; this led to a feeling that those with little understanding of pedagogical needs were effectively controlling what could be achieved in the classroom, with individual teachers having little power to change this.

It must be borne in mind that school networks are complex by nature, use and diversity. They are often more complex than small to medium sized enterprises and in some cases use a wide range of infrastructure topologies. They service a diversity of users who require many differentiated profile settings, and individual departments have their own suite of software and hardware requirements.

The need for safe and secure operation of a school computer network is clearly an important priority for an organisation holding sensitive information on young people but operating an overly restrictive policy on what can be used by the students can impede teaching and learning.

Thus, management of a school network is not straightforward. It is exacerbated by other issues:

- **Incentives:** Internal support groups have no incentive to provide additional services and a direct incentive to keep the operating environment as simple and unchanging as possible. Symptoms include:
  - Exaggerating the difficulties of providing services.
  - Exaggerating the threat posed by security without substantiation.
  - Over-zealous approach to 'locking down' the environment.
- **Ad hoc approach to service provision:** What is delivered by IT support departments is usually defined by non-technical managers in terms of outputs (printing, Word Processing) and specified over the short term. Schools need medium and long-term IT strategies and a planning process into which the academic departments, including Computer Science, can have input. Such strategies cover the underlying services (sub netting, virtual machines, laptop support, security layers, remote access, .NET support), desktop applications and operating systems.
- **Isolated management:** The problem is that school management is usually not well placed to put together such strategies or to understand them. School management and IT teams need a "Guide to Best Practice" to help them understand the wider implications for their school network and strategies for solving local issues can be documented.

142 Science & Technology Committee 2011 *Practical experiments in school science lessons and science field trips: Government and Ofqual responses*. (See www.publications.parliament.uk/pa/cm201012/cmselect/cmsctech/1655/165502.htm)

Conclusion
Important aspects of Computer Science and Information Technology teaching and learning are being compromised by the need to maintain network security.

Recommendation 4
School infrastructure service providers, working with others, should prepare a set of off-the-shelf strategies for balancing network security against the need to enable good teaching and learning in Computer Science and Information Technology, and should encourage schools to discuss and adopt them with their service providers. Such a "Guide to Best Practice" should be used by schools and local authorities as part of any tendering process for outsourced service provision.

Recommendation 5
Suitable technical resources should be available in all schools to support the teaching of Computer Science and Information Technology. These could include pupil-friendly programming environments such as Scratch, educational microcontroller kits such as PICAXE and Arduino, and robot kits such as Lego Mindstorms.

7.9 The status of Computer Science and Information Technology amongst school leaders

Teacher participants at stakeholder meetings repeatedly pointed to the low status of their subject amongst school leadership teams as being an issue that affected both the recruitment of specialist teachers and the extent to which teachers were able to argue for network restrictions to be lifted. BECTA also points the perceptions of senior management as being a barrier to uptake of ICT CPD[143]. This was also a consistent theme in responses to our own survey on CPD and E&E opportunities.

This low status appears to be the result of a vicious circle involving the following elements:

- Difficulty in recruiting specialist teachers, partly due to the well-paid alternatives, and partly to the subject's low status in schools.
- ICT is often taught by non-specialists partly due to the lack of available specialists.
- The focus on undemanding user skills in ICT, partly due to the non-specialist teachers
- The academically undemanding nature of ICT qualifications, and their heavy emphasis on coursework that can be re-submitted repeatedly, leading to high grades but low expectations.
- Driven by league tables, school leaders encourage large ICT enrolments, leading to heavy workloads (exacerbated by the coursework bias), large classes, and a complete lack of an ethos of "bright students do this subject" which applies to, say, mathematics.
- An ICT specialist is also often pressed into service as a service technician, to support the school's IT infrastructure, mend broken printers etc.

These factors reinforce each other to maintain the status quo.

143 Twining, P; Albion, P. & Knezek, D. (2011) Report from TWG3: *Teacher Professional Development*. EDUsummIT 2011: International Summit on ICT in Education. June 2011. Paris: UNESCO

Appendix A: Advisory Group membership

Professor Steve Furber CBE FRS FREng (Chair), ICL Professor of Computer Engineering, University of Manchester

Dr Liz Bacon, Dean of School, Computing and Mathematical Sciences, University of Greenwich, Vice-President and Trustee of the BCS, the Chartered Institute of IT, Chair of BCS Academy of Computing

David Bethune, Consultant, currently working on qualifications development for SQA, formerly Principal Teacher of Computing at Hawick High School

Roger Boyle, Department for Lifelong Learning, University of Aberystwyth

Professor Muffy Calder OBE FRSE, Professor of Computing, University of Glasgow, former Chair of UKCRC

Professor David Harper, Head of EMEA University Relations, Google Switzerland

Mandy Honeyman, KS4 ICT Coordinator and IT Operations Coordinator, Linton Village College

Simon Humphreys, Coordinator, CAS, and formerly Sixth Form Teacher, Hills Road College, Cambridge

Graham Macleod, Teacher, Bradfield College

Professor David May FRS FREng, Professor of Computer Science, University of Bristol

Professor John McCanny OBE FRS FREng, Director of the Institute of Electronics, Communications and Information Technology (ECIT), Queen's University Belfast

Dr Bill Mitchell, Director, BCS Academy of Computing

Professor John Mitchell OBE FRS, Principal Research Fellow, Met Office

Professor Ian Nussey OBE FREng, University relations, IBM UK Ltd

Professor Simon Peyton-Jones, Principal Researcher, Microsoft Research Ltd

Karen Price, CEO, e-skills UK

Neil Sheldon, Manchester Grammar School, Member of ACME Outer Circle

Mark Wakefield, IBM UK Ltd, Royal Society Education Committee

Professor William Webb FREng, CTO, Neul

Dr Damon Wischik, Royal Society University Research Fellow, University College London

Dr John Woollard, University of Southampton School of Education

Appendix B: Acknowledgements

Review Panel Membership

Professor Andrew Hopper FRS (Chair)

Professor Andrew Blake FRS

Professor Peter Buneman FRS

Professor Sally Fincher

Professor Ian Horrocks FRS

Peter Thomas

Other acknowledgements and thanks

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James Beressem

Professor Tom Crick

Gabriel Goldstein

Liz Hollingworth, e-skills UK

Professor John Howson

Professor Ruth Jarman

Juliet Sizmur, NFER

Linda Sturman, NFER

Dr Lisa Payne

Dr Carmen Vidal Rodeiro, Cambridge Assessment

Dr David Walker

Royal Society Secretariat

Martin Smith

Cathryn Evans

Dr Anne Helme

David Montagu

Lara Statham-Taylor

Libby Steele

Nick von Behr

Appendix C: Call for Evidence respondents

Alison Allen, Outstream Consulting

Reiss Allen-Smith

Hayden Amos

Tony Attwood

Eduard Babulak

Nathanae Bastone

Miles Berry, Naace

Maggie Berry, Women in Technology

Kevin Bond

Gleen Booth, Giffard Park Primary School

Peter BradshawVital

Martin Brain

Roger Broadie

Mark Brownrigg, Learning and Teaching Scotland

Alan Bundy

Tom Campbell

Brian Caswell

Judy Challinor

William Chaplin

Kieran Charleson, BT

Sheena Clohessy, I Can Do Learning Ltd

Andrew Connell

David Cooper, Rugby High School

David Coull, SIoCE

Chris Coulter, RAEng

Dana Crandall, BT

Artur Czumaj, Department of Computer Science, Warwick

Chris Davies

Matthew Dean, Association of Colleges / Association for Learning Technology (Joint)

Peter Denning

Hugo Donaldson, The IET

Peter Donaldson

Sam Dutton

Alaia E. A.

James Franklin

Terry Freedman

Neil Gordon

Philip Gray, University of Glasgow

Richard Green, DATA

Andy Greenhow

Peter Gregory

Mark Griffiths, Shevington High School

Claire Griffiths

Steve Groombridge

Adrian Hall

Chris Hall

Michael Hammond

Bob Harding

Brian Hartington

Stephen Heppell

Shaun Hexter

Albert Hickey

Assiya Hussain

Edward James

Jess Jones

Stuart Jones

Lin Jones, National Museum of Computing

Christopher Kilding

Tracy Kimberley, Kingshurst CTC Academy

Iris Lapinski, CDI Europe

Thomas Leaton

Chris Lewis

Tricia Lockhart

Ian Lynch, The Learning Machine Ltd

John Maher

Dave Main, SQA

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Gerry McAllister, HE Academy ICS Subject Centre

Andrew McGettrick, University of Stratclyde

Fraser McKay

Scott McLaughlin

Greg Michaelson, Scottish Heads of Computing

Richard Millar, University of Ulster, Faculty of Computing and Engineering

Bill Mitchell, BCS

Glyn Moody

Cathy Morgan

Hardip Mothada

David Muir

Steve Nash

Richard Needham, ASE

Asaad Noori

Ruth Nutall

Michael O'Duill

Janet Osisiogu, AQA

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Terry Patterson

Lisa Payne

Simon Peyton-Jones, Computing At School

Christina Preston, MirandaNet

Karen Price, e-skills UK

Michael Reid

Clarke Rice

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Judy Robertson

Peter Rudd, NFER

John Rutherford

Daniel Sandford-Smith, Gatsby

Martin Schofield

Karen Schofield, OCR

Jim Scott, School Leaders Scotland

Sue Sentance

Teresa Shaw, High School for Girls

John Shawe-Taylor, Department of Computer Science, UCL

Anton Shterenlikht

Ian Simons

Richard Taylor

Jacqui Taylor, Flying Binary

Clare Thomson, IoP

Kathryn Tipper, Suffolk County Council

Robert Tuck

David Turner, Merchiston

Castle School

Richard Veryard

Mark Wakefield, IBM

Mary Watson

Mary Webb, Technology Mediated Learning Research Group, King's College London, Department of Education and Professional Studies

Chris Whelan

Oliver Williams, Queen Elizabeth High School

Chloe Williams, National STEM Centre

Barbara Wilson

Zena Wood

John Woollard

Dave Wright

Keith Wyles

Appendix D: Attendees at stakeholder meetings

18 March 2011 (Manchester) teachers

Name	Job title	Organisation
Hayley Aston	Teacher	St Ambrose College
Adele Barrow	Assistant Headteacher	Wentworth High School
Liz Burd	Chair, Educational Activities Board	IEEE
Debra Charnley		TDA
Andrew Connell	Teacher Training	Keele University
Andy Greenhow	Head of ICT	Altrincham Girls Grammar School
Judith Hartley	Computing teacher	The Sheffield College
Sarah Lawrey	Computing and ICT teacher	Altrincham Grammar School for Boys
Jacob Lester		Research Together
Janet Osisiogu	Senior Subject Manager for ICT and Computing	AQA
Michael Reid	Teacher	Broughton Hall High School
Jack Roberts		Newcastle College
George Rouse	Examiner - Computing	OCR
Tony Ryan	ICT Advisor	Salford Children's Services
Paul Spedding	Chief Examiner - Computing	WJEC
Torben Steeg		D&T Association
Barbara Wilson		

22 March 2011 (Glasgow) teachers

Name	Job title	Organisation
Jason Bain	Teacher of Computing	Glenwood High School
Alan Bundy	Vice President	BCS Academy of Computing
Jennifer Butler	Principal Teacher	Albyn School
Kate Farrell	Glow Development Officer and Lead Teacher for Computing	City of Edinburgh Council
Julie-Anne Graham	Teacher	Carluke High School
Claire Griffiths	ICT & Glow Support Officer	
Alison Kidd	Quality Improvement Officer, Learning and Teaching, Technologies	City of Edinburgh Council
David McCorkindale	Head of Computing	High School of Glasgow
Janet McDonald	Computing Teacher	The Glasgow Academy
Mick McGowan	Head of Computing	Port Glasgow High School
Martin McGranaghan	Computing Teacher	The Glasgow Academy
Kenneth McLaughlin		Glasgow University
Ann McVey	Computing Teacher	Eastwood High School
Lorraine Muir	Computing Teacher	Cathkin High School
Derek Park	Principal Teacher of Computing	Dalziel High School

22 March 2011 (Glasgow) teachers continued

Name	Job title	Organisation
Fiona Sabba	Teacher	Lochend Community High School
Aquila Singh	Principal Teacher of Computing & Business Education	Belmont House School
Craig Steele	Research Assistant	University of Glasgow
Sandra Sterkenberg	Principal Teacher of Computing	Jordanhill School
Leona Urquhart	Teacher	Woodfarm High School
Mary Watson	Teacher	Merchiston School

24 March 2011 (Leeds) HE

Name	Job title	Organisation
Ross Anderson	Professor of Security Engineering	University of Cambridge
Gareth Bellaby	School of Computing, Engineering and the Physical Sciences	University of Central Lancashire
Jeremy Bradley	Senior Lecturer, Dept of Computing	Imperial College London
Steven Bradley	Engineering and Comupter Sciences	University of Durham
Philip Bryant	Technology & ICT Qualifications Team Manager	OCR
Stephen Cameron	Computing Laboratory	Oxford University
David Chan	Department of Computing	City University
Maria Chondrogianni	Principal Lecturer,	High School of Glasgow
Undergraduate Unit Leader,	Computing Teacher	The Glasgow Academy
School of Electronics and Computer Science	University of Westminster	Port Glasgow High School
Tony Cowling	Department of Computer Science	University of Sheffield
Tom Crick	Lecturer in Computing	University of Wales Institute, Cardiff (UWIC)
Roy Crole	Admissions Tutor, Computer Science	University of Leicester
Fintan Culwin	Head of Department, Informatics	London South Bank University
Lynne Dagg	Trainer of ICT/Computing teachers	University of Sunderland
Colin Dalton	Senior Lecturer	University of Bristol
Neil Gordon		Hull University
Peter Gregory	Research Fellow	Strathclyde University
John Grey	Trainer of ICT/Computing teachers	University of Sunderland
Stephen Hunt	University Lecturer, Computer Science	University of Hertfordshire
Adrian Jackson	Staff Tutor, Mathematics, Computing and Technology Faculty	The Open University in the North West
Sian Jones	Communications Manager Technocamps	Swansea University
Gavin Lowe	Admissions Coordinator for Computer Science	Oxford University

24 March 2011 (Leeds) HE continued

Name	Job title	Organisation
Greg Michaelson	School of Mathematical & Computer Sciences	Heriot-Watt University
Faron Moller	Director, Technocamps	Swansea University
Cathy Morgan	Independent education consultant (former specialist advisor for ICT at Ofsted)	n/a
Richard Needham	Chair	The Association for Science Education
Lisa Payne	Honorary Lecturer and PhD Student, Computing Department	Coventry University
Iain Phillips	Head of Department, Computer Science	Loughborough University
Steve Russ	Lecturer in Computing	Warwick University
Martin Schofield	Technology Analyst	CSC
Sarah Snowdon	Independant Education Consultant	n/a
Ian Stevenson	Senior Lecturer in ICT in Education	King's College London
Andrew Tuson	Department of Computing	City University
Gary Unthank	Principal Lecturer - Recruitment and Software Engineer Team Leader, Dept. of Computing, Engineering and Technology	University of Sunderland
Brian Williams	Independent technology education consultant	D&T Association
Annette Wilson	Head of School of Computing	University of Plymouth
Zena Wood	Teaching Fellow	University of Exeter

28th March 2011 (London) Others

Name	Job title	Organisation
David Barlex		D&T Association
Agneau Belanyek	Principal Examiner	OCR
Maggie Berry	Managing Director	Women in Technology
Kieran Charleson		Teach First
Margaret Cox	Professor of Information Technology in Education	King's College London
Sam Dutton	School 'e-govenor' and software developer	n/a
Debbie Forster	Head of Partnering	CDI Europe
Terry Freeman	Independent educational ICT consultant	n/a
Karen Hedger	Curriculum Development Manager	Open College Network London Region
Patrick Lees	Chair of Governors. (also Head of the Department, School of Electronics and Computer Science, University of Westminster)	Quintin Kynaston School
Adam Lewis		Teach First
Derek O'Rourke		Wiltshire LA

28th March 2011 (London) Others continued

Name	Job title	Organisation
Terry Patterson	Head of e-Learning	London Borough of Tower Hamlets
Richard Smartt	Education Manager	CDI Europe
Jacqui Taylor	CEO	Flying Binary
Kathryn Tipper	County Adviser for ICT	Suffolk County Council
Alec Titterton	National Network Coordinator for Maths and Computing Colleges	Specialist Schools and Academies Trust
Ann Weidmann	Senior Business Manager for ICT	Edexcel

31st March 2011 (London)

Name	Job title	Organisation
Miles Berry	Vice chair	Naace
Sean Byrne	GCSE Computing Chief Examiner	OCR
Tom Campbell	Curriculum Leader for ICT and Computing	Hardenhuish School
Judy Challinor	Teacher	Newham Sixth Form College
Ian Crosby	Head of Computing	Hills Road Sixth Form College
Caroline Croydon	Teacher	Felsted School
Hari Denton	ICT Teacher	Mossbourne Community Academy
James Franklin	Teacher	Chichester High School for Boys
Chris Hall	11-19, Learning & Achievement ICT Consultant	Coventry City Council
Ruth Hillard	Teacher	Hove & Sussex VIth Form College
Jill Ilott	Head of ICT	St Margaret's School
Alex Issachsen	Director of ICT	Cheltenham College
Shaun Joynson	ICT Teacher	Central Saint Martins College of Art & Design
Peter Kemp		Teach First
Anne Mayne	ICT Teacher and Year 6 Co-ordinator	Britannia Village Primary School
Asaad Noori	Former teacher	n/a
Bosede Onifade	Head of Comupting and ICT	St Olaves Grammar School
Gary Owen	Teacher	Tonbridge Grammar School
Lorna Panesar	Computing Subject Leader	The Emmbrook School Wokingham
Susan Pearce	Head of Computing and IT	Forest School
Barry Phillips	Head of ICT	St Pauls School, Greenwich
Grace Porter	Former ICT/Computing teacher, and computing professional	n/a
Vanessa Radford	Teacher of ICT	Bishop Luffa School
Sue Sentance	Senior Lecturer in ICT Education	Anglia Ruskin University
Richard Taylor	Subject Manager	International Baccalaureate Organization

Appendix E: Royal Society National Curriculum Review Submission

Computing and ICT

This response to the National Curriculum Review is on behalf of the Royal Society and refers specifically to matters relating to Computing and Information and Communication Technology (ICT). This submission complements the Royal Society's input regarding the National Curriculum for science which it is making through the SCORE partnership.

For the purposes of this submission, we use the word 'Computing' to mean the concepts and fundamental principles of the subject such as algorithms, programming, design, problem-solving etc. By 'ICT' we mean the technology and application of computers, including the skills of using computer applications, systems management and computer networks.

Headline issues:

- ICT is not the same thing as Computing (also called Computer Science). While the current National Curriculum seeks to cover both, in a significant number of schools it is interpreted in a narrow way which has led to a negative perception of this subject and a conflation of the terms.

- Decisions relating to the inclusion or exclusion of ICT or Computing in the National Curriculum should be made with a full understanding of the differences between the two, and of other terminological issues which may cloud decisions.

- Essential knowledge, including principles, concepts and methodologies, exist across the ICT and Computing landscape. These are distinct from the skills of using office applications which some might associate with the subject.

- Inclusion of a statutory component of Computing may be necessary to ensure that both Computing and ICT are taught in schools in an appropriate way.

- There appears to be a shortage of specialist Computing teachers which would affect delivery of a statutory component and this would need to be addressed.

- The Royal Society is undertaking work in this area which will be highly relevant to the Department's decision on ICT and Computing in the National Curriculum.

Background

The Royal Society is now part-way through a review of Computing and ICT in schools which is highly relevant to the Department's deliberations in this area. Our project began in 2010 with a call for evidence which attracted a large number of responses from a range of organisations and individuals, and has continued in 2011 with a series of stakeholder meetings with teachers, HE and others. Our project is supported by partners in industry, other learned societies and HE institutions.

The final report is due to be published at the end of 2011, and the Royal Society would like to engage with the Department for Education as this work progresses. The Society has not yet completed its investigations and does not wish to pre-empt the remaining work to be done in this area, but we present in this document a small number of important messages from the initial stages in order to support a request for further dialogue with the Department on the place of ICT in a new National Curriculum.

Terminological difficulties

There are considerable terminological difficulties in this area which can lead to confusion among teachers, students, parents, school leaders and policy-makers, and can have an impact on progression in the subject. An important message from our call for evidence phase was that 'Computing' – in the sense of rigorous topics such as programming and algorithms – is distinct from 'ICT', which is associated with the skills of using computer applications, systems management and networks. Computing is associated with understanding concepts.

ICT in the current National Curriculum

Although the existing ICT curriculum provides some scope for the teaching of computing concepts, it would appear from our call for evidence that the flexibility – or vagueness – of the current National Curriculum has allowed a significant number of schools to teach a restricted diet of 'learning how to use word-processing packages and spreadsheets', without being required to explore the more rigorous and challenging aspects of computing.

Possible reasons for this approach include a shortage of specialist teachers in this area, and the Society is investigating this as part of its project. The existing curriculum has the flexibility to be 'deliverable' by teachers with a range of backgrounds, knowledge and confidence. Many examples of excellent teaching of Computing certainly exist where a teacher is knowledgeable and enthusiastic, but the results of our call for evidence suggest that there is considerable variation in what pupils experience and the opportunities they have to make informed decisions about Computing.

Negative trends in numbers studying Computing post-16 and at undergraduate level suggest that a significant number of young people are deciding against the subject on the basis of an impoverished ICT curriculum experience. This is ultimately to the detriment of the economy.

ICT/Computing in a new National Curriculum

The formulation of 'ICT' as a National Curriculum subject is therefore not without its problems, and its brand has been eroded in recent years. However, current progress with our project suggests that a body of 'essential knowledge' across the ICT and Computing landscape exists and could be included in a National Curriculum in place of the existing entitlement. If our investigations reveal a considerable shortage of specialist teachers in these areas then a statutory component could help ensure that recruitment difficulties will not dissuade schools from striving to teach these important subjects.

The Society stands ready to engage further with the Department on these issues, with the message that terminological issues or 'brand' problems should not cloud decisions in this highly important area. There is a risk that Computing and ICT will be conflated in the Review and that a decision to remove one from the National Curriculum will amount to a decision to exclude both.

14 April 2011

Appendix F: Examples of Enhancement and Enrichment activities

Examples of Enhancement and Enrichment (E&E) opportunities in ICT and Computing from the survey of school and college teachers in the UK.

Events, courses and resources aimed at teachers that focused on developing E&E opportunities in the classroom:

- Game to Learn: Take 2! Conference organised by Learning Teaching Scotland's Consolarium[144];
- CPD courses offered by AOK Learning, such as the VB 2005 programming course[145];
- courses for teachers offered through Naace's ICT CPD 4 free scheme[146];
- courses and meetings offered by VITAL[147].

E&E opportunities that benefit students directly and which were felt by survey respondents to be 'good':

- Computer Science Inside resources offered by the University of Glasgow[148];
- Undergraduate Ambassadors scheme run at the University of Glasgow, which puts final-year computer science students in schools where they work with teachers in developing and delivering computing workshops for students;
- First Lego League, hosted by the University of Edinburgh[149];
- An annual animation competition run at the University of Manchester[150];
- The National Cipher Challenge run by the University of Southampton[151];
- British Informatics Olympiad, an annual competition in computer programming for secondary schools and sixth form colleges which has more limited appeal to keen programmers and good mathematicians[152];
- Computing at School meetings, such as its sixth form conferences;
- the wide range of talks from visiting speakers offered through the BCS Academy of Computing[153];
- visits to local university computer science departments, organised via the Computing At Schools initiative;
- industrial visits to, for example the Imagineering Jaguar Land Rover Partnership Centre[154] at Gaydon JLR Design and Engineering site where students see the application of ICT in real-world contexts;
- Linux boot camps run by the University of West of England[155], which offers A-level students the opportunity to explore practical technical computing using Linux operating system;
- Robot ARM simulation, offered by Rickitt Educational Media[156];
- The Java-based programming software Greenfoot, maintained by Michael Kölling at the University of Kent[157];
- Extra-curricular ICT clubs run by teachers.

Computer Science for High Schools (cs4hs.com)
Funding for universities to provide teacher training and resources for high school teachers to enable them to teach CS.

Google RISE Awards (google.com/diversity/rise)
Google provides funding and support from engineers for non-profits to run projects engaging under-represented groups in STEM and CS in schools across EMEA. In 2011 in the UK Teen Tech was an award recipient. Teen Tech runs events for secondary school children to enthuse them about becoming creators of technology as opposed to simply consuming technology.

Generating Genius (generatinggenius.org.uk)
Generating Genius works with education and industry to encourage, guide and inspire gifted and talented young people from under-represented groups into Science, Technology, Engineering and Mathematics (STEM) studies and careers.

144 www.gametolearn.org
145 www.aokonline.com/computing.html
146 www.ictcpd4free.co.uk
147 www.vital.ac.uk
148 csi.dcs.gla.ac.uk
149 www.firstlegoleague.org
150 www.cs.manchester.ac.uk/animation11
151 www.cipher.maths.soton.ac.uk
152 www.olympiad.org.uk
153 www.bcs.org/category/9231
154 imagineering.org.uk/special-activities/overview
155 www1.uwe.ac.uk/et/csct/aboutthedepartment/outreachandpublicengagement/linuxbootcamp.aspx
156 www.r-e-m.co.uk/rem/xrem.php?T=17116&view=
157 www.greenfoot.org

Google Code In (code.google.com/opensource/gci)
Global competition aimed at getting 13 – 17 year old students involved in development on open source software. Students complete tasks of various types and difficulties to win points and can earn 100 USD for each 3 tasks completed up to a maximum of 500 USD. Grand prize: an all-expenses-paid trip to Google's headquarters in Mountain View, California.

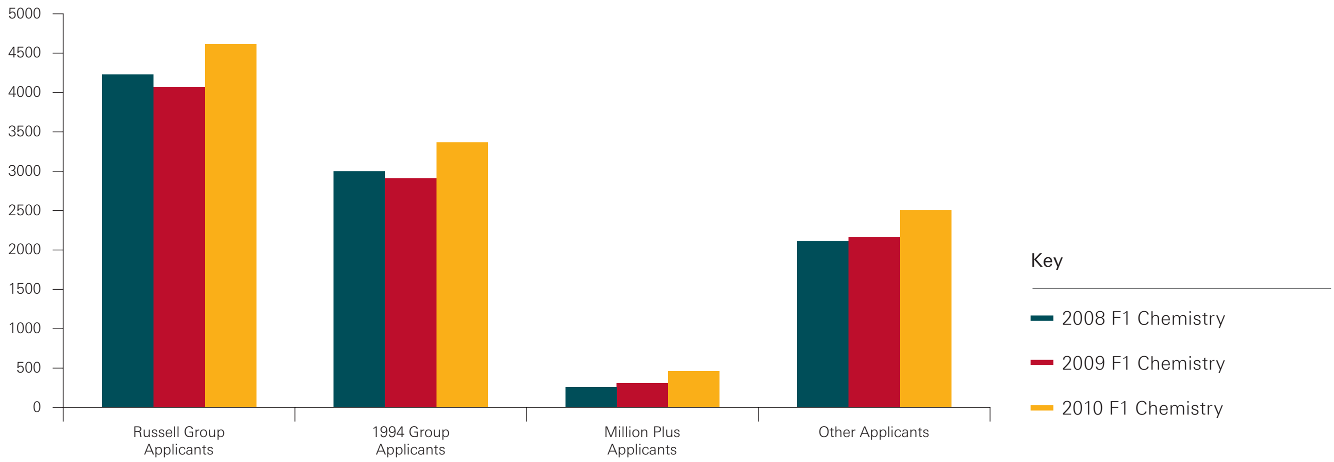
Many other organisations offer E&E activities – including Naace – and can supply details on request.

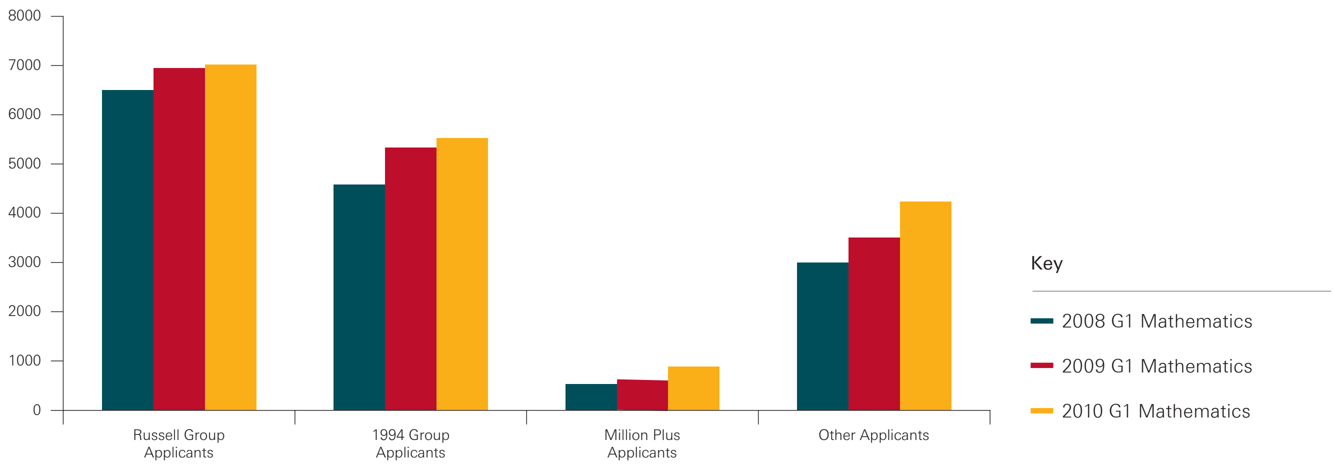
Appendix G: Applicants to Higher Education courses by institution type

Since 2008, it has become possible to differentiate the UCAS applicant data by institution type. Figure A6.1 shows variation in the numbers of UK-domiciled individuals applying for a range of higher education courses categorised according to institution type. It shows that considerably higher proportion of chemistry and mathematics applicants apply to study at the 20 Russell Group and 18 1994 Group universities[158] than at the 27 Million Plus and 364 other higher education institutions in the UK. However, the situation is reversed when more vocational courses in computing and engineering are considered; that is, unlike in chemistry and mathematics, the majority of applications to study Computing are outside the Russell Group and 1994 Group.

Although these data relate to institutions all over the UK (albeit not to all UK institutions),[159] these observations clearly reflect the relative greater capacity and strength of/dependence on the FE and Skills sector for provisioning first degree or equivalent courses in computing. Notably, the corresponding figures for acceptances (not shown) demonstrate a similar pattern for all subjects shown.

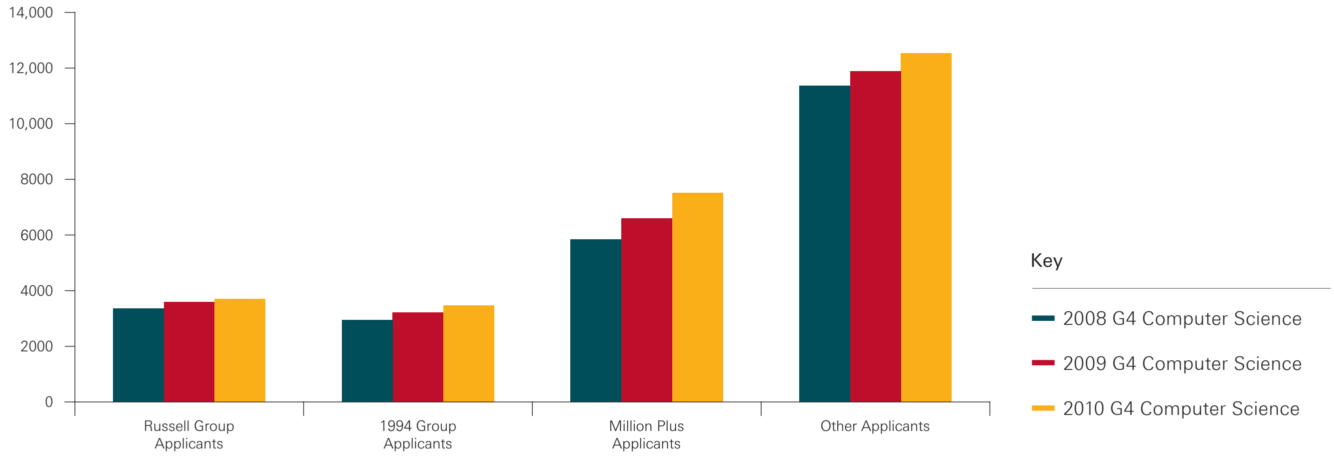
Figure A6.1 Numbers of UK-domiciled applicants to selected first degree courses by institution type (2008–2010)

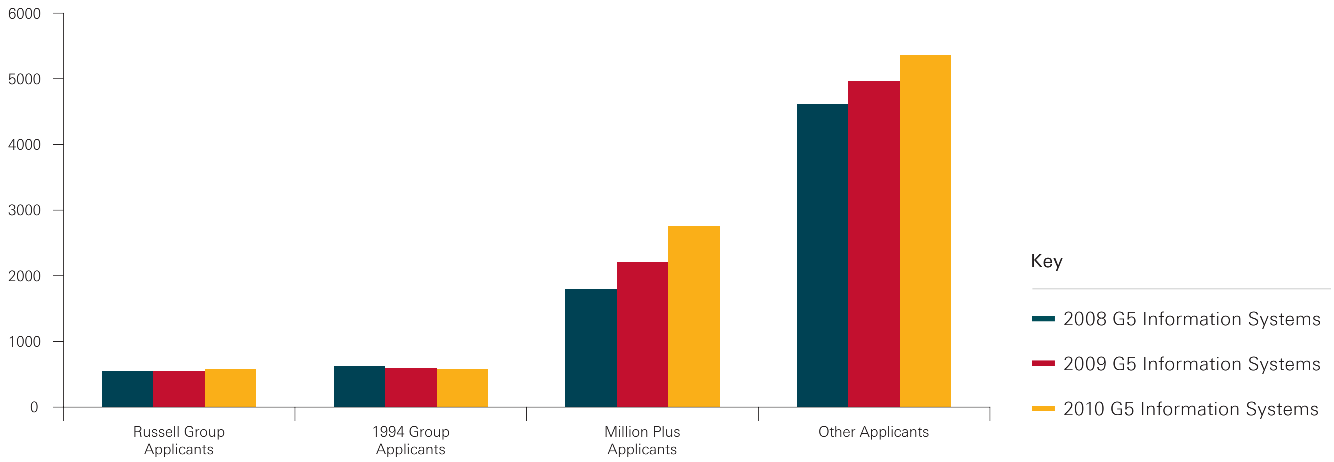


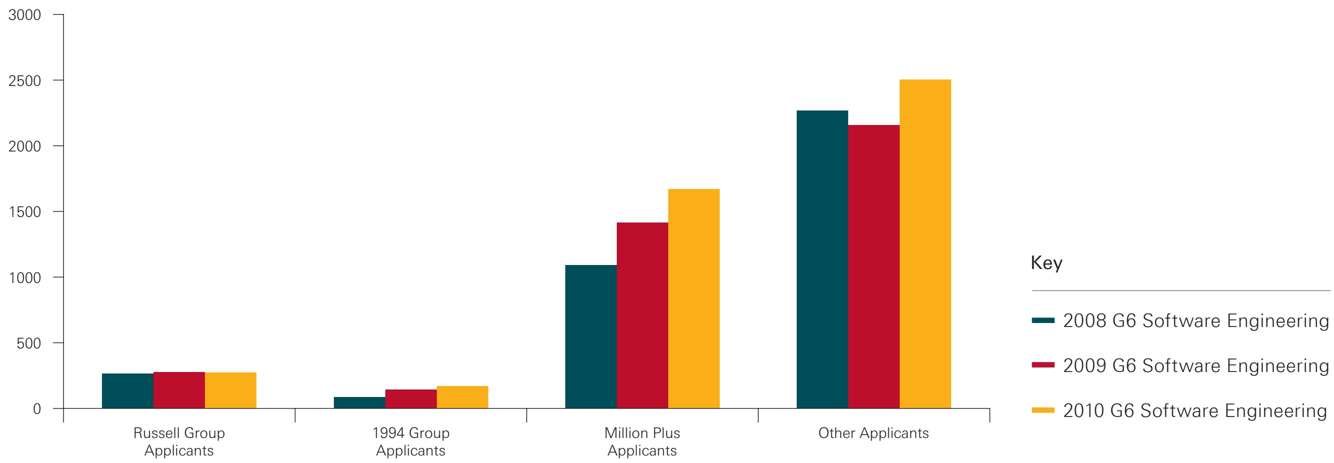


158 Note: the Institute of Education does not offer first degrees in these subjects and, therefore, does not feature in the list of 1994 Group institutions.

159 As above.


14,000
12,000
10,000
8000
6000
4000
2000
0
Russell Group Applicants
1994 Group Applicants
Million Plus Applicants
Other Applicants
Key
2008 G4 Computer Science
2009 G4 Computer Science
2010 G4 Computer Science


6000
5000
4000
3000
2000
1000
0
Russell Group Applicants
1994 Group Applicants
Million Plus Applicants
Other Applicants
Key
2008 G5 Information Systems
2009 G5 Information Systems
2010 G5 Information Systems

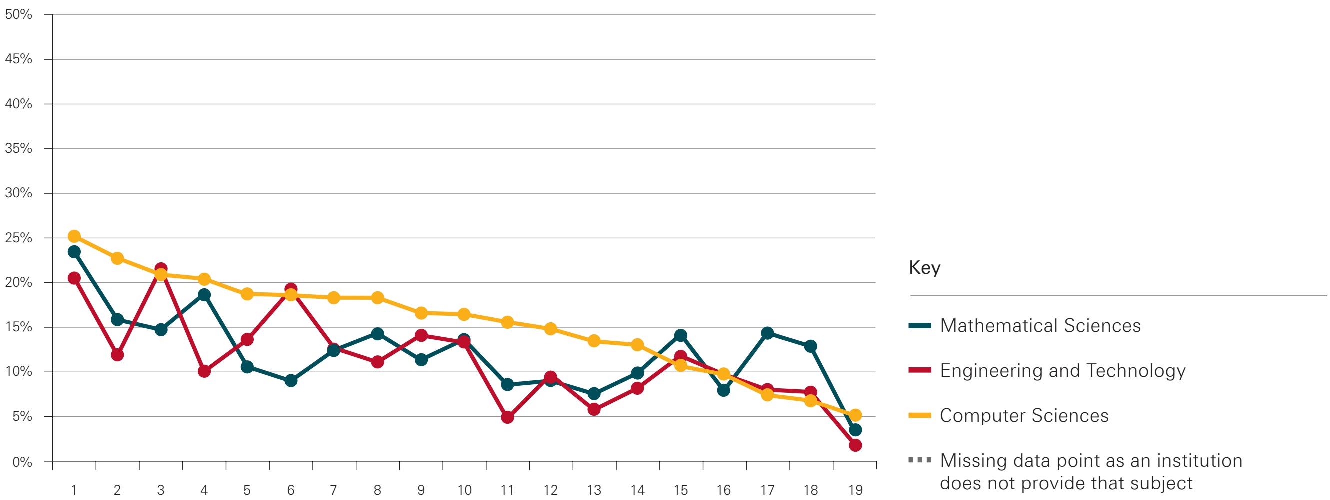

3000
2500
2000
1500
1000
500
0
Russell Group Applicants
1994 Group Applicants
Million Plus Applicants
Other Applicants
Key
2008 G6 Software Engineering
2009 G6 Software Engineering
2010 G6 Software Engineering

Source: UCAS.

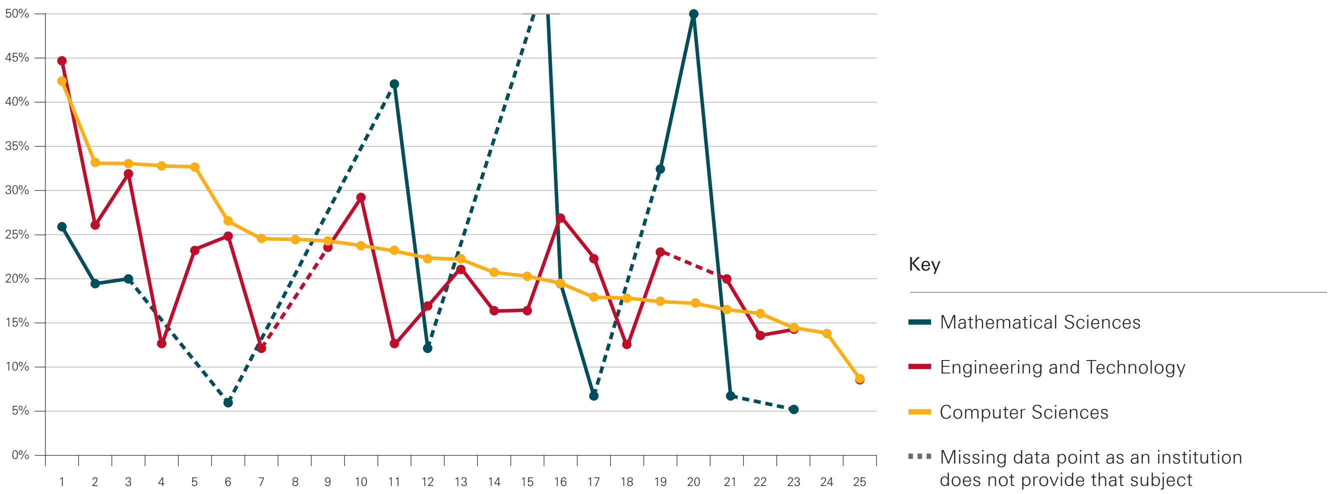
Appendix H: Higher Education attrition by mission group

Figure A6.2 Attrition rates for Computer Science compared to mathematics and engineering/technology at institutional level using measure C (2006/07–2008/09)

Russell group



Milton +

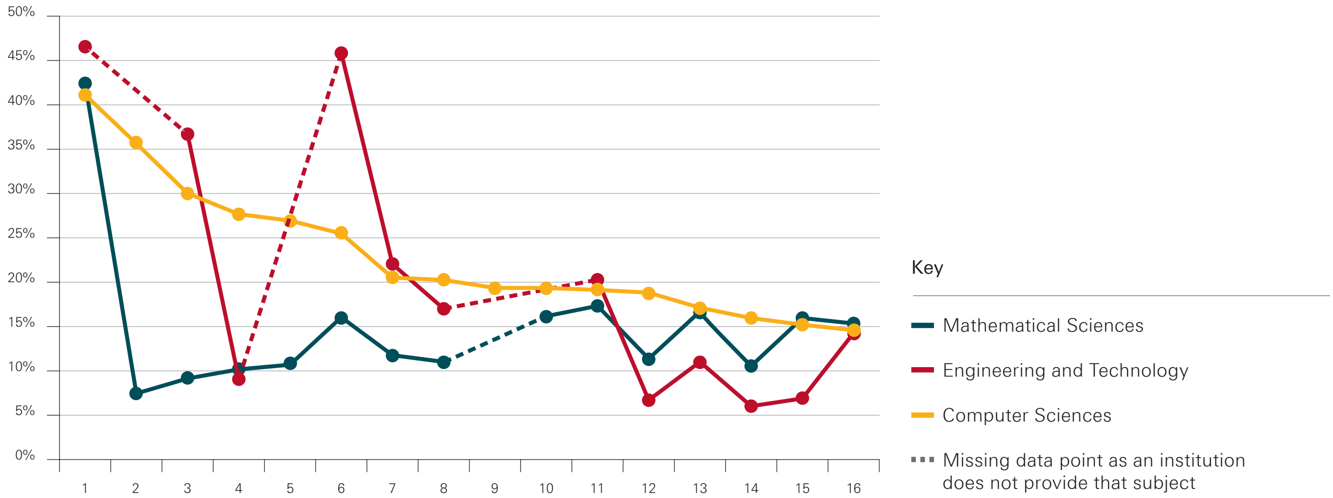


The graphs above give the information for measure C by institution, separated by mission group (see §6.2). The individual institutions are represented by divisions on the x axis and have been sorted by their attrition rate for Computer Science (creating the smooth yellow line). From this chart we can see that in the Russell Group the attrition rate for Computer Science is almost always higher than in Engineering and Technology or Mathematical Sciences – there are only a small number of institutions for which this is not true. We can also see that the attrition rate ranges from 5% to 25%.

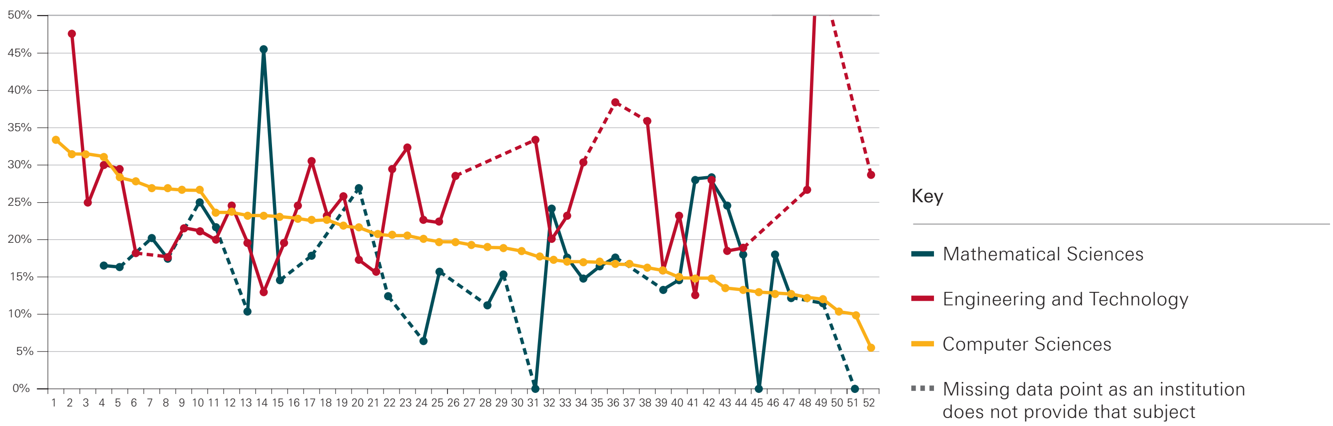
Beyond the Russell Group patterns are harder to discern. In the 1994 Group the attrition rate for Computer Science is almost always higher than in mathematical sciences, but the pattern breaks down in the Million+ and unclassified groups.

The HESA data do not provide an explanation for students wishing to change subject or leave their course, but anecdotal evidence from the call for evidence phase suggests the drop-out rate is a consequence of the terminological problems highlighted in chapter 2. Conversely, a study of

1994 group



Not member of group



Source: HESA.

first year drop-out which was conducted by the HE Academy included responses from 14 Computer Science students, half of whom cited the quality of teaching as a reason for non-completion; only 29% felt that they had simply chosen the wrong course.

Appendix I: Entry requirements to HE courses in the UK

This table summarises the information available on university websites relating to entry requirements for Computer Science degree courses (accessed October 2011).

The analysis in the final four columns is arranged as follows:

1 – A Computing or ICT A-level is an essential course requirement and no other A Level subject will be accepted as a substitute.

2 – A Computing A-level can be used as an alternative to a science and mathematics qualification as part of the essential course requirements.

3 – Science or Maths subjects are stated as being more desirable (whether or not a Computing A-level is mentioned).

4 – The course can ultimately be studied without a Computing or ICT A-level (even if a Computing A-level is referred to as useful).

Universities are arranged by mission group (Russell Group, Million+, 1994 Group, Not affiliated)

Abbreviations: C = Computing, ICT(A) = Applied ICT, M = Mathematics, FM = Further Mathematics, P = Physics, Psy = Psychology

Institution	Course	UCAS No.	Requirements	Essential	Preferred	Useful
Russell Group						
The Queen's University of Belfast	Computer Science	G400	BBB	Chem or CS or ICT or M or P or ICT(A)		
	Computing and Information Technology	GG45	ABB or BBB	C/ ICT(A) or STEM		
The University of Birmingham	Computer Science	G400	AAB	M or P or CS or Psy		
The University of Bristol	Computer Science	G400	AAA	M		
The University of Cambridge	Computer Science	G400	A*AA	M	FM and/or a Physical Science	
Cardiff University	Computer Science	G400	ABB			
The University of Edinburgh	Computer Science	G400	AAA - ABB	M		
The University of Glasgow	Computing Science	G400	ABB		M, Two Science subjects	
	Computing Science Fast Route	G401	AAA	M, CS		
King's College London	Computer Science	G400	AAB	M or CS or P or El or S		
The University of Leeds	Computer Science	G400	AAB	M		
The University of Liverpool	Computer Science	G400	AAB	M (to at least AS level with B grade)		
Imperial College London	Computer Science	G400	A*AA	A* in M	A* in FM,	
London School of Economics and Political Science	N/A					

Comments from university website	URL	1	2	3	4	N
	www.qub.ac.uk/schools/eeecs/ProspectiveStudents/UndergraduateStudies/CSc/AbouttheCourse/		✓		✓	
	www.qub.ac.uk/schools/eeecs/ProspectiveStudents/UndergraduateStudies/CIT/AbouttheCourse/		✓		✓	
It is desirable, but not essential, to have some experience of writing computer programs	www.birmingham.ac.uk/students/courses/undergraduate/cs/computer-sci.aspx		✓		✓	
	www.cs.bris.ac.uk/admissions/ug/apply.html				✓	
We don't require any qualifications in computer science or any prior knowledge of programming. It's essential to have Mathematics at A-level. Science subjects are also viewed favourably – often more so than subjects such as IT, which are more vocational in nature.	www.cam.ac.uk/admissions/undergraduate/courses/compsci/				✓	
Computing experience is not required. Applications from those offering alternative/vocational qualifications (eg Access, Vocational A-level) are welcome	www.cardiff.ac.uk/for/prospective/ug/applyingtocardiff/admissionscriteria/comsc/				✓	
				✓	✓	
	www.gla.ac.uk/undergraduate/degrees/computingscience/			✓	✓	
		✓				
	www.kcl.ac.uk/prospectus/undergraduate/computer-science/entryrequirements		✓		✓	
	www.engineering.leeds.ac.uk/computing/undergraduate/degree-computer-science/index.shtml			✓	✓	
We give a one grade bonus for each mathematical subject (Mathematics, Further Mathematics, Pure Mathematics, Computing/Computer Science, and Physics) which may lead to lower offers.	www.csc.liv.ac.uk/student/entryrequirements.html		?	✓	✓	1
If you are ...worried that a lack of computing experience will leave you at a disadvantage, don't be...You do not need to have taken A-level Computing or ICT to do the degree. We look for people who are good at Maths and are excited by computing.	www3.imperial.ac.uk/computing/teaching/undergraduate/computing/admissions			✓	✓	

Entry requirements to HE courses in the UK continued

Institution	Course	UCAS No.	Requirements	Essential	Preferred	Useful
The University of Manchester	Computer Science	G400	AAB	M		
The University of Newcastle-upon-Tyne	Computer Science	G400	AAB-ABB/AAC			
The University of Nottingham	Computer Science	G400	ABB	One A-level Science	M or CS	
The University of Oxford	Computer Science	G400	A*AA	1 A* must be in M or FM or P or CS		
The University of Sheffield	Computer Science	G402	AAB	M		
The University of Southampton	Computer Science	G400	AAA	M		
University College London	Computer Science	G400	AAA-AAB	M		
The University of Warwick	Computer Science	G400	AAA	M		
	Computing Systems	G410	AAA	M		
Million+						
University of Abertay Dundee	Computing	G400	CCD			
Anglia Ruskin University	Computer Science	G400	200 UCAS Points			
Bath Spa University	N/A					
University of Bedfordshire	Computer Science	G400	200 UCAS Points			
Birmingham City University	Computer Science	G400	280 UCAS Points			
The University of Bolton	Computing	G400	240 UCAS points			
Buckinghamshire New University	Computing	G400	200-240 UCAS points			
The University of Central Lancashire	Computing	G400	240-280 UCAS points			
Coventry University	Computer Science	G400	BBC	STEM or CS or T		
	Computing	G404	BCC	STEM or CS or T		
University of Derby	Computing	G403	280 UCAS points			
	Information Technology	G502	280 UCAS points			

Comments from university website	URL	1	2	3	4	N
	www.cs.manchester.ac.uk/undergraduate/programmes/programmes.php?pathwayid=&code=00560&pg=3			✓	✓	
	www.ncl.ac.uk/undergraduate/course/G400/entrance-requirements				✓	
	www.nottingham.ac.uk/computerscience/prospective/undergraduate/undergraduateentryqualifications.aspx		?	✓	✓	2
Candidates are expected to have Mathematics to A-level (A grade), Further Mathematics or a Science would also be highly recommended.	www.ox.ac.uk/admissions/undergraduate_courses/courses/computer_science/computer_science__1.html			✓	✓	
	www.sheffield.ac.uk/prospectus/courseDetails.do?id=4839362012			✓	✓	
	www.soton.ac.uk/study/undergraduate/courses/2012/computer_science_software_ngineering.shtml			✓	✓	
We are keen to admit students with an interest in subjects that relate to applications of computer technology.	www.ucl.ac.uk/prosp-students/prospectus/engineering-sciences/computer-science/index.shtml			✓	✓	
	www2.warwick.ac.uk/fac/sci/dcs/admissions/cscience			✓	✓	
	www2.warwick.ac.uk/fac/sci/dcs/admissions/csystems			✓	✓	
	www.abertay.ac.uk/studying/find/ug/computing/				✓	
	www.anglia.ac.uk/ruskin/en/home/prospectus/ugft/computer_science_.html				✓	
	www.beds.ac.uk/howtoapply/courses/undergraduate/computer-science				✓	
	www.bcu.ac.uk/courses/computer-science				✓	
	www2.bolton.ac.uk/coursefinder/DisplayCourse.aspx?ProgId=c3f42362-3abe-4c5a-bedb-d8aa5c7edd04				✓	
	bucks.ac.uk/en?t=/customCode/courseFinder/view/course&ParentID=1295428942034&courseCode=BT1CTG1&tab=2				✓	
	www.uclan.ac.uk/information/courses/bsc_hons_computing.php				✓	
	wwwm.coventry.ac.uk/course/ug2012/Pages/Computer_Science_BSc_Hons_degree.aspx#mb_Overlay-Offers		✓		✓	
	wwwm.coventry.ac.uk/course/ug2012/Pages/Computing_BSc_Hons_degree.aspx#mb_Overlay-Offers		✓		✓	
	www.derby.ac.uk/computing/computing-bsc-hons?csId=&courseQuery=COMPUTING#coursesummary				✓	
	www.derby.ac.uk/computing/information-technology-bsc-hons?csId=&courseQuery=COMPUTING				✓	

Entry requirements to HE courses in the UK continued

Institution	Course	UCAS No.	Requirements	Essential	Preferred	Useful
The University of East London	Computing	G400	200 UCAS points	STEM or ICT or Geo or BS		
	Computer Technology	N/A	240 UCAS points	STEM		
Edinburgh Napier University	Computer Systems and Networks	N/A	CCD			
University of Gloucestershire	Computing	G406	240-280			
The University of Greenwich	Information and Communications Technology	G560 M	200 UCAS points			
Kingston University	Computer Science	G401	280 UCAS Points			
	Computing Studies	G402	160 UCAS points			
	Information Systems	G565	280 UCAS Points			
Leeds Metropolitan University	Computing	G400	240 UCAS points			
London South Bank University	Computer Systems & Networks	H650	240 UCAS points	M		
Middlesex University	Computer Science	G404	200 UCAS points			
	Information Technology	G561	200 UCAS points			
The University of Northampton	Computing	G400	260-300 UCAS points			
Roehampton University	Information Management	G4GM	320 UCAS points			
Southampton Solent University	Computing	G405	160 UCAS points			
	Information and Communication Technology	GH56	160 UCAS points			
Staffordshire University	Computer Networks and Security	G425	240 UCAS points.			
	Information Systems	G506	240 UCAS points.			
The University of Sunderland	Computing	G400	260 UCAS points			
	Computer Science	G401	260 UCAS points			
	Information Communication Technology	G420	260 UCAS points			
Thames Valley University	Computing and Information Systems	GG45	200 UCAS points	Level 2 Maths		
University of the West of England, Bristol	Computer Science	G400	300 UCAS points			
	Computing	G401	260 UCAS points			

Comments from university website	URL	1	2	3	4	N
	www.uel.ac.uk/programmes/ace/undergraduate/computing.htm		✓		✓	
	www.uel.ac.uk/programmes/ace/undergraduate/summary/computertechnology-beng.htm			✓	✓	
	www.courses.napier.ac.uk/U56205.htm				✓	
	www.glos.ac.uk/courses/undergraduate/co/Pages/entry2011.aspx				✓	
	www2.gre.ac.uk/study/courses/ug/it/g560				✓	
	www.kingston.ac.uk/undergraduate-course/computer-science-2012/entry-requirements.html				✓	
	www.kingston.ac.uk/undergraduate-course/computing-studies-2012/entry-requirements.html				✓	
	www.kingston.ac.uk/undergraduate-course/information-systems-bsc-2012/entry-requirements.html				✓	
	courses.leedsmet.ac.uk/computing				✓	
	prospectus.lsbu.ac.uk/courses/course.php?UCASCode=H650			✓	✓	
	www.mdx.ac.uk/courses/undergraduate/computing_it/computer_science_bsc.aspx				✓	
	www.mdx.ac.uk/courses/undergraduate/computing_it/information_technology_bsc.aspx				✓	
Previous experience of Computing is desirable.	www.northampton.ac.uk/courses/38/computing-bsc-hons/				✓	
	www.roehampton.ac.uk/undergraduate-courses/information-management/index.html				✓	
	www.solent.ac.uk/courses/undergraduate/computing_bsc/course_details.aspx				✓	
	www.solent.ac.uk/courses/undergraduate/information_and_communication_technology/course_details.aspx				✓	
	www.staffs.ac.uk/courses_and_study/courses/computer-networks-and-security-tcm428028.jsp				✓	
	www.staffs.ac.uk/courses_and_study/courses/information-systems-tcm428362.jsp				✓	
	www.sunderland.ac.uk/course/361/computing#entryreqs				✓	
	www.sunderland.ac.uk/course/966/computer_science#entryreqs				✓	
	www.sunderland.ac.uk/course/967/information_communication_technology_ict#entryreqs				✓	
This course particularly welcomes applicants with Progression or Advanced Diploma in IT	courses.uwl.ac.uk/CourseDetails.aspx?CourseInstanceID=32125		??	??	✓	3.i
Any Science or Technology subject	courses.uwe.ac.uk/G400/2012#entry		??	??	✓	3.ii
Any Science or Technology subject	courses.uwe.ac.uk/G401/2012#entry				✓	

Entry requirements to HE courses in the UK continued

Institution	Course	UCAS No.	Requirements	Essential	Preferred	Useful
The University of Wolverhampton	Computer Science	G400	160 UCAS points			
	Information Technology	G501	160 UCAS points			
1994 Group						
The University of Bath	Computer Science	G400	AAA	M		
	Computer Information Systems	G500	AAA			
University of Durham	Computer Science	G400	AAB	M		
The University of East Anglia	Computing Science	G400	ABB	STEM or Cs or El or Ec		
	Computer Systems Engineering	HG65	ABB	STEM or Cs or El or Ec		
The University of Essex	Computer Science	G400	BBB			
	Computers and Electronics	GH4P	BBB			
	Computer Systems Engineering	H650	BBB			
	Information and Communication Technology	GH56	BBB			
The University of Exeter	Computer Science and Mathematics	GG41	A*AA-AAB	M or FM		
Goldsmiths College	Computer Science	G400	BBB		STEM	
	Computing & Information Systems	G500	BBC		STEM	
The University of Lancaster	Computer Science	G400	ABB			
The University of Leicester	Computer Science	G400	ABB		M	
	Computing	G405	BBB			
Loughborough University	Computer Science	G400	ABB-AAB	M		
Queen Mary and Westfield College	Computer Science	G400	280+ UCAS points			
	Computing and Information and Communications Technologies	I100	280+ UCAS points			
The University of Reading	Computer Science	G400	BBB/ABC		STEM	
	Information Technology	G502	BBB/ABC			

Comments from university website	URL	1	2	3	4	N
	courses.wlv.ac.uk/course.asp?code=CS001H31UVD&tab=entryreq#courseNav				✓	
	courses.wlv.ac.uk/course.asp?code=CI007H31UVD&tab=entryreq#courseNav				✓	
We particularly value evidence of logical and analytical thinking, such as science subjects	www.bath.ac.uk/study/ug/courses/SUG-H1?progCode=UUUH1-G400			✓	✓	
We particularly value evidence of logical and analytical thinking, such as science subjects	www.bath.ac.uk/study/ug/courses/SUG-H1?progCode=UUUH1-G500				✓	
	www.dur.ac.uk/ecs/ecs_undergraduate/undergraduate/entry_requirements			✓	✓	
	www.uea.ac.uk/cmp/courses/bsc-computing-science#overview		✓		✓	
	www.uea.ac.uk/cmp/courses/beng-computer-systems-engineering#requirements		✓		✓	
	www.essex.ac.uk/coursefinder/course_details.aspx?course=BSC+G400				✓	
	www.essex.ac.uk/coursefinder/course_details.aspx?course=BENGGH4P				✓	
	www.essex.ac.uk/coursefinder/course_details.aspx?course=BENGH650				✓	
	www.essex.ac.uk/coursefinder/course_details.aspx?course=BSC+GH56				✓	
Mathematics underpins computer science and computer science opens up new areas of mathematics. This synergistic interplay makes a degree in Computer Science and Mathematics a natural combination.	www.exeter.ac.uk/undergraduate/degrees/computerscience/comscimaths/entry			✓	✓	
	www.gold.ac.uk/ug/bsc-computer-science			✓	✓	
	www.gold.ac.uk/ug/bsc-computing-info-systems			✓	✓	
	www.lancs.ac.uk/study/undergraduate/courses/computer-science-bsc-hons-g400/?show=entry-requirements				✓	
	www.cs.le.ac.uk/admissions/BSc/programmes/ComputerScience#section-4			✓	✓	
	www.cs.le.ac.uk/admissions/BSc/programmes/Computing#section-4				✓	
	www.lboro.ac.uk/study/undergraduate/courses/departments/computerscience/computerscience			✓	✓	
Vocational A-levels are acceptable	www.eecs.qmul.ac.uk/teaching/ug/G400#reqs				✓	
Vocational A-levels are acceptable	www.eecs.qmul.ac.uk/teaching/ug/entry.php				✓	
	www.reading.ac.uk/Study/ug/ComputerScienceBSc.aspx			✓	✓	
	www.reading.ac.uk/Study/ug/InformationTechnologyBSc.aspx				✓	

Entry requirements to HE courses in the UK continued

Institution	Course	UCAS No.	Requirements	Essential	Preferred	Useful
Royal Holloway and Bedford New College	Computer Science	G400	ABC/BBB	M or P or equivalent		
The University of St Andrews	Computer Science	G400	AAB	M		
The School of Oriental and African Studies	N/A					
The University of Surrey	Computer Science	G400	AAB	M or P or CS		
	Computing and Information Technology	G560	AAB		STEM	
The University of Sussex	Computing Science	G400	ABB			
The University of York	Computer Science	G400	AAB	M		
Not affiliated						
The University of Aberdeen	Computing	G402	BBB			
	Computing Science	G400	BBB	2 STEM		
	Information Systems and Management	GN52	BBB			
Aberystwyth University	Computing Science	G400	BBB	2 STEM		
Aston University	Computing Science	G400	BBB-ABB		M, CS	
Bangor University	Computer Science	G400	240-280 UCAS points			
Bishop Grosseteste University College Lincoln	N/A					
Bournemouth University	Computing	G610	300 UCAS points		CS, ICT or Science	
The University of Bradford	Computer Science	G400	240 UCAS points			
The University of Brighton	Computer Science	G400	BBB			
Brunel University	Computer Science	G402	BBB			
The University of Buckingham	Computing	G400	260 UCAS points			

Comments from university website	URL	1	2	3	4	N
We look for students with some aptitude for computer science demonstrated by, for example, experience in programming, or an A-level with an analytical component, such as Maths or Physics. An A-level in ICT is not regarded as being a sufficiently analytical subject.	www.rhul.ac.uk/computerscience/coursefinder/bsccomputerscience.aspx			✓	✓	
	www.cs.st-andrews.ac.uk/prospective-ug/requirements			✓	✓	
	www.surrey.ac.uk/undergraduate/courses/computing		✓		✓	
	www.surrey.ac.uk/undergraduate/courses/computing			✓	✓	
	www.sussex.ac.uk/study/ug/2012/1512/24688#tabs-3				✓	
Note that we do not specifically require or prefer Computing, or ICT, or anything similar, at any level, for any of our programmes. Computer Science/Studies or Computing or IT or ICT does not count as a mathematical subject within our requirements at A-level, nor in place of a physical science at GCSE.	www.cs.york.ac.uk/undergraduate/entry-requirements			✓	✓	
	www.abdn.ac.uk/courses/undergraduate.php?code=computing&prog=arts				✓	
	www.abdn.ac.uk/courses/undergraduate.php?code=computing_science&prog=science			✓	✓	
	www.abdn.ac.uk/courses/undergraduate.php?code=information_systems&prog=arts				✓	
	www.abdn.ac.uk/courses/undergraduate.php?code=computing_science&prog=science			✓	✓	
	www1.aston.ac.uk/study/undergraduate/courses/school/eas/bsc-computing-science		?	?	?	4
	www.bangor.ac.uk/courses/undergrad/index.php en?view=course&prospectustype=undergraduate&courseid=123&subjectarea=4				✓	
	courses.bournemouth.ac.uk/courses/undergraduate-degree/computing/bsc-hons/36/		?	?	?	5
Whilst many of our students coming in with A-levels studied Computing, ICT, Mathematics and/or sciences, it is not essential to do so. We welcome applicants taking any combination of subjects for any of the courses.	www.bradford.ac.uk/undergraduate/computer-science				✓	
	www.brighton.ac.uk/courses/study/computer-science-bsc-hons				✓	
	www.brunel.ac.uk/courses/undergraduate/G402				✓	
	www.buckingham.ac.uk/sciences/bsc/computing				✓	

Entry requirements to HE courses in the UK continued

Institution	Course	UCAS No.	Requirements	Essential	Preferred	Useful
Canterbury Christ Church University	Computing	G400	240 UCAS points			
University of Wales Institute, Cardiff	Computing	G400	280 UCAS points	1 'relevant' subject		
University of Chester	Computer Science	G400	240 – 280 UCAS points			
The University of Chichester	N/A					
The City University	Computer Science	G400	360 UCAS points		STEM	
University of Cumbria	Applied Business Computing	G490	240 UCAS points			
De Montfort University	Computer Science	G400	260 UCAS points			
The University of Dundee	Computing Science	G400	BCC			
Edge Hill University	Computer Science	G401	240 UCAS points	Evidence of numeracy.		
University of Glamorgan	Computer Science	G40C	280 UCAS points			
	Information Communication Technology	G500	280 UCAS points			
Glasgow Caledonian University	Computing (Information Systems Development)	G501	CC			
Glyndŵr University	Applied Computing	G490	240 UCAS points			
Harper Adams University College	N/A					
Heriot-Watt University	Computer Science - Level 1 Entry	G400	BBB	M		
	Computer Science - Level 2 Entry		ABB	M and CS		
University of Hertfordshire	Computer Science	G400	240 UCAS points			
	Information Technology	G501	240 UCAS points			
The University of Huddersfield	Computing Science	G400	280 UCAS points			
	Information and Communication Technology	G5GK	240 UCAS points			
The University of Hull	Computer Science	G400	260–280 points			
The University of Keele	Computer Science	G400	BBC			

Comments from university website	URL	1	2	3	4	N
	www.canterbury.ac.uk/StudyHere/Undergraduate/courses/c.asp?courseUrl=computing				✓	
	www3.uwic.ac.uk/English/StudyAtUWIC/Courses/Cardiff-School-of-Management/Pages/Computing-BSc-Hons.aspx		?	?	?	6.i
	www.chester.ac.uk/undergraduate/computer-science				✓	
	www.city.ac.uk/courses/undergraduate/computer-science			✓	✓	
	www.cumbria.ac.uk/Courses/Subjects/BusinessComputing/Undergraduate/AppliedBusinessComputing.aspx				✓	
	www.dmu.ac.uk/courses/computer-science-105				✓	
For entry to Computing, competence in Mathematics is essential.	www.dundee.ac.uk/undergraduate/courses/computing_science.htm		?	?	✓	7.i
	www.edgehill.ac.uk/study/courses/computing		?	?	✓	7.ii
	courses.glam.ac.uk/courses/425-bsc-hons-computer-science				✓	
	courses.glam.ac.uk/courses/509-bsc-hons-information-communication-technology				✓	
	www.gcu.ac.uk/study/undergraduate/courses/computing-information-systems-development-8462.php?loc=uk				✓	
	www.glyndwr.ac.uk/en/Undergraduatecourses/AppliedComputing/#d.en.15713				✓	
	www.undergraduate.hw.ac.uk/programmes/G400/#requirements			✓	✓	
	www.undergraduate.hw.ac.uk/programmes/G400/#requirements	✓				
	www.herts.ac.uk/courses/Computer-Scienceug.cfm				✓	
	www.herts.ac.uk/courses/Information-Technology.cfm				✓	
	www.hud.ac.uk/courses/course/index.php?ipp=00000131&year=2012-13				✓	
We do not require students to have prior computing qualifications	www.hud.ac.uk/courses/course/index.php?ipp=00000823&year=2012-13				✓	
	www2.hull.ac.uk/undergraduate_students/next/computer_science/computer_science.aspx				✓	
There are no specific subject requirements for entry to our computing courses, and no previous experience of computing or computer programming is assumed. The courses do not involve an advanced level of mathematics.	www.keele.ac.uk/ugcourses/computerscience/				✓	

Entry requirements to HE courses in the UK continued

Institution	Course	UCAS No.	Requirements	Essential	Preferred	Useful
The University of Kent	Computer Science	G401	320 UCAS points			M
	Information Technology	G503:K	300 UCAS points			M
University of Wales, Trinity St David (merger between 0176 The University of Wales, Lampeter and 0092 Trinity University College)	Computing	G400	Entry is based on individual merit.			
Leeds Trinity University College	N/A					
The University of Lincoln	Computer Science	G403	280 UCAS points			
Liverpool John Moores University	Computer Technology	H610	280 UCAS points	80 points from STEM.		
	Information Technology and Multimedia Computing	GG54	240 UCAS points			
	Computer Studies	G401	260 UCAS points			
The Liverpool Institute for Performing Arts	N/A					
University of the Arts, London	N/A					
The Manchester Metropolitan University	Computing	G400	240-280 UCAS points			
Newman University College	Combined honours Information Technology	N/A	260 UCAS points			
The University of Wales, Newport	Information Security	G551	260 UCAS points			
The University of Northumbria at Newcastle	Computer Science	G400	280 UCAS points			
	Computer and Network Technology	H621	280 UCAS points	STEM		
The Nottingham Trent University	Computer Studies	G401	240 UCAS points	Science or CS or I		
	Information and Communications Technology	GH56	240 UCAS points	Science or CS or I		
	Information Systems	G501	240 UCAS points	Science or CS or I		

Comments from university website	URL	1	2	3	4	N
	www.kent.ac.uk/courses/undergrad/2012/subjects/computer-science			✓	✓	
	www.kent.ac.uk/courses/undergrad/2012/subjects/information-technology			✓	✓	
	www.trinitysaintdavid.ac.uk/en/courses/undergraduatecourses/a-zcourses/bsccomputing/				✓	
	www.lincoln.ac.uk/socs/_courses/undergraduate/computer_science/full_details.asp				✓	
	www.ljmu.ac.uk/courses/undergraduate/2012/course.asp?CourseId=H610			✓	✓	
	www.ljmu.ac.uk/courses/undergraduate/2012/course.asp?CourseId=GG54				✓	
	www.ljmu.ac.uk/courses/undergraduate/2012/course.asp?CourseId=G401				✓	
	www.mmu.ac.uk/study/undergraduate/courses/2012/9290/				✓	
	www.newman.ac.uk/courses/Undergraduate/single_and_combined/main_subjects/?pg=630				✓	
	www.newport.ac.uk/study/undergraduate/courses/Pages/InformationSecurity.aspx				✓	
	www.northumbria.ac.uk/?view=CourseDetail&code=UUSCSC1&page=requirement				✓	
	www.northumbria.ac.uk/?view=CourseDetail&code=UUSCNT1&page=requirement			✓	✓	
	www.ntu.ac.uk/apps/pss/course_finder/60845-1/39/BSc_(Hons)_Computer_Studies.aspx?yoe=4&st=1&sv=computing#course		✓		✓	
	www.ntu.ac.uk/apps/pss/course_finder/60851-1/39/BSc_(Hons)_Information_and_Communications_Technology.aspx?yoe=4&st=1&sv=computing		✓		✓	
	www.ntu.ac.uk/apps/pss/course_finder/60854-1/39/BSc_(Hons)_Information_Systems.aspx?yoe=4&st=1&sv=computing		✓		✓	

Entry requirements to HE courses in the UK continued

Institution	Course	UCAS No.	Requirements	Essential	Preferred	Useful
Oxford Brookes University	Computer Science	G403	BBC or equivalent		Science	
University College Plymouth St Mark and St John	N/A					
The University of Plymouth	Computer Science	G407	300 UCAS points		M or BS or Cs or En.	
	Computing	G401	300 UCAS points		M or BS or Cs or En.	
	Information Technology Management	G5N1	280 UCAS points		M or BS or Cs or En.	
The University of Portsmouth	Computer Science	G400	260-300 UCAS points			
	Computing	GG46	260-300 UCAS points			
	Computer Engineering	H601	260-300 UCAS points	M, STEM		
Ravensbourne	N/A					
The Robert Gordon University	Computer Science	G400	BB/CCC			
Rose Bruford College	N/A					
The University of Salford	Computer Science	G400	300 UCAS points	STEM or CS		
Sheffield Hallam University	Computer Science	G400	260 UCAS points	2 “relevant” subjects		
The University of Stirling	Computing Science	G400	BBC	M		
The University of Strathclyde	Computer Science	G400	ABC	M, CS		
University Campus Suffolk	Computing and Management	GN42	200 UCAS points			
Swansea Metropolitan University	Computing and Information Systems	G500	200 UCAS points		M, ICT, CS, P	
	Computer Systems and Electronics	H610	200 UCAS points		M, ICT, CS, P	

Comments from university website	URL	1	2	3	4	N
Our course covers many topics you will not have seen before, even if you have already taken A-level Computer Studies or a course such as a BTEC Level 3 qualification in a computing subject.... Any previous experience you happen to have might help you to get started more comfortably.	www.brookes.ac.uk/studying/courses/undergraduate/2012/computing			✓	✓	
	www1.plymouth.ac.uk/courses/undergraduate/3429/Pages/EntryRequirements.aspx		✓		✓	
	www1.plymouth.ac.uk/courses/undergraduate/2594/Pages/EntryRequirements.aspx		✓		✓	
	www1.plymouth.ac.uk/courses/undergraduate/3706/Pages/EntryRequirements.aspx				✓	
	www.port.ac.uk/courses/coursetypes/undergraduate/BScHonsComputerScience/				✓	
	www.port.ac.uk/courses/coursetypes/undergraduate/BScHonsComputing/				✓	
	www.port.ac.uk/courses/coursetypes/undergraduate/BEngHonsComputerEngineering/#tab5			✓	✓	
	www.rgu.ac.uk/computing/study-options/undergraduate/computer-science-bsc-hons				✓	
	www.salford.ac.uk/courses/computer-science?mode=er		✓		✓	
	www.shu.ac.uk/prospectus/course/1120/entry/		?	?	✓	6.ii
	www.stir.ac.uk/undergraduate-study/course-information/courses-a-to-z/school-of-natural-sciences/computing-science			✓	✓	
	www.strath.ac.uk/cis/courses/bschonourscomputerscience/	✓				
	www.ucs.ac.uk/Courses/UG/ComputingandManagement/Computing-and-Management-FdABA-(Hons)-(Prog).aspx				✓	
Subjects at Advanced Level should/may include Maths, ICT, Physics or similar. GCSE Maths grade C or above is preferred. Other qualifications deemed to be equivalent by the Academic Board will also be considered.	www.smu.ac.uk/index.php/potential-students/faculty-of-applied-design-and-engineering/ac/50-bschons-computing-and-information-systems		✓		✓	
Subjects at Advanced Level should/may include Maths, ICT, Physics or similar. GCSE Maths grade C or above is preferred. Other qualifications deemed to be equivalent by the Academic Board will also be considered.	www.smu.ac.uk/index.php/potential-students/faculty-of-applied-design-and-engineering/ac/70-benghons-computer-systems-and-electronics		✓		✓	

Entry requirements to HE courses in the UK continued

Institution	Course	UCAS No.	Requirements	Essential	Preferred	Useful
Swansea University	Electronics with Computing Science	H6G4	ABB-BBB	2 x STEM		
The University of Teesside	Computer Science	G400	280 UCAS points			
	Computing	G402	280 UCAS points			
	Information and Communication Technologies (ICT)	G500	280 UCAS points			
UHI Millennium Institute	Computing	G400	D			
University of Ulster	Computer Science	G401	280 UCAS points			
	Computing	G403	280 UCAS points			
	Information and Communication Technologies	G500	300 UCAS points			
The University of the West of Scotland	Computer Networking	H601	BBC	M or P or CS		
	Information Technology	G502	CC			
	Computing	G401	CC			
The University of Westminster	Computer Science	G402	CCC/AA			
	Computer Systems Engineering	H657	CCD/AB			
The University of Winchester	N/A					
The University of Worcester	Computing	G400	240 UCAS points			
York St John University	N/A					

1 The University of Liverpool lists a Maths A-Level as a mandatory course requirement, but does offer a "one grade bonus" if Computer Science or another relevant STEM subject is studied at A Level.

2 The University of Nottingham states that one A Level science subject is a mandatory requirement for its Computer Science degree course. In addition, Maths and Computer Science A-Levels are considered to be highly desirable as complementary, although non-compulsory, subjects. In this instance it is therefore possible to infer that Computer Science is considered to be as relevant as, or even a valid alternative to, a Maths A-Level in the pursuit of a Computer Science degree. This is in spite of the fact that a Computer Science A Level it is not considered to be an obligatory pre-requisite for the course.

3.i, 3.ii The University of the West of England states that any Science or Technology subject would be considered as useful to its Computer Science and Computing degree courses, but does not specify any specific subjects. Computer Science is therefore not considered essential, but may be considered as beneficial dependant on how this statement is interpreted.

4 Aston University considers Maths and/or Computer Science A Levels as desirable subjects, but does not specify that either subject is mandatory for its Computing Science degree course.

5 Bournemouth University states that Computer Science/ ICT or Science A Levels are desirable subjects for entry onto their Computing degree course, but does not specify that any of these subjects are mandatory requirements.

6.i The University of Wales Institute states that "one relevant subject" is a mandatory prerequisite for its Computing degree course but does not specify which subjects are considered "relevant", nor whether a Computer Science A Level is one of these "relevant" subjects.

Comments from university website	URL	1	2	3	4	N
	www.swan.ac.uk/ugcourses/engineering/bengelectronicswithcomputerscience/			✓	✓	
	www.tees.ac.uk/undergraduate_courses/Computing/BSc_(Hons)_Computer_Science.cfm				✓	
	www.tees.ac.uk/undergraduate_courses/Computing/BSc_(Hons)_Computing.cfm				✓	
	www.tees.ac.uk/undergraduate_courses/Computing/BSc_(Hons)_Information_and_Communication_Technologies_(ICT).cfm				✓	
	www.uhi.ac.uk/en/courses/computing-and-it/bsc-computing				✓	
	prospectus.ulster.ac.uk/course/?id=8017				✓	
	prospectus.ulster.ac.uk/course/?id=8092				✓	
	prospectus.ulster.ac.uk/course/?id=7958				✓	
	www.uws.ac.uk/courses/ug-courseinfo.asp?courseid=721		✓		✓	
	www.uws.ac.uk/courses/ug-courseinfo.asp?courseid=722				✓	
	www.uws.ac.uk/courses/ug-courseinfo.asp?courseid=826				✓	
	www.westminster.ac.uk/schools/computing/undergraduate/computer-science-and-software-engineering/bsc-honours-computer-science				✓	
	www.westminster.ac.uk/schools/computing/undergraduate/computer-systems-engineering/bsc-honours-computer-systems-engineering				✓	
	www.worcester.ac.uk/journey/computing-bsc-hons.html				✓	

6.ii Sheffield Hallam University similarly states that "two relevant subjects" are mandatory prerequisites for their degree course, but also does not specify which subjects are considered "relevant", nor whether a Computer Science A Level is one of these "relevant" subjects.

7.i, 7.ii The University of Dundee and Edge Hill University both specify that numeracy and competence in Mathematics are essential for their respective degree courses, but do not stipulate which specific subjects would be essential to demonstrating these numerical skills and to what level such subjects would need to be studied.

Appendix J: Timeline of major developments in Computing in schools in England[163]

Year	Event	Terminology
1966-68	The first schools acquire a computer and serve others in their local authority	
1969	Some mathematics departments begin to offer courses leading to a CSE (Certificate of Secondary Education) in Computer Studies or to Advanced Level Computing.	Computer Studies Computing
1970	BCS report 'Computer Education for All' published, recommending that all pupils be taught elements of computing through direct teaching and through applications in the curriculum.	Computer education
1972 – 75	Several exam boards offer new syllabuses in 'Computer Studies' (CSE, mainly Mode 3) and 'Computer Science' (A-level) – different names pre- and post-16.	Computer Studies Computer Science
19721 1974	'Computer Education in Schools' project (CES) is formed, starts to deliver curriculum materials for secondary school computer studies. CES produces a simplified assembler/high-level language with just fourteen instructions – the CES Instructional Language (CESIL). Most project work for pre-16 examinations (mainly Mode 3) is done in Basic or CESIL.	Computer Education
1975 – 81	New O-level qualifications in Computer Studies gain popularity in schools	Computer Studies
1980	The Department for Education and Science establishes the Microelectronics Education Programme (MEP) to maximise the application of microelectronics in the whole school curriculum. 'Microelectronics' covers more than computers.	Microelectronics
1986	Teachers' associations in every subject have published booklets on how new technologies may be applied to their subject1	
1987	A range of qualifications are available – GCSE Computer Studies, and a new subject called 'Information Technology' emphasising IT applications. The latter subject is approved by the Schools Examinations Council (SEC) under its criteria for "General Subjects", not under the criteria for "Computing"	Computer Studies Information Technology
1987	A joint GCSE in 'Business Studies and IT' is offered by Southern Examining Board alongside its Computer Studies course, designed to cover commercial applications of computers, and omitting control applications.	IT
1987 – 89	HMI Survey on Computing as a specialist subject in schools and sixth form colleges concludes that 'The study of Computing can and should be stimulating and fascinating for pupils. As experienced by many, it is sometimes dry, dull and unexciting'.	Computing
1989	HMI Curriculum Matters report on 'IT from 5 to 16' states that IT applications should be promoted in subject studies throughout the 5-16 curriculum, where this leads to greater challenge and achievement in the subject. IT/Computing should also be an elective study for older pupils who show interest and ability in it.	IT Computing
1990	First National Curriculum introduces Information Technology as part of the Design and Technology curriculum, rather than a separate subject	Information Technology
1995	Second National Curriculum has 'IT' is a distinct subject of the National Curriculum with its own Programmes of Study and (later) statutory assessment requirements.	IT
1996	Sir Denis Stevenson is commissioned by the Labour Party (while in opposition to investigate the use of computers in schools. The final report Information and Communications Technology in UK Schools introduces the term 'ICT' for the first time[165].	ICT
1995/6	Pilot courses of study become available to pupils aged 14 to 19 leading to GNVQs (General National Vocational Qualifications) in IT, and later ICT.	IT ICT

163 www.greenfoot.org

Year	Event	Terminology
1998	The Qualifications and Curriculum Authority (QCA) publishes a definitive scheme of work for 'IT' for Keys Stages 1-2	IT
1999	ICT is increasingly spoken of as a 'Key Skill' alongside numeracy and literacy, in addition to being a vocational and an Advanced Level subject study. The third National Curriculum identifies ICT as a general teaching requirement, alongside language across the curriculum, health and safety, etc. This Curriculum identifies specific links between ICT and elements of other subjects.	ICT
2000	The Qualifications and Curriculum Authority (QCA) publishes a definitive scheme of work for 'ICT' for Key Stage 3	ICT
2004	A-levels in 'Computing' and 'ICT' recorded separately by JCQ	Computing ICT
2004	OCR National Qualifications in ICT available	ICT
2011	GCSE in Computing piloted	Computing

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