After the reboot: computing education in UK schools

THE ROYAL SOCIETY

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Issued: November 2017 DES4633
ISBN: 978-1-78252-297-3

This report can be viewed online at
royalsociety.org/computing-education

Contents

Executive summary

Data and digital technologies promise revolutionary transformational changes across the full range of industry sectors and spheres of life. This unprecedented digital revolution will impact everyone. It will have extraordinary implications on the range of skills that today's young people will require in every aspect of their lives. Computing education must enable young people to continue to keep up with the pace of technological change so that they can remain effective, well-informed and safe citizens.

However, our evidence shows that computing education across the UK is patchy and fragile. Its future development and sustainability depend on swift and coordinated action by governments, industry, and non-profit organisations. Neglecting the opportunities to act would risk damaging both the education of future generations and our economic prosperity as a nation.

There is much to celebrate and there are many pockets of excellence. The broad subject of computing – covering the three vital areas of computer science, digital literacy and information technology (IT) – has become mandatory in English schools from ages 5 to 16. In Scotland, we have seen the implementation of the Significant Aspects of Learning, a framework where computing is broken down into distinct areas of knowledge. In Wales, the Digital Competence Framework is bringing computing in schools to the forefront, while Northern Ireland has continued to deliver a comprehensive computing framework. From ages 5 to 14, pupils typically have one hour per week of computing lessons, and some schools take opportunities to teach computing within other subjects.

However, a majority of teachers are teaching an unfamiliar school subject without adequate support. Moreover, they may be the only teacher in their school with this task. Governments must address a severe and growing shortage of computing teachers. From 2012 to 2017, England met only 68% of its recruitment target[1]. Since 2005, Scotland has also seen a 25% decrease in the number of computing teachers[2].

In our survey, 44% of secondary school teachers only felt confident teaching the earlier stages of the curriculum where there is less of a computer science focus. Despite this lack of confidence, 26% of the secondary school teachers we surveyed indicated that they had not undertaken any computing-related professional development activities in the past year[3].

To truly transform computing education, teachers need unhindered access to a structured and ongoing programme of professional development. The programme must support teachers in all schools across the country. The existing university-based Computing At School Network of Excellence has been successful with minimal resources through a model built on enthusiastic volunteers developing a mutually supportive community of practice. However, the current level of resourcing and approach to execution is not sufficient to meet the challenges we have identified. A fully resourced national professional development programme building on the Network of Excellence requires a tenfold increase in funding from government and industry. This would provide computing teachers with a comparable level of support to mathematics and the sciences[4].

1. House of Commons Education Committee 2017. Recruitment and retention of teachers: Fifth Report of Session 2016 – 17.
2. Computing At School Scotland. 2016. Computing Science Teachers in Scotland 2016.
3. Pye Tait. 2017. After the Reboot: The State of Computing Education in UK Schools and Colleges.
4. For example, the Maths Mastery Programme was introduced in 2012 to provide a professional development network for mathematics teachers (See https://www.mathematicsmastery.org, accessed 11 October 2017.), the Stimulating Physics Network supports physics teachers through an extensive CPD programme (See http://www.stimulatingphysics.org, accessed 11 October 2017.) and STEM Learning provides CPD support for science teachers. (See https://www.stem.org.uk, accessed 11 October 2017.)

Though many of the great pioneers of computing were women, across the UK computer science is an overwhelmingly male-dominated subject and workforce. At GCSE, there is a 20% uptake from girls, while Scotland also had a 20% female uptake at National 5 in 2017. At A level, there is only a 9% uptake from girls, and this has not changed for many years. Scotland has a similar picture with 14% female uptake at Advanced Highers. Although Information and Communication Technology (ICT) qualifications fared better, they still only had 36% female uptake at A level[5].

Making computing education compulsory will not automatically lead to a higher proportion of young women choosing to study the subject once it becomes optional at 14. Compulsory mathematics and physics to age 16 has not significantly improved the gender balance in these subjects in post-16 education or higher education. In order to meet the current and future skills needs in the UK, governments, employers and schools must prioritise changing the gender balance in computing. This is a challenge that requires people to take innovative approaches and draw on lessons learned in other disciplines.

Today, 70% of students in England attend schools offering GCSE computer science, which is a positive development. However, although the overall number of entries continues to grow, only a disappointing 11% of all students take GCSE computer science[6]. Moreover, the range of qualifications on offer does not reflect the full breadth of computing. It should be possible to study computer science or information technology (or both). GCSE ICT makes up 55% of the total entry numbers of all computing qualifications at age 16 and there is a risk that there will be a drastic drop in the number of pupils studying computing as ICT is phased out[7]. The qualification landscape needs urgent attention to ensure the broadest range of pupils become equipped with relevant digital skills.

Understanding the pedagogies and assessment methodologies that underpin computing education helps teachers improve pupil outcomes. Our literature reviews show that a majority of the research in computing education relates to higher education and the volume of education research in computing is much smaller than in subjects such as physics or mathematics.

With the emergence of computing in schools, and organisations such as the Education Endowment Foundation seeking to grow the evidence base in attainment in education, there is an ideal opportunity for the UK to conduct research to develop computing pedagogies and assessment. However, the capacity of the current research base is limited and needs further support if the UK is to lead the world in computing education research for schools.

The Society's 2012 report, *Shut down or restart? The way forward for computing in UK schools*, found that the delivery of computing education in many UK schools was highly unsatisfactory[8]. The recommendations we made then paved the way for schools to introduce computing into the curriculum; but this was only the first step. This new report provides a snapshot of the changes that have taken place since 2012 and examines the impact of these changes across the UK. We have identified a number of urgent challenges that governments, industry and school leaders need to address in order to safeguard our future efficacy in the digital world.

5. JCQ. 2017. Examination results: A, AS and AEA results, Summer [2017]. See https://www.jcq.org.uk/examinationresults/gcses/2017 (accessed 125 August 2017).
6. GOV.UK. 2017. Find and compare schools in England. See www.gov.uk/school-performance-tables (accessed 10 July 2017).
7. JCQ. 2017. See www.jcq.org.uk/examination-results/gcses/2017 (accessed 24 August 2017).
8. The Royal Society. 2012. *Shut down or restart? The way forward for computing in UK schools*. See https://royalsociety.org/topics-policy/projects/computing-in-schools/report/ (accessed 15 February 2017).

RECOMMENDATIONS

Recommendations

COMPUTING FOR ALL

To realise the ambition of recent curriculum and qualification reforms.

RECOMMENDATION 1

In England, school governors and Ofsted should monitor whether and how schools are teaching computing to all pupils.

RECOMMENDATION 2

Ofqual and the government should work urgently with the learned societies in computing, awarding bodies, and other stakeholder groups, to ensure that the range of qualifications includes pathways suitable for all pupils, with an immediate focus on information technology qualifications at Key Stage 4.

The learned societies in computing should establish an curriculum committee, to provide government with ongoing advice on the content, qualifications, pedagogy, and assessment methods for computing.

IMPROVING GENDER BALANCE

To improve gender balance in computing.

RECOMMENDATION 3

Research projects on pedagogy and curriculum development in computing should also investigate how to improve female participation.

RECOMMENDATION 4

Government and industry-funded interventions must prioritise and evaluate their impact on improving the gender balance of computing.

TEACHER SUPPLY

To ensure there is a strong supply of computing teachers entering the profession.

RECOMMENDATION 5

Governments should introduce quality-assured computing conversion courses for existing teachers, equivalent to those in physics and mathematics. Individual teachers or schools should not have to contribute to the costs of this training.

RECOMMENDATION 6

Governments should work with higher education providers and the British Computer Society to develop and accredit pre-service subject content courses to enable more people from a wider variety of backgrounds to become computing teachers.

Existing initiatives to support and develop computing degree courses with qualified teaching status should be continued and, if successful, expanded.

RECOMMENDATION 7

Higher education providers need to promote careers in computing education to a wide range of students.

RECOMMENDATION 8

Industry and academia should support and encourage braided[9] careers for staff who want to teach as well as work in another setting.

9. A braided career describes someone who is working in two sectors simultaneously. For example, working part-time in an academic position and part-time in an industry position.

RECOMMENDATIONS

EXISTING TEACHER CONFIDENCE

To support in-service teachers, with and without expertise in computing.

RECOMMENDATION 9

Governments and industry need to play an active role in improving continuing professional development (CPD) for computing teachers, as exemplified by the Network of Excellence. Investment in a national network needs at least a tenfold increase to expand the reach, and to have rigorous evaluation measures in place to strengthen the offer of such networks. Importantly financial support should be made available to schools to release staff to attend professional development opportunities.

RECOMMENDATION 10

Industry and non-profit organisations need to work with and through the British Computer Society and STEM Learning to provide a coherent offer of teaching support to teachers and schools.

EVIDENCE-INFORMED EDUCATION POLICY AND PRACTICE

To improve the availability of computing education research in the UK.

RECOMMENDATION 11

Education research funders, researchers, teachers and policymakers should develop a strategic plan that achieves:

- the establishment of the long-term research agenda for computing education in schools;
- a commitment to this programme by a number of stakeholders;
- the development of UK capacity to conduct the research; and
- the effective sharing of knowledge between researchers, teachers and teacher trainers.

RECOMMENDATION 12

The Economic and Social Research Council (ESRC) and other funders of education research should work to address the research priorities identified in this report.

Introduction

In 2012, the Royal Society published *Shut down or restart? The way forward for computing in UK schools* – a review of computing education in the UK[10]. Despite the near ubiquity of technology, the Society found that there was a dwindling interest in computing in schools and identified a number of actions to address this issue.

During the past 18 months, the Society has reviewed the impact on computing education of policy changes made since 2012. This report explores how governments, industry, schools and others can build on these changes to ensure that the promise of our original recommendations is realised. Table 1 summarises the progress made against those recommendations.

TABLE 1

Review of the recommendations made in *Shut down or restart? The way forward for computing in UK schools*.

Achieved	
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.	'Computing' is now used to describe the subject that includes digital literacy, information technology and computer science. In England, the current computing curriculum covers all three strands and differs from the previous ICT curriculum, which placed far more emphasis on information technology and digital literacy.
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.	Schools have not received ring-fenced funding for technical resources to complement computing curricula. However, there are a number of new, free software resources available. Hardware has also been provided at a low cost from Raspberry Pi and micro:bit, which has made a substantial impact in schools.

10. The Royal Society. 2012. *Shut down or restart? The way forward for computing in UK schools.* See https://royalsociety.org/topics-policy/projects/computing-in-schools/report/ (accessed 15 February 2017).

TABLE 1 (continued)

Partly achieved and a source for concern	
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. 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.	In England, the Government set new targets and funded bursaries for computing teachers. Recruitment levels have missed set targets, so this remains an area of major concern. In Scotland, 17% of schools have no computing specialist to deliver the experiences and outcomes for the subject.
Recommendation 6 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, eg 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 English national curriculum introduced computing as a new subject and removed ICT. The Government reformed qualifications, with new computer science qualifications replacing old ICT and computing qualifications. However, new disincentives are now impacting computing education, particularly at ages 14 – 16. There remain concerns about the information technology qualifications.

TABLE 1 (continued)

Partly achieved and a source for concern (continued)	
Recommendation 10 Awarding organisations should consult with the UK Forum (see recommendation 11) and HE departments to develop rigorous Level 3 academic qualifications in computer science.	Consultation was limited between the awarding organisations and the now disbanded UK Forum for Computing Education known as UKForCE. This has resulted in a subject that some schools view as difficult and only offer to high-performing pupils.

Not achieved and a source of concern	
Recommendation 3 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.	Governments have taken a passive role in ensuring there are minimum levels of CPD that teachers are required and supported to undertake. Scotland continues to require that teachers undertake 35 hours of CPD a year; however, the CPD doesn't have to be subject-related. Overall, there are large disparities in the CPD hours undertaken by computing teachers, with some teachers not receiving any CPD at all.
Recommendation 6 The schools inspectorates should monitor the implementation of this change to ensure that the problems of the ICT curriculum are not replicated.	School inspectorates need to put further measures in place to ensure that inspectors are monitoring the subject appropriately and effectively.
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 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 (eg computer science, information technology and digital literacy).	Awarding bodies have developed computer science qualifications. However, there are no qualifications for IT. Subsequently, this has caused computing qualifications to be narrow and schools are only offering it to high-performing pupils. In England, schools need further support to teach the non-assessed part of the computing curriculum at Key Stage 4.

TABLE 1 (continued)

Not achieved but not a priority	
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.	Schools are managing the implementation of school IT infrastructure on their own. Some schools have reported difficulties in achieving balance between network security and an environment suitable for teaching, however it has not been a major issue overall.
Recommendation 8 The UK Forum should advise awarding organisations on appropriate assessment methods for qualifications in digital literacy, information technology and computer science. **Recommendation 9** The UK Forum 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 the Science, Technology, Engineering and Mathematics Network (STEMNET) will have a role to play in implementing this. **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.	Hosted by the Royal Academy of Engineering, the UK Forum for Computing Education was formed shortly after the launch of *Shut down or restart? The way forward for computing in UK schools*. However, in 2016 a decision was made to disband the forum and support the work of Computing At School and the Royal Society's Computing Education Project.

What is the school subject of computing?

Computing in schools is a wide-ranging subject composed of three strands: information technology, digital literacy and computer science (see Box 1). A complete curriculum ensures that all three strands are covered. Computational thinking is a core component of a computing curriculum, and is not only important in coding, but can also be an important life skill for solving problems[11].

Mathematics, the social sciences, arts and design all underpin computing. Computing qualifications may cover one or more of the three strands, and qualifications in other disciplines may cover aspects of computing. Some components of digital literacy may be taught to all pupils in other lessons, such as Personal, Social and Health Education, but not examined.

BOX 1

Terminology

In this report, we use and develop the terminology used in our previous report, *Shut down or restart? The way forward for computing in UK schools*.

Computing as a school subject encompasses three strands: information technology, digital literacy and computer science.

Information technology means the assembly, deployment and configuration of digital systems to meet user needs for particular purposes.

Digital literacy means the basic skill or ability to use a computer confidently, effectively and safely, including the ability to use office software such as word processors, email and presentation software, and the ability to use a web browser and internet search engines. Digital literacy also includes understanding the morality and ethics of the personal and societal implications of digital technologies. These are the skills that secondary school teachers of other subjects should be able to assume that their pupils have, as an analogue to being able to read and write.

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 and problem-solving.

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.

11. Wing J. 2006. Computational Thinking. *Communications of the ACM*, 49(3).

INTRODUCTION

Computing education in the UK

Education policy is devolved in the UK and each of the four nations has its own curriculum. The way the school curricula across the UK nations include the skills, knowledge and understanding in information technology, digital skills and computer science varies, as does the level of detail provided (see Box 2).

BOX 2

Curricula across the UK

England

New National Curriculum for computing, introduced from September 2014.

- The new computing curriculum is non-prescriptive and there are no specified coding languages, software or hardware to use.
- From age 5, pupils are taught the principles of information and computation and how digital systems work. They go on to learn how to put this knowledge to use through programming. Building on this, pupils are equipped to use information technology to create programs, systems and a range of content.
- At Key Stage 4 (equivalent to GCSE), all pupils must have 'the opportunity' to study aspects of information technology and computer science.
- As part of a wider programme of qualifications reform, revised AS and A levels in computer science have recently been introduced into schools. GCSE qualifications in ICT have been withdrawn.

Source: Department for Education.

Scotland

Curriculum for Excellence – Technologies (refreshed as part of the 2016 Digital Learning and Teaching Strategy for Scotland).

- The Scottish Government introduced the Curriculum for Excellence in 2010 – 2011. This set out to help children and young people gain the knowledge, skills and attributes needed for the 21st century.
- The Technologies area sets out experiences and outcomes for pupils in a range of contexts spanning: business; computing science; food and textiles; and craft, design, engineering and graphics.
- From 2013 to 2014, the Scottish Qualifications Authority introduced new qualifications to align with the Curriculum for Excellence that included computing science.
- As part of the 2016 Digital Learning and Teaching Strategy for Scotland, the Scottish Government has refreshed the experiences and outcomes in the Technologies area of the Curriculum for Excellence. This includes discrete units covering (among others): digital literacy, computer science and technological developments in society (including business education).

Source: The Scottish Government.

"Here in the UK, it's clear to me that computer science has a great future with the talent, educational institutions and passion for innovation we see all around us."

Google CEO Sundar Pichai, November 2016

BOX 2 (continued)

Curricula across the UK

Wales

The 2008 National Curriculum for Information and Communication Technology (ICT) is due to be replaced by a new Curriculum for Life, including aspects of computer science.

- The current ICT curriculum in Wales applies to pupils from Key Stage 2 (ages 7 – 11) to Key Stage 4 (ages 14 – 16) in maintained schools. Learners develop their ICT skills by finding, developing, creating and presenting information and ideas and by using a wide range of equipment and software.
- In September 2016, a new Digital Competence Framework was made available for schools and other settings in Wales, making it the responsibility of all teachers and practitioners to include digital competence within lessons.
- The new Curriculum for Life is expected to be launched in September 2018. This will include six 'Areas of Learning and Experience'. One of these (Science and Technology) will include computer science.

Source: Welsh Government.

Northern Ireland

'Using ICT' is embedded across the Northern Ireland Curriculum.

- Across the Northern Ireland Curriculum in primary and secondary schools, pupils are expected to develop the skills of 'Using ICT' by engaging in meaningful research and purposeful activities set in relevant contexts.
- They should use ICT to handle and communicate information, solve problems, pose questions and take risks. They should process, present and exchange their ideas and translate their thinking into creative outcomes that show an awareness of the audience and purpose. They should also use ICT to collaborate within and beyond the classroom, to share and exchange their work.
- At a level appropriate to their ability, pupils are expected to develop their ICT skills in five key areas: Explore; Express; Exchange; Evaluate; and Exhibit.

Source: Department of Education (Northern Ireland).

Our evidence gathering

To understand how computing is being taught in the UK, we surveyed 341 primary school teachers and 604 secondary school teachers with a responsibility for computing education over a two-month period[12,13]. The purpose of the survey was to understand the impact of recent policy changes on computing education. We were seeking to identify additional actions that governments, industry, non-profit organisations and schools could take in order to ensure young people gain the skills and expertise they need to thrive in a rapidly developing and increasingly technology-rich world. Some of the issues explored in the survey include the level of teacher confidence in teaching an unfamiliar subject, the resources teachers use to improve their subject knowledge, the resources used to teach in the classroom and the way in which schools have implemented computing curricula.

The survey targeted teachers with some responsibility for delivering the computing curriculum, irrespective of their level of confidence, knowledge and experience. The survey was promoted through various networks such as the Royal Society's associate schools and colleges, Computing At School, and online subject-specialist groups. Other organisations such as Raspberry Pi, Primary Science Quality Mark, Teach Primary, Technocamps (Wales), C2k (Northern Ireland), Education Scotland, OCR and AQA also assisted with the promotion of the survey to reach as many teachers as possible.

To complement the findings of the survey, we also held eight small teacher meetings across the UK to delve deeper into some of the findings in the survey. The survey and teacher meetings also enabled us to identify some case study schools where a school's approach to teaching computing was having a positive impact. This report also showcases a series of case studies that we have sourced of people using digital literacy, computer science and IT skills in a wide variety of roles.

We commissioned an analysis of existing government and other datasets, on school examinations, the teaching workforce and university students. These data establish benchmarks regarding the health and capacity of computing in schools, colleges and higher education.

These data were also used to develop statistical models to explore the uptake of GCSE computer science at Key Stage 4 and A level computer science at Key Stage 5. We refer to these models in the report as the pathways analysis. The first model analyses GCSE uptake pathways where schools have at least one pupil completing the subject. The second model explores computing uptake at A level for those who have previously taken the subject at GCSE. Both models examine individual pupil characteristics to understand how these affect uptake.

We commissioned three literature reviews to summarise available evidence on effective computing pedagogies and assessment in schools and universities. This review now summarises the existing evidence base and identifies gaps in knowledge where future studies may be appropriate.

Finally, we have met with a number of individuals and organisations to gather evidence.

12. Pye Tait. 2017. After the Reboot: The State of Computing Education in UK Schools and Colleges. p18.
13. There are approximately 21,000 primary schools and 4,000 secondary schools in the UK.

Chapter one
Computing for our pupils

Left
© kali9.

Computing for our pupils

"Today's [computer] simulation techniques so pervade scientific practice that they have added a third basic tool to those of theory and experiment. They have moved on from assisting scientists in doing science, to transforming both how science is done and what science is done. They are fundamental to many open questions in science, in domains that span from Climate and Earth System science to Epidemiology (especially pandemic models, eg Ferguson), from Species Distribution modelling to Immunology."

From the Royal Society Science Policy report *Science as an open enterprise*, 2012.

Introduction

- The demand for computing skills and knowledge is growing – the nation's economy depends on it, and young people must be equipped with the necessary skills for the future.
- Computing as a subject is growing in England, but only 11% of Key Stage 4 pupils take GCSE computer science.
- In Scotland, where computer science has long been established as a discrete subject, the uptake of the subject is decreasing.
- Computing curricula and qualifications must continue to evolve.

Education provides young people with knowledge and understanding of how the world works and opportunities to embark on exciting life journeys. In the sciences, mathematics and computing, there is a strong alignment between the intellectual and cultural needs of the individual and the economic needs of the nation. As jobs are increasingly becoming dependent on technology, a high-quality computing education should give pupils the opportunity to gain the skills and knowledge they need to be successful in the technology-rich future.

In this chapter, we examine the demand for computing skills, and the attitudes to and participation of young people in computing. To understand possible career outcomes that computing can bring, we have included three case studies of young people currently working in a computing-related role. We also consider the role of the primary and secondary computing curriculum in meeting knowledge and skills needs and motivating young people.

The demand for pupils with computing expertise

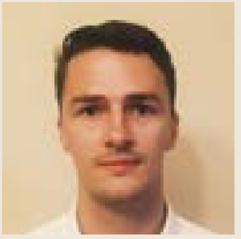
Employers project that the number of careers depending on computing skills will grow[14]. Many young people currently starting out in school could end up in jobs that do not currently exist. Cybersecurity is another emerging skill valued by employers. Jobs in cybersecurity now make up 15% of UK-based IT jobs and are set to grow by 10% each year until 2020[15]. Another example is the emergence of machine learning, which is a branch of artificial intelligence that allows computer systems to learn directly from examples, data and experience, and is beginning to transform many sectors from transport to healthcare. The demand for machine learning is already changing the types of digital skills that are highly sought after by employers[16].

Our first case study is based on an interview with Tim Sherratt, a developer, whose career has taken him to Silicon Valley. It highlights how developments in computing lead to the creation of new businesses. Tim's experience is typical for an entrepreneur with a computer science degree from a world-leading university.

14. UK Commission for Employment and Skills. 2017. The Labour Market Story: Skills for the Future. p24. See www.gov.uk/government/uploads/system/uploads/attachment_data/file/344441/The_Labour_Market_Story-_Skills_for_the_Future.pdf (accessed 4 July 2017).
15. Future of Tech. The importance of keeping cyber security skills sharp. See www.futureoftech.co.uk/cyber-security/theimportance-of-keeping-cyber-security-skills-sharp (accessed 3 July 2017).
16. The Royal Society. 2017. Machine learning: the power and promise of computers that learn by example. p62. See https://royalsociety.org/~/media/policy/projects/machine-learning/publications/machine-learning-report.pdf (accessed 28 June 2017).

CASE STUDY 1

Tim – opportunities in start-ups



Tim Sherratt is about to embark on a new business venture, one that will exploit his experience and knowledge of both business and computer science. For the past six years, he has been involved in setting up two, very different, web-based companies.

Tim attended the University of Bristol, where he studied computer science, and after graduating, joined a small telecoms company as a programmer. Three years later, together with a colleague, he took what they both saw as the 'next obvious step' and started a business of their own, designing websites. For the next two years, he and his colleague worked hard to get the business off the ground, and in the process they learned a lot, mainly about business. Crucially, he says, he discovered the world of start-ups, helping many to build their products. This was to prove decisive in the next step in his career.

Tim was approached by an entrepreneur in the US who had raised around $3m in venture capital for a start-up to build a website and apps aimed at amateur sport teams and leagues. Despite the growing success of their company, Tim and his colleague decided the US venture was worth the risk, so they wound up their company and went to the US. For the next four years, as one of the co-founders of the start-up, Tim helped develop apps and a website.

These were both challenging and exciting times for Tim. "Creating a business that hadn't been done before was hugely exhilarating and we worked hard to achieve this. To win this market we had to be the single successful company". For this reason, they focused their time on growing the user base, at the expense of generating revenue. The consequences were defining. When the venture capital market took a downturn about a year ago they were forced to close down; but not, says Tim, without success – the website was reaching a few million users per month and what he learned about running a business and the constantly evolving technology was invaluable.

In the future, says Tim, every business will be transformed by computer technology much like Uber is transforming the taxi business, and with current developments in artificial intelligence (AI) and machine technologies, very little will be beyond automation. "This", he says, "makes it crucial for computing to be a core subject from primary school onwards so that children have the tools they need to participate and be successful in the world".

The range of roles that will require computing expertise is varied. Sammy Elwardany works in a non-IT role, and his case study shows why an understanding of computing is useful for a wide range of jobs.

Sammy says Amazon is a digital company that doesn't pre-date computing, therefore having a computer science background means he can function in the company knowing and understanding how and why they use technology.

Computing in primary and early secondary

Getting the curriculum right is the first step needed to ensure that pupils leave school, college and university well equipped to embark on successful professional careers and to become astute and responsible citizens. To do this, governments and school leaders must make sure that school curricula include all three aspects of the computing curriculum, including digital literacy, information technology and computer science, and that children begin to study computing at the earliest age possible[17].

CASE STUDY 2

Sammy – computing skills in non-IT roles

Sammy Elwardany works in a non-IT role. He is a senior programme manager in the department of product imaging at Amazon UK, responsible for the photography of all products that go on this electronic shopping website. However, working at Amazon – a company that relies on IT – is not entirely separated from his previous work experience or the need for a computer science background. Prior to this job, Sammy spent 13 and a half years years at Ford Motors in Brentwood, Essex, in a variety of IT roles. He studied computer science with business at the Queen Mary University of London (QMUL).

The course at QMUL, he says, was brilliant because it was practical and relevant. "The idea that you can take a technology and apply it to solve a problem relevant to everyday life, or use it to improve the quality of life, is what really interests me".

Sammy went from QMUL to Ford, where he worked in a number of IT roles in logistics and sales. He eventually moved into digital marketing, where he was responsible for developing part of Ford's global network platform.

His time at Ford was all about the application of computer systems to manage a process to meet business needs. Sammy believes his computer science background in programming was a necessary part of his education. "You can't work effectively in this business environment without some technical grounding. You need to understand programming and how software is built in order to use IT systems effectively, and to be comfortable to discuss any issues and ask the right questions of the technical teams".

At Amazon, Sammy leads a team of programme managers, who are based in Japan, the US, Germany and India, and who initiate and plan the launch of any new category of images online. This involves everything from finding or building a suitable studio, through to training staff, and delivering the product images online. It's working with people from different parts of the world and with diverse skill sets that he enjoys most about his job. "To launch new products and new studios online, I need to work with people from IT, logistics, retail and marketing, as well as with reports and analysis – it is truly cross-functional and global".

17. Kind A. 2015. Computing Attitudes: Will Teaching 2nd Grade Students Computer Science Improve their Self -Efficacy and Attitude and Eliminate Gender Gaps? *Rising Tide* 8, 1–34. (See http://www.smcm.edu/mat/educational-studiesjournal/a-rising-tide-volume-8-summer-2015/, accessed 15 September 2017).

Governments have changed school curricula since 2012. Computing is now a mandatory subject in the national curriculum in England to age 16. Scotland has also refreshed the Technologies area of the Curriculum for Excellence to reflect the changing digital landscape, with computer science given as a technologies outcome at broad general education. In Wales, the Government is introducing a new Curriculum for Life, with elements of computer science, and the Northern Ireland Department of Education is embedding 'Using ICT' across the curriculum to engender informed and responsible users of technology.

The new primary school computing curricula should help pupils to build foundational skills, such as computational thinking, and gain an understanding of the technological world in which they live. Starting computing education in primary school has the potential to encourage more pupils to take it to a higher level and reduce the proportion of pupils that perceive computing as 'not for them'. In addition, when computing is embedded within other subjects in primary school, there is potential to give pupils an understanding of the subject's relevance and its potential applications.

In secondary education, school timetables need to allow sufficient time for classes to cover the three strands of the computing curriculum. Schools that only provide one hour a week or a fortnight for computing at 11 – 14 do not provide teachers with enough time to ensure the subject is adequately covered (as indicated by 40% of surveyed secondary schools). In upper secondary, pupils also need access to high-quality computing qualifications and we discuss these in the next section.

BOX 3

Computational thinking

The phrase computational thinking is shorthand for the thought processes involved in formulating problems and their solutions. Computational thinking can be used to create working, useful and usable computational systems to understand and reason about both natural and artificial systems and processes[18,19].

At its core is the idea that the solutions to many problems are not easily quantified as direct answers but rather as algorithms that lead to the answer; solutions to whole classes of problems encoded in a set of instructions that can be followed by computers or humans. In addition, it encompasses the idea that by using algorithmic techniques, computational systems can model many phenomena, from climate change to the way our brains work and the working of cancer cells. Computational thinking allows the development of practically useful algorithmic solutions even for very complex problems.

The computing curriculum

One major change in the English computing curriculum has been a new emphasis on the principles and concepts of computer science, alongside digital literacy and IT. This means students gain the skills needed to represent real-world problems in a form amenable to computational investigation, together with the skills needed to explore those representations to develop algorithmic solutions, and practical experience of writing computer programs implementing those solutions. The way of thinking about and solving problems in computer science is often referred to as 'computational thinking' (see Box 3).

18. Computing At School. 2015. Computational Thinking – A Guide for Teachers. (See www.computingatschool.org.uk/computationalthinking, accessed 7 August 2017).

19. Wing, J. 2010. Computational Thinking: What and Why? *The Link*, Spring 2011. pp. 20–23. (See http://www.cs.cmu.edu/sites/default/files/11-399_The_Link_Newsletter-3.pdf, accessed 15 September 2017).

Programming languages provide an exact and efficient way to describe the implementation of abstract algorithmic solutions. The choice of language is not critical to pupils' understanding and teachers can use a wide variety of programming languages to explain and demonstrate the principles of computer science. We asked teachers which programming languages they used in their classrooms and found that a wide range of different languages can be in use simultaneously, sometimes even in the same class. Typically, primary school teachers reported using block-based programming languages, such as Scratch (38%), Logo (17%) and Kodu (15%). At secondary level, there was a shift to text-based languages, with Python being the most popular (21%).

Teachers can also use 'unplugged' pedagogies to teach computational thinking (see Box 4), as well as a wide range of programming concepts and general computer science concepts. These focus on teaching those principles and concepts away from computers, for example, through analogy with everyday activities, games and puzzles, and through the role-play of computation. They turn abstract and invisible computational ideas into physical and tangible activities that are easier to explore and ultimately understand.

RECOMMENDATION

In England, school governors and Ofsted should monitor whether and how schools are teaching computing to all pupils.

BOX 4

Unplugged computing

Unplugged computing is a constructivist approach to teaching computing concepts and computational processes away from computers. It involves a variety of techniques including kinaesthetic activities such as the role-play of computational processes, games, puzzles and magic tricks that make intangible, abstract concepts concrete and physical. Representing abstract ideas with physical entities makes them easier to explore, manipulate, ask questions about, and so understand. The activities also often link computing ideas to everyday objects and activities allowing pupils to extend their existing understanding of the real world into the computing realm.

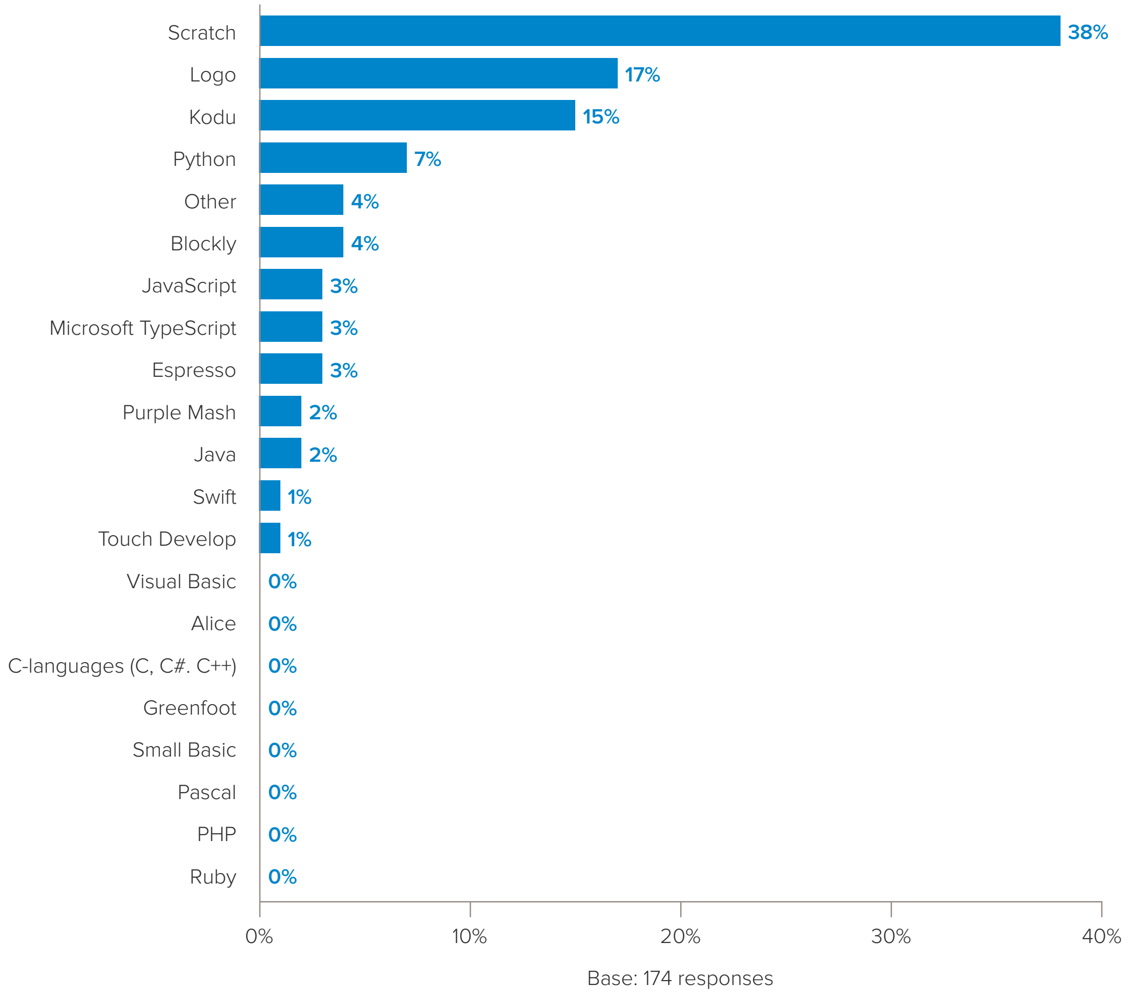
BOX 5

cs4fn

Created in 2005 at the Queen Mary University of London, cs4fn is a free magazine that strives to support digital learning to provide a bigger picture of computing and its links to other subjects. The magazine looks to promote the real world that goes beyond the syllabus and aims to inspire young people. Subscribed to (free) by over 2,000 schools, cs4fn is published twice a year with a circulation of 20,000 copies.

FIGURE 1

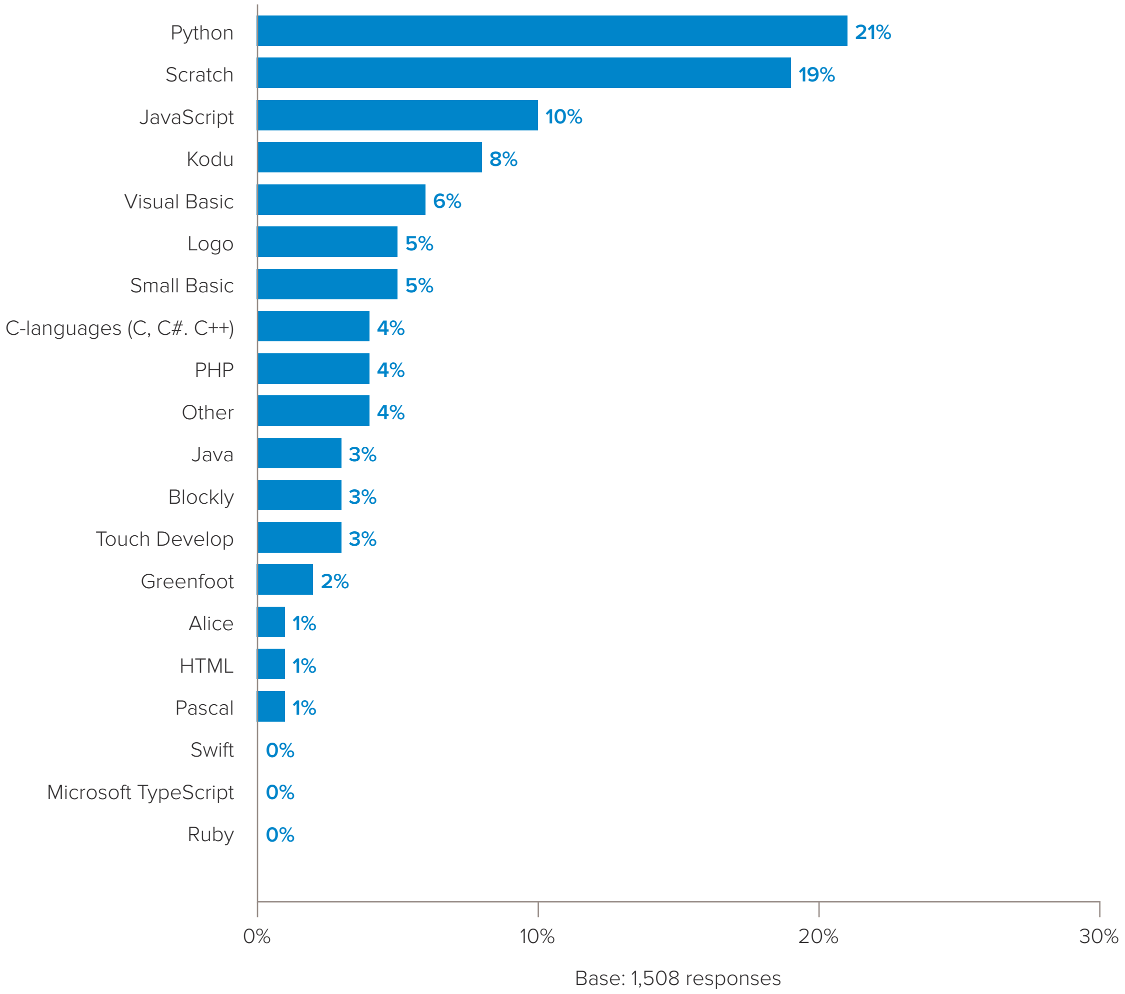
Percentage of primary school respondents using indicated programming language.



Source: Pye Tait.

FIGURE 2

Percentage of secondary school respondents using indicated programming language.



Source: Pye Tait.

CHAPTER ONE

How young people have responded

In *Shut down or restart? The way forward for computing in UK schools*, the Society commented on the image of computing and noted that many pupils found it 'repetitive and boring'[20]. We asserted that this image was one of the reasons there had been a steady decline in the number of pupils studying the subject since 2007. Lauren's case study shows how previous generations of young people have had to adapt and learn computing skills that weren't included in their school curriculum.

We wanted to find out how pupils' views of computing had changed in the past five years. The Wellcome Trust, through a project called the Science Education Tracker (SET), surveyed a representative sample of 4,000 young people in state-funded schools in England between ages 14 – 18[21]. The purpose of the survey was to investigate young people's attitudes towards and experiences of science education (including computing) and careers.

The top reasons cited for pupils not taking computing were a lack of interest in the subject, the school not offering the subject, or pupils prioritising other subjects ahead of computing.

Encouragingly, 11% of those interviewed expressed interest in a career in computer science and this was the third most popular science career[22]. However, only 3% of girls were interested in computer science as a career, compared with 17% of boys. This compares with 27% interested in medicine (14% of boys, 44% of girls) and 24% for engineering (34% of boys, 10% of girls). See Table 14 on page 103.

Opportunities for computing 14 – 19

In the later years of secondary schooling, pupils across the UK make choices about which subjects they will continue to study. However, pupils can only choose to study computing if schools and colleges offer relevant qualifications. Encouragingly, in England approximately 70% of secondary pupils attend a school where GCSE computer science is on offer.

Our pathways analysis revealed that if there were two equally able pupils in different schools, the pupil in the lower-performing school would be more likely to study computing at Key Stage 4. This may be suggestive of higher-performing schools deliberately focusing on other subjects, such as those more likely to provide high results in key performance measures.

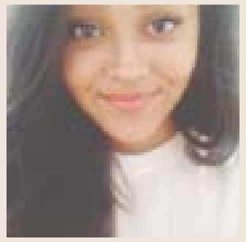
Schools not only need to offer computing qualifications, they also have to encourage pupils to study the subject. At present, only 11% of Key Stage 4 pupils choose to take GCSE computer science compared with 14% of Key Stage 4 pupils choosing ICT[23]. Soft signals, such as how the subject is timetabled, who teaches the subject and how it is portrayed within the school, are all likely to affect uptake. Based on their predicted mathematics grade, many schools may also allow only their brightest students to take computing courses[24].

The other subjects a teacher teaches will also send signals to pupils and parents about what the subject relates to. We found that secondary computing teachers also teach a variety of other subjects, with business studies, mathematics and design technology being the most common[25].

20. The Royal Society. 2012. *Shut down or restart? The way forward for computing in UK schools*. See https://royalsociety.org/topics-policy/projects/computing-in-schools/report/ (accessed 15 February 2017).
21. Wellcome Trust. 2017. Young people's views on science education. Science Education Tracker Research Report. See https://wellcome.ac.uk/sites/default/files/science-education-tracker-report-feb17.pdf (accessed 14 March 2017).
22. Wellcome Trust. 2017. Young people's views on science education. Science Education Tracker Research Report See https://wellcome.ac.uk/sites/default/files/science-education-tracker-report-feb17.pdf (accessed 14 March 2017).
23. GOV.UK. 2017. Find and compare schools in England. See www.gov.uk/school-performance-tables (accessed 10 July 2017).
24. Kemp P, Wong B, and Berry M. 2016. The Roehampton Annual Computing Education Report.
25. Pye Tait. 2017. After the Reboot: The State of Computing Education in UK Schools and Colleges.

CASE STUDY 3

Lauren – having to make up for a lack of computing in school



Lauren is currently doing a one-year, level 3 software development apprenticeship at Viridian Housing Association in South-West London. Lauren left school at 16 with eight good GCSEs, despite protests from her teachers, who saw her future underpinned by A levels and a university degree. "My main goal was to go to work", she says. "I was, and still am, driven by my passion for working".

She first went to the local FE college to do a one-year, level 2 course in business administration, and then picked up a one-year apprenticeship with the skills development organisation City & Guilds to get the level 3 qualification in the same subject. This route allowed her to gain a qualification while getting invaluable work experience, she says.

At the end of her training she was offered a full-time job at City & Guilds (C&G), taking on various admin roles. During this time, she worked for the Head of Learning Technology Development, and it was in this role that she became interested in software development. "At C&G they were always looking to use new technology to help learners and I thought I would like to be involved in similar development projects. From that time, I knew that software development was the industry that I wanted to be in".

Lauren decided to take a risk: she opted for voluntary redundancy being offered by C&G and applied for an apprenticeship in software development through QA Apprenticeships. Her application was successful and she was put forward for her current apprenticeship at Viridian.

Lauren's skills training is done in 1 – 2 week blocks in between work experience. "By the time I apply for my next job I will not only have a useful qualification but I will have gained real know-how in my chosen career", she enthuses.

Lauren has learned a range of programming languages and operating systems. As part of the course, she must also do three in-depth projects, which require some research and independent learning. She has just completed her first one, which involved designing a survey to assess the company's training programmes. On a day-to-day basis, she works with SQL Server, writing the code that is needed to gain access to stored data and information on the company's business portfolio.

Lauren sees her job as being very creative in a forever-expanding industry. One of the most rewarding aspects of her job, she says, is her growing confidence and ability. "When I started my apprenticeship, I had only basic ICT skills. But I have learned so much in a short space of time and can now be set a task and be confident in the software I am producing".

Looking back at her career pathway so far, Lauren says her careers advice could have been better. "My strongest subjects at school were IT and maths, I loved doing puzzles and this is really what software development is all about – but no one ever said that those skills might be good in an IT role. I strongly believe children should be encouraged in what they are good at and shown the host of alternative routes to university education that exist".

CHAPTER ONE

How well do computing qualifications work?

The Society's previous report – *Shut down or restart? The way forward for computing in UK schools* – recommended a review of computing and ICT qualifications that included increasing the range of qualifications available for pupils. There were concerns about the diversity and confusion presented by the range of ICT qualifications on offer. Some of the qualifications did not seem to be valued, either as prerequisites for further education and training, or by employers as proof of an individual's ability or potential to fill a role. There had also been a drift away from computer science qualifications.
Since 2012, the qualification suite in England, Wales and Northern Ireland has been refined, with the intention of making it more coherent. In 2013, the Scottish Qualifications Authority (SQA) introduced the new National Qualifications courses that replaced the previous intermediates. The new National Qualifications in computing science and subsequent changes to Higher and Advanced Higher have a stronger focus on computing and move away from ICT. It is now appropriate to examine what progress has been made, and what more might need to be done.

The English, Welsh and Northern Irish awarding bodies have introduced a new GCSE in computer science. The number of entries for the new GCSE have increased slightly from 60,146 taking the qualification in 2016, to 65,205 pupils in 2017 (see Table 2). Since the introduction of the new National Qualifications in Scotland, the numbers for National 5 computing science have remained stable with 7,442 entries in 2017 (see Table 3).

The natural progression from the GCSE is A level computer science, although the GCSE will also prepare pupils for future opportunities in computer science. One measure of success of the introduction of GCSE computer science is whether A level entries have also increased, and by this measure, the introduction of computer science appears successful. At A level, the number of qualifications has also gone up each year and in 2017, 8,299 pupils took a computer science A level in England, Wales and Northern Ireland, up around a third compared to 2016[26]. In Scotland, there were 641 entries to the Advanced Higher Computing Science in 2017, slightly up from the 485 entries in 2016.

The current trend in A level participation is positive, however for many pupils, the possibility of a one-year AS-level in computing was a bridge that sometimes led to a full A level. Many schools are no longer offering AS levels, and without this pathway, pupils must make decisions one year earlier. Changes to the post-16 funding model are also likely to decrease the number of AS and A levels that pupils study. The Government must monitor the impact of these policy changes on A level computer science participation.

Increasing 14 – 16 participation

In *Shut down or restart? The way forward for computing in UK schools*, we recommended that a timetable distinction should 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. The 2016 post-16 Skills Plan published by the Department for Education promises a common core for all technical pathways that includes English, mathematics and digital skills[27]. Many T levels will also require some level of computing expertise. If schools do not teach the skills required in these new technical pathways from ages 14 – 16, the new T level technical and vocational qualifications will not fulfil their potential. In England, a number of factors are impacting the availability, take-up and effectiveness of computing education for 14 – 16 year olds.

26. Kantar Public. 2017. The Royal Society: Computing Education Strand 1 report. Note that the A level qualification title has changed from computing to computer science.

27. Department for Business Innovation & Skills, Department for Education. 2016. Post-16 Skills Plan.

TABLE 2

ICT, Computing, History, Geography, Business Studies and Mathematics GCSE qualifications taken in England, Wales and Northern Ireland (2012 – 2017). All UK candidates aged 16.

	2012	2013	2014	2015	2016	2017
ICT	46,471	63,832	87,512	103,342	78,161	69,008
Computing	–	3,867	15,842	33,607	60,146	65,205
History	209,566	243,852	244,988	237,378	252,075	250,590
Geography	175,319	208,447	214,815	218,685	235,818	240,616
Business Studies	65,987	71,888	85,161	91,383	90,169	89,192
Mathematics	491,777	512,312	596,524	596,767	570,459	573,822

As Mathematics is mandatory, it has been included to provide a relative indicator of cohort size. Note: the Joint Council for Qualifications (JCQ) uses the category 'Computing' to include all GCSE qualifications in computing and computer science.

Source: JCQ.

TABLE 3

Computing Science, Business Management, Geography and History National 5 Qualifications taken in Scotland (2015 – 2017)*.

	2015	2016	2017
Computing Science	7,664	7,927	7,442
Business Management	7,603	7,986	8,015
Geography	11,574	11,018	10,757
History	15,777	15,943	15,078

* In 2014, the SQA introduced the new National Qualifications courses in line with the national Curriculum for Excellence development. Only statistics from 2015 have been included due to the dual running of the new National 5 and predecessor Intermediate 2 courses in 2014 while the new qualifications were phased in.

Source: SQA.

The qualification suite

The GCSE in ICT is being phased out and there is no GCSE information technology option. Since 2016, there has been a review and a significant reduction of level 1 and level 2 computing qualifications. There are a number of non-GCSE qualifications available that cover IT and digital literacy, however teachers have expressed concern about their credibility, whether they cover the full spectrum of content, and whether they can be taught to mixed level 1 and level 2 cohorts. Respondents to our survey, and the teachers who attended our meetings, were concerned that as a result some pupils will leave compulsory education in England at age 16 not prepared for further study or employment.

Assessing computing appropriately

Finally, many teachers in England, Wales and Northern Ireland raised the new Non-Examined Assessment arrangements for GCSE computer science qualifications as a cause for concern. These teachers felt that the new rules on GCSE Non-Examined Assessment (NEA) are onerous, and consume a disproportionate amount of teacher time and teaching opportunities in the computer science GCSE. Early indications are that the 'endorsement' model recently adopted by science subjects is proving successful. Ofqual should review the endorsement model and consider applying it to computer science exams, as soon as possible. Awarding bodies may want to explore alternative assessment methods, as they have done in the other sciences.

Computer science – the difficult option?

Our evidence gathering suggests that computer science GCSE is increasingly regarded by teachers and pupils as a 'difficult option', one that is really only suitable for the most able pupils and, in particular, pupils who are high achievers in mathematics. If teachers, pupils or parents identify computing as a specialist subject, this will affect the future job prospects of pupils and narrow opportunities for particular groups of young people.

In our Belfast teacher meeting, teachers noted that the image of computer science can be a barrier to implementation where school senior leaders perceive the subject as 'specialist' rather than 'mainstream'. Although awarding bodies do not place prerequisite restrictions on their qualifications, quite often schools will offer computing to only more academically inclined pupils. We found indicators that the subject may be attracting only those that are more academically inclined in mathematics[28,29]. Our pathways analysis also reflects this trend. This research showed that as pupils gained each additional grade in GCSE mathematics the probability of the pupil studying GCSE computer science increased by 1.4 times[30].

These perceptions and additional barriers are troubling, as we already have evidence from physics and mathematics education in particular, that perceptions of the difficulty of a subject can affect pupil progression[31]. These perceptions have the consequence of making the subject appealing to a narrower set of pupils.

28. Sentance S. 2016. CAS 2016 Teacher Survey Analysis.
29. Kemp P, Wong B, and Berry M. 2016. The Roehampton Annual Computing Education Report.
30. Kantar Public. 2017. Royal Society: Computing Education Strand 3 technical report.
31. Ofqual. 2017. Perceptions of A levels, GCSEs and Other Qualifications in England: Wave 15. Change to the Ofqual relative difficulty reference, lined to 2017 board papers.

TABLE 4

Level 3 ICT and Computing qualifications taken in England, Wales and Northern Ireland (2007 – 2017).

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Entries for academic qualifications											
Computer Science (GCE A level)	5,610	5,068	4,710	4,065	4,002	3,809	3,758	4,171	5,383	6,242	8,299
ICT (GCE A level)	13,360	12,277	11,948	12,186	11,960	11,088	10,419	9,479	9,124	8,737	7,607

Source: JCQ.

TABLE 5

Higher and Advanced Higher Computing qualifications taken in Scotland (2014 – 2017).

	2014	2015	2016	2017
Computing Science (Higher)	4,468	3,008	4,454	4,476
Computing Science (Advanced Higher)	440	509	485	641

Source: SQA.

Conclusion

The demand for computing skills is increasing as we move towards a more technology-focused world. To prepare pupils for the future, schools need to ensure there are opportunities provided to all young people to study the subject and become astute digital citizens. Pupils are beginning to recognise the opportunities that knowledge and understanding of computing brings. Computing isn't a subject that should be reserved for a subset of pupils. As long as computing is perceived as a specialist subject, the uptake of the subject from 14 – 18 year olds will not increase rapidly enough. The qualifications suite must provide opportunities to study all aspects of computing once the subject becomes a choice. Pupils should be encouraged to study the subject and realise the benefits it brings.

In England, the qualifications framework for computing pupils aged 14 – 16 is a cause for serious concern, due to an unfortunate combination of the factors described above. It needs urgent attention from DfE, Ofqual and the awarding bodies.

RECOMMENDATION

Ofqual and the government should work urgently with the learned societies in computing, awarding bodies, and other stakeholder groups, to ensure that the range of qualifications includes pathways suitable for all pupils, with an immediate focus on information technology qualifications at Key Stage 4.

The learned societies in computing should establish an curriculum committee, to provide government with ongoing advice on the content, qualifications, pedagogy, and assessment methods for computing.

Chapter two
Widening access

Left
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Widening access

Introduction

- Computing in the UK is a male-dominated subject and actions need to be taken to improve the gender balance.
- Urban schools are more likely to offer computing. Pupils in rural schools need greater opportunities to study the subject.
- Pupils with special educational needs and disabilities (SEND) can benefit greatly from computing, and more research will enable teachers to understand best practice for involving these pupils.

It is vital that all young people have opportunities to take computing. At the stage where the subject becomes a choice however, the cohort of computing pupils is not representative of the pupil population. Gender is the most significant diversity issue within the subject. However, there are also equity issues for other groups. Computing skills cannot be limited to a narrow demographic if we want to ensure that the next generation have equal opportunities to succeed, and for the country to make best use of its pool of potential talent.

In this chapter, we consider the diversity of pupils who study computing and how computing can be made accessible to all under-represented groups, including female pupils, pupils from low socio-economic backgrounds, and ethnic minorities. We also consider the inclusion of pupils with SEND.

Computing in the UK is a male-dominated subject, and a male-dominated career

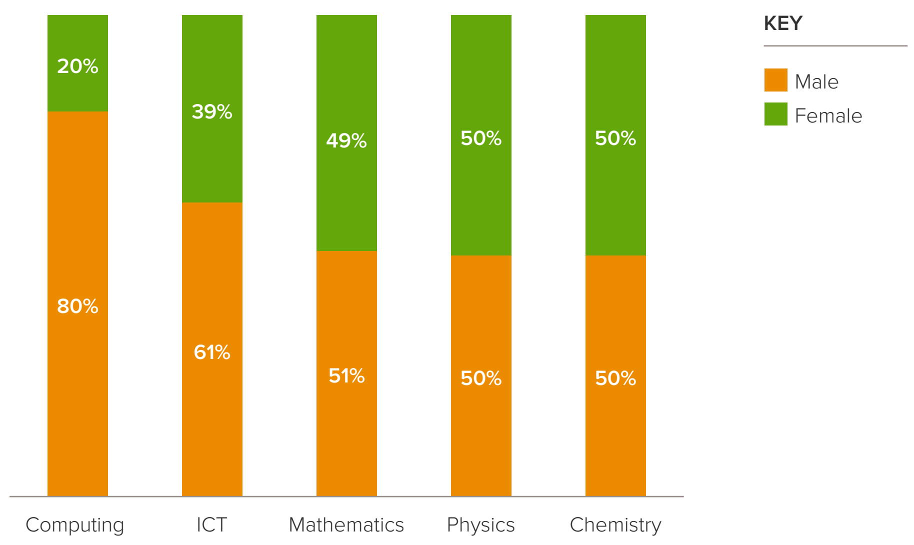
Increasing the proportion of girls and young women studying computing in schools, colleges and universities would go a long way to addressing computing skills gaps in the UK. When compared to physics, ICT, mathematics and chemistry, computer science has the most gender-skewed entries for qualifications.

In 2017, as shown in Figure 3, only 20% of GCSE computing candidates were girls. Although better, the related subject of ICT was also gender-skewed, with a 39% uptake by girls[32]. Mathematics has a strong correlation with computing participation, but has a less gender-skewed profile as 49% of GCSE mathematics candidates were female[33]. In Scotland, the female uptake at National 5 is similar, at 20% in 2017[34].

32. JCQ. 2017. See www.jcq.org.uk/examination-results/gcses/2017 (accessed 24 August 2017).
33. JCQ. 2017. See www.jcq.org.uk/examination-results/gcses/2017 (accessed 24 August 2017).
34. Scottish Qualifications Authority. 2017. Statistics 2016. See www.sqa.org.uk/sqa/63001.8312.html (accessed 29 September 2017).

FIGURE 3

Gender balance percentage at GCSE for computing, ICT, mathematics, physics and chemistry (all UK 16-year-old candidates).



Note: JCQ uses the category 'computing' to include all GCSE qualifications in computing and computer science.
Source: JCQ.

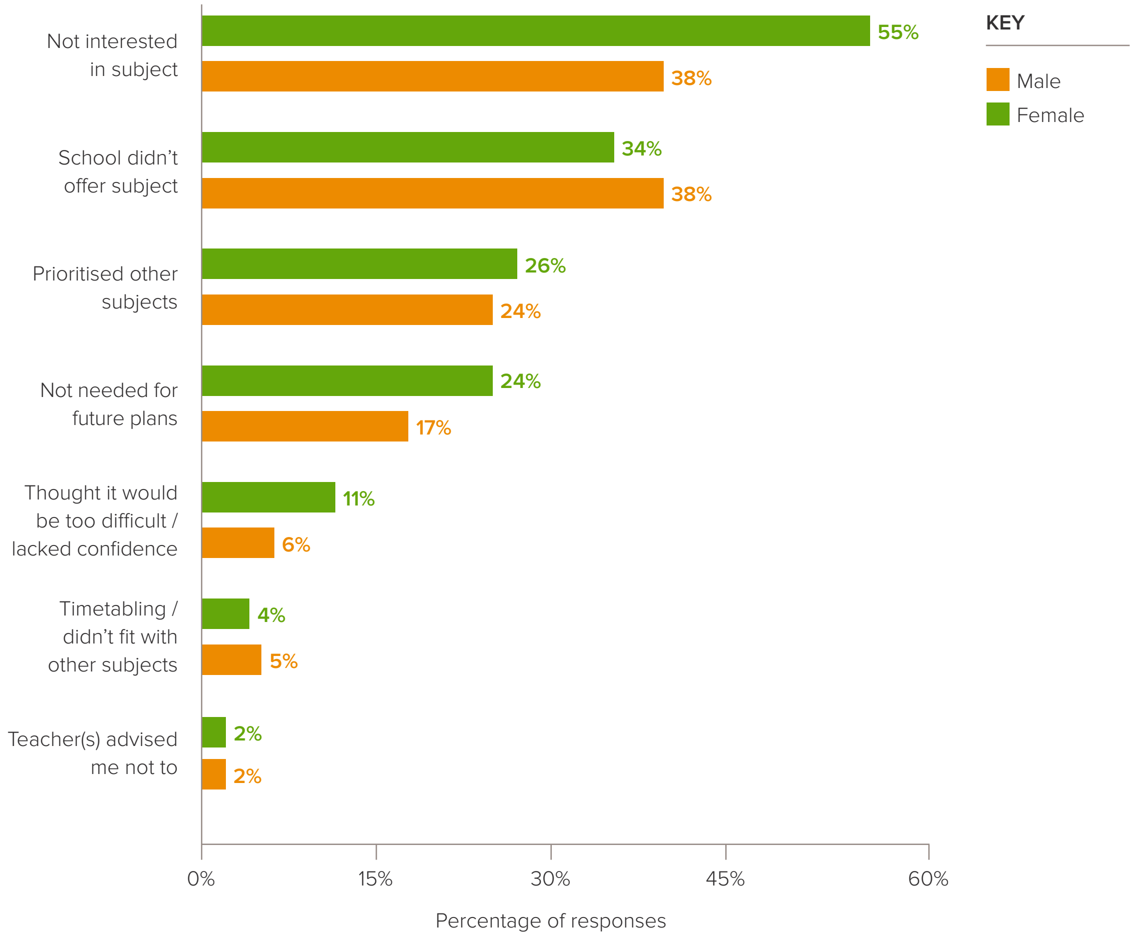
Higher education reflects this trend as outlined in 2016's Shadbolt Review of Computer Sciences Degree Accreditation and Graduate Employability. Within this review, women only represented 13% of the total number of first-degree entrants at publicly funded English higher education institutions (HEIs) for full-time computer science degrees, compared with 32% female entrants for other STEM degrees[35].

We used the Wellcome Trust Science Education Tracker (SET) to explore the reasons why girls chose not to study computer science at GCSE level[36]. Figure 4 shows that girls were more likely to attribute lack of interest, not needed for career plans, and the perception of the subject's difficulty or their lack of confidence in studying it, as reasons for not studying computer science. About a third of both boys and girls said their school did not offer computer science, which is also very significant.

35. Department for Business, Innovation & Skills and Higher Education Funding Council for England. 2016. *Shadbolt Review of Computer Sciences Degree Accreditation and Graduate Employability*. p33. See www.gov.uk/government/uploads/system/uploads/attachment_data/file/518575/ind-16-5-shadbolt-review-computer-sciencegraduate-employability.pdf (accessed 25 May 2017).
36. Wellcome Trust. 2017. Young people's views on science education. Science Education Tracker Research Report. See https://wellcome.ac.uk/sites/default/files/science-education-tracker-report-feb17.pdf (accessed 14 March 2017).

FIGURE 4

Cited reasons for not studying computer science at GCSE level.



Source: Wellcome Trust SET Tracker.

CHAPTER TWO

TABLE 6

Uptake of GCSE computing within English schools where at least one pupil completed GCSE computing.

	Male pupils		Female pupils	
	Boys' schools	Mixed schools	Girls' schools	Mixed schools
Uptake of GCSE computing	2,735 21.5%	23,307 19.8%	1,259 12.3%	3,774 3.4%
Total number of Key Stage 4 pupils within schools where at least one pupil completed GCSE computing	**12,740**	**117,898**	**10,274**	**109,626**

Source: Kantar Public.

In common with previous research on physics participation by girls[37], we found that single-sex schools had a positive impact on the uptake of computing at GCSE. As shown in Table 6, the uptake at girls' schools was 12.3% compared to just 3.4% at mixed schools. In physics, the Institute of Physics found that girls in a single-sex school were nearly 2.5 times more likely to study A level physics than in a mixed school[38]. Boys were equally likely to take computing in single-sex and mixed schools. This suggests that in the right environment, more girls will choose to study computing. Researchers, teacher trainers and curriculum developers should investigate if anything can be learned from the teaching practices and learning environment in single-sex schools.

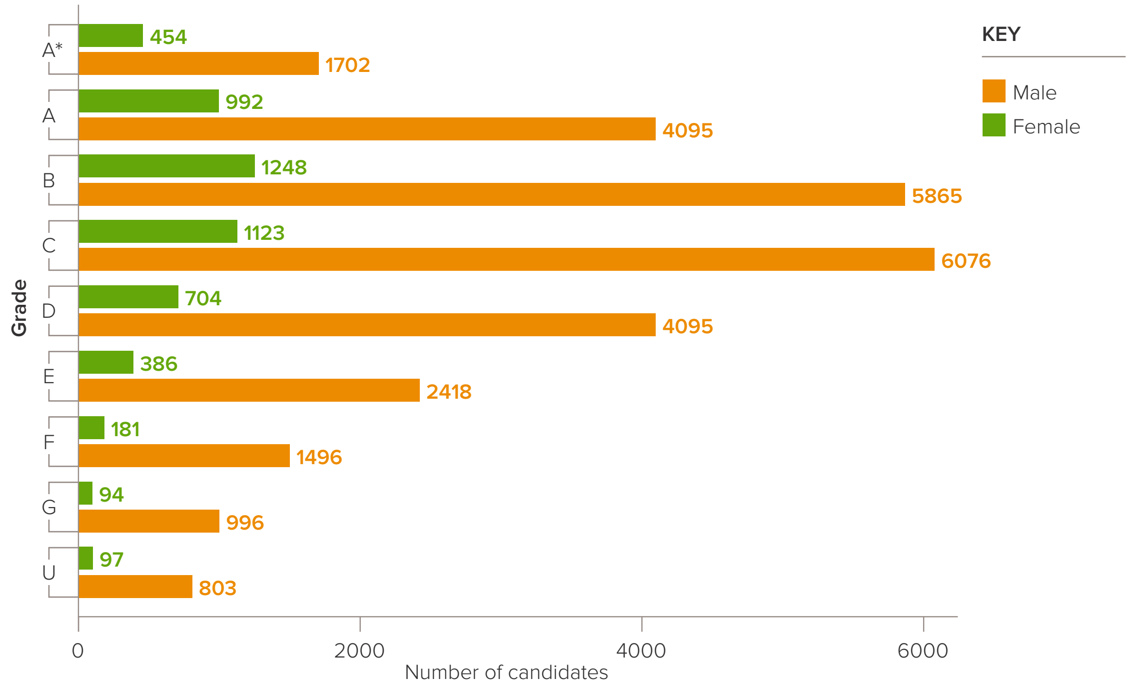
Female pupils who pursue computing do at least as well as, or outperform, their male counterparts overall[39]. The *Roehampton Annual Computing Education Report* used the Department for Education's National Pupil Database (NPD) to extract individual pupil examination and characteristic data to understand how girls performed in computing compared to boys. The analysis uncovered evidence that girls have achieved proportionally more A* – B grades in computer science at both GCSE and A level (see Figure 5 and Figure 6). This could be the result of less able students choosing not to take computing due to lack of confidence or their perception of the subject's difficulty.

37. The Institute of Physics. 2015. Opening Doors: A guide to good practice in countering gender stereotyping in schools. See www.iop.org/publications/iop/2015/file_66429.pdf (accessed 26 November 2016).
38. The Institute of Physics. 2012. It's Different for Girls: The influence of schools. See www.iop.org/education/teacher/support/girls_physics/file_58196.pdf (accessed 18 September 2017).
39. Kemp P, Wong B, and Berry M. 2016. The Roehampton Annual Computing Education Report.

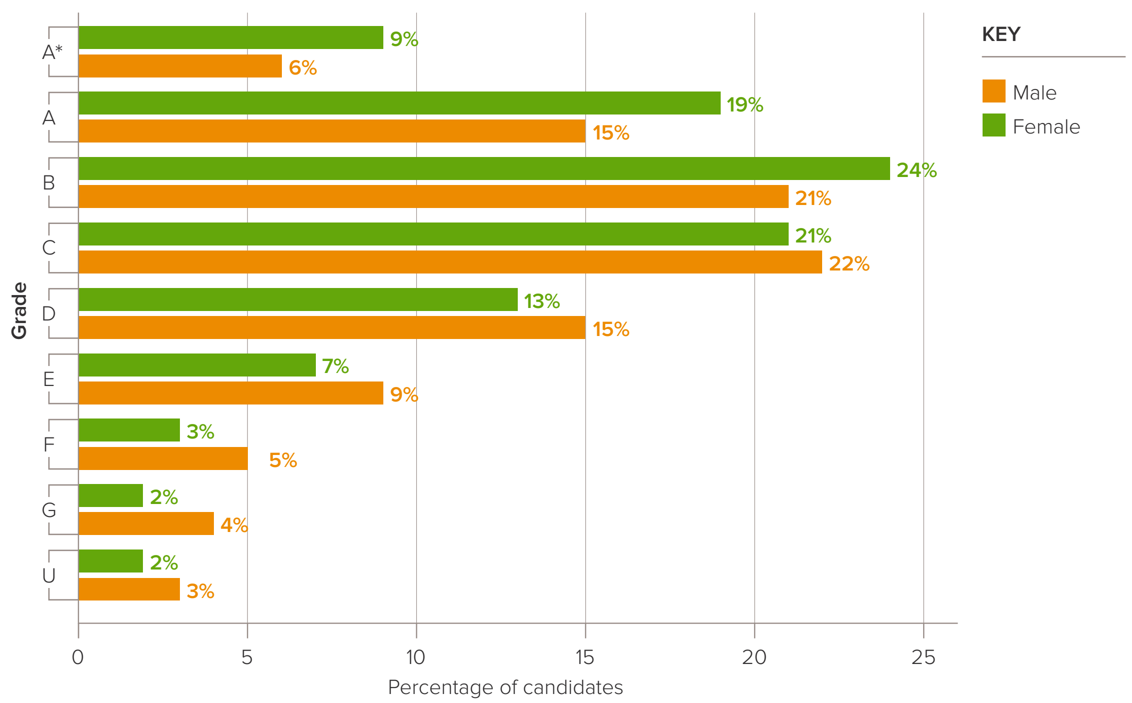
FIGURE 5

2015 GCSE computer science gender results: the total and proportion of females and males achieving GCSE grades A* to E and ungraded (U).

Gender total students



Gender proportional distribution

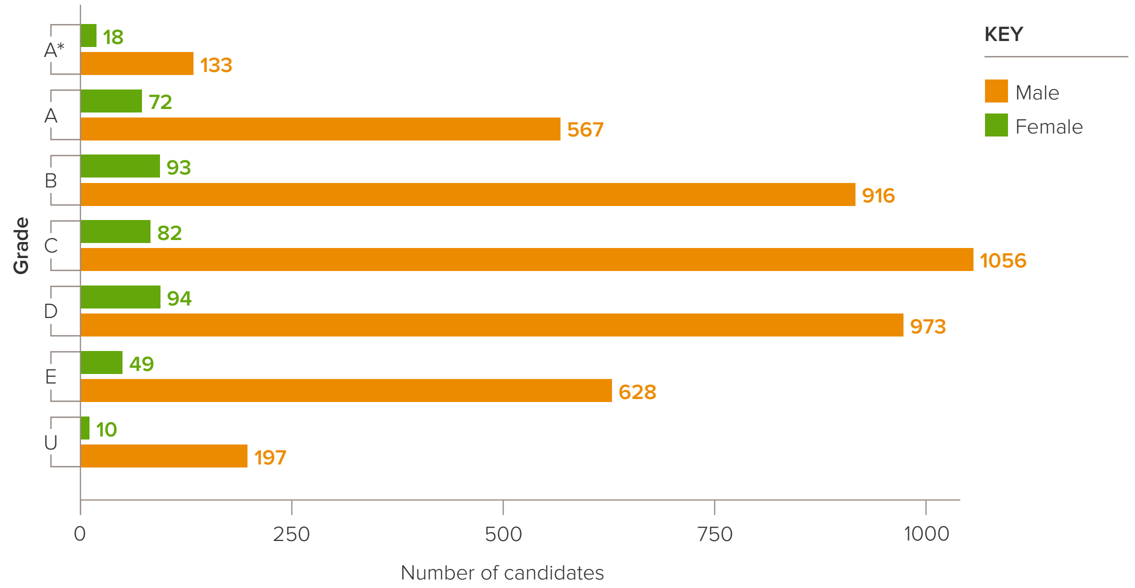


Source: The *Roehampton Annual Computing Education* Report.

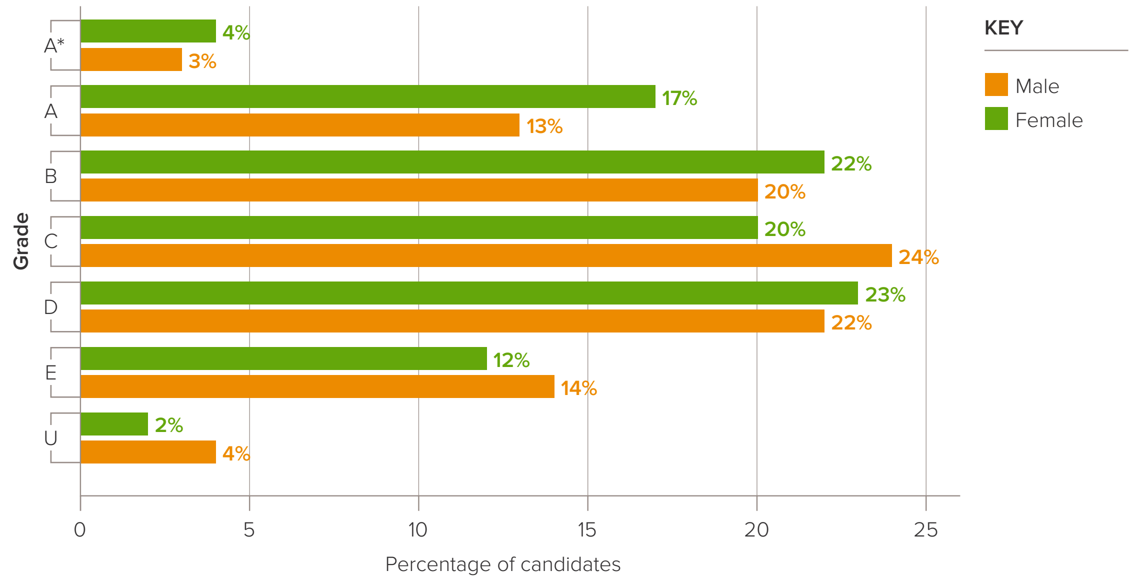
FIGURE 6

2015 A level computing gender results: the total and proportion of females and males achieving A level grades A* to E and ungraded (U).

Gender total students



Gender proportional distribution



Source: The *Roehampton Annual Computing Education* Report.

Can we improve the gender balance in computing?

Historically, for STEM subjects and careers that have been gender-skewed, the skew has been very hard to shift. Including computing as a core subject for all pupils from the age of five may help, but we cannot rely on this. Mathematics and physics are still gender-skewed despite being part of the primary school curriculum for over 20 years.

Our approach has been to consider research about the factors influencing young people's decisions, to explore what we can learn from the approaches taken to address gender-skew in other subjects and to seek out computing interventions that aim to address gender imbalance in school computing education.

The ASPIRES research programme[40] looked at young people's attitudes towards science over a five-year period through surveys and interviews. This research found that while most young people had high career aspirations, their desired career paths were highly influenced by their 'science capital'.

A young person's 'science capital' refers to how much science features in their everyday lives, whether it means having family members with qualifications in science who can influence their understanding and knowledge of science, or social activities such as the regularity with which they may visit a science museum. The ASPIRES research suggests that science capital can play a strong role in developing a young person's understanding of the natural sciences and their perceptions of the subject. Researchers should investigate whether the ASPIRES methodology results in similar findings for computing, engineering and mathematics.

Unconscious bias in curriculum resources, in teaching and in school policies may contribute to the male dominance of computing. Our most promising avenue comes from work undertaken by the Institute of Physics (IoP)[41]. Coupled with subject-level initiatives, the Institute trialled a whole-school approach to combat gender bias within schools (against both boys and against girls) through their Opening Doors Project. This project created an environment that applies good practice to counter gender stereotypes, including a culture that does not tolerate sexist and gendered language.

The researchers found that school culture played a key role in influencing how pupils view and choose certain subjects. The researchers also found that providing pupils with careers guidance at an early age, and promoting a gender champion from the senior leadership team, could have a positive impact on gender biases. The work undertaken by the IoP is very promising and the Government should consider funding further research to explore whether the model has potential for computing and other gender-skewed subjects.

RECOMMENDATION

Research projects on pedagogy and curriculum development in computing should investigate how to improve female participation.

40. Department of Education & Professional Studies, Kings College London. 2017. ASPIRES: Young people's science and career aspirations, age 10–14. See www.kcl.ac.uk/sspp/departments/education/research/ASPIRES/ASPIRES-final-report-December-2013.pdf (accessed 17 July 2017).

41. The Institute of Physics. 2015. Opening Doors: A guide to good practice in countering gender stereotyping in schools. See www.iop.org/publications/iop/2015/file_66429.pdf (accessed 26 November 2016).

BOX 6

Barclays *IT Girls Allowed*

The Barclays *IT Girls Allowed* event was designed to demonstrate that computing careers are accessible to girls and to inspire them to consider this as a subject choice in the short term, and as a career choice in the long term. The event provides pupils in Years 8 and 9 with activities that include insights into cryptography, programming robots, design and hardware.

Evaluating impact

Through some of our case study schools, and our wider evidence gathering, we have found a number of initiatives that seek to increase the proportion of girls and young women studying computing. However, we have found very little robust evidence of the impact of these projects that could enable teachers to transfer lessons learned to every school.

RECOMMENDATION

Government and industry-funded interventions must prioritise and evaluate their impact on improving the gender balance of computing.

Where you live matters

Whether you have the option to study computing aged 14 and beyond varies depending on where you live. This variation disadvantages pupils in some areas of the country and may limit the capability of sectors reliant on computing and data skills to be based in these areas. New or growing companies may be reluctant to establish themselves in an area with low provision of computing qualifications and available graduates.

It is curious that, while 70% of pupils attend schools which offer GCSE computer science, this only represents 46% of secondary schools. This means that the remaining 54% of secondary schools have only 30% of the country's pupils on the roll. The difference in proportions is the result of smaller schools, with fewer pupils, being considerably less likely to offer GCSE computer science. Just 1.7% of schools with a GCSE cohort size of 1 – 11 pupils and 10.5% of schools with a cohort size of 12 – 89 offered the subject, compared with 51.9% of schools with a GCSE cohort size of more than 200 pupils[42]. Therefore, pupils who live in areas where there are predominantly smaller schools are less likely to have access to a school that offers computing.

CASE STUDY 4

Craigmount High School

Craigmount High School, West Edinburgh would like to encourage more pupils to take computing at S3, particularly girls. To help with this, the school takes part in the UK-wide extracurricular club, Tech Future Girls, in which pupils participate in activities such as making up their own dancing algorithm and then creating an animation of the dance using the Scratch programming language[43].

42. Kantar Public. 2017. Royal Society: Computing Education Strand 3 technical report. p14.

43. Pye Tait. 2017. After the Reboot: The State of Computing Education in UK Schools and Colleges. Annex 1: Case Study Schools. p21.

The *Roehampton Annual Computing Education* Report has shown that schools in urban areas are more likely to offer the subject than schools in rural areas (Table 7). This may relate to our finding that large schools are more likely to offer the subject than smaller schools, as rural schools tend to be smaller. The Roehampton report indicated that in 2015, 29.5% of urban English schools offered GCSE computing, while in rural schools this dropped to 22.7%[44].

The data is even starker when regional areas are broken down further as indicated by Table 8. In rural hamlets and isolated dwellings, only 11.2% of schools offered GCSE computer science, while 31.1% of schools in urban city and town areas offered the subject.

Location not only affects whether there is an opportunity to study computing, but also the amount and type of extra support a school can access. Extracurricular activities tend to cluster in urban areas, and support from relevant employers and universities is more readily found in urban areas[45].

In an analysis of English local authority data, we found the percentage of Key Stage 4 pupils in local authorities undertaking GCSE computer science ranged from 4% to 23%, while the percentage of local authority schools offering the subject ranged from 18% to 71%. Walsall, Calderdale, Blackburn with Darwen, Rutland, Shropshire, Tower Hamlets, and Kensington and Chelsea are local authorities that have been identified as key opportunity areas where there is low offering of the subject and a low uptake of pupils undertaking GCSE computer science. Despite Tower Hamlets and Kensington and Chelsea being in urban areas, the data shows that they have smaller Key Stage 4 cohorts, in line with our findings regarding cohort size. Details are available in the appendix, Table 20.

TABLE 7

2015 GCSE computing provision by aggregated urban and rural categories.

Type	Total Schools	Total pupils	Subject Providers	Providers %	Subject pupils	Pupils %	Average Cohort Size
Urban	4,246	517,054	1,254	29.5	29,116	5.6	23.2
Rural	789	79,673	179	22.7	3,708	4.7	20.7
Totals	**5,035**	**596,727**	**1,433**	**28.5**	**32,824**	**5.5**	**22.9**

Source: The *Roehampton Annual Computing Education* Report.

44. Kemp P, Wong B, and Berry M. 2016. The Roehampton Annual Computing Education Report.
45. Wohl B. 2017. The Conversation. See https://theconversation.com/when-it-comes-to-computing-rural-schools-are-at-risk-ofbeing-left-behind-57861 (accessed 26 June 2017).

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TABLE 8

2015 GCSE computing provision by all urban and rural categories.

Type	Total Schools	Total pupils	Subject providers	Providers %	Subject pupils	Pupils %	Average Cohort Size
Urban city and town	2,318	286,985	721	31.1	16,757	5.9	23.2
Urban major conurbation	1,759	208,516	467	26.5	10,948	5.3	23.4
Rural town and fringe	381	51,898	115	30.2	2,583	5	22.5
Urban minor conurbation	162	21,078	63	38.9	1,363	6.5	21.6
Rural village	164	11,533	28	17.1	488	4.2	17.4
Rural hamlet and isolated dwellings	188	11,530	21	11.2	339	2.9	16.1
Rural town and fringe and a sparse setting	35	3,805	11	31.4	268	7	24.4
Urban city and town in a sparse setting	7	1,375	3	42.9	48	3.5	16
Rural village in a sparse setting	10	540	3	30.0	14	2.6	4.7
Rural hamlet and isolated dwellings in a sparse setting	11	367	1	9.1	16	4.4	16
Totals	**5,035**	**596,727**	**1,433**	**28.5**	**32,824**	**5.5**	**22.9**

Source: The *Roehampton Annual Computing Education* Report.

The impact of disadvantage

The impact of disadvantage on pupils' participation and attainment in computing is unclear. Our pathway analysis showed that measures of deprivation such as IDACI (Income Deprivation Affecting Children Index), individual eligibility for free school meals, and percentage of pupils in the school eligible for free school meals, did not have an impact on the uptake of computing at GCSE. However, the *Roehampton Annual Computing Education Report* for 2015 showed that those on pupil premium were under-represented compared to other subjects. In 2015, computing had the seventh-lowest pupil premium intake at 19%, while all subjects had an aggregated 26.6% pupil premium intake[46].

The best way for governments to increase the proportion of disadvantaged pupils taking computing may be to ensure that more schools in disadvantaged areas offer computer science[47]. As we will see in the next chapter, schools face significant challenges offering the subject because there is a shortfall of computing teachers. Where schools are unable to find a suitable computing teacher, they can either find a non-specialist to teach the subject or decide not to offer it at GCSE.

46. Kemp P, Wong B, and Berry M. 2016. The Roehampton Annual Computing Education Report. p51.
47. Kantar Public. 2017. The Royal Society: Computing Education Strand 3 technical report. p15.

The impact of ethnicity

Our pathways analysis shows that Chinese pupils and pupils from other Asian backgrounds were significantly more likely than white pupils to study computing GCSE. Black pupils on the other hand were significantly less likely to take computing than white and Asian pupils.

Although Asian pupils were more likely to take computing at GCSE, our analysis showed that they were less likely than white pupils to continue with the subject at Key Stage 5. At A level, university degrees will influence subject choices and Table 9 shows that Asian pupils will tend to study subjects such as chemistry, biology and mathematics.

Table 10 further supports this, showing that in higher education, Asian pupils are more likely to study subjects such as medicine.

Maximising opportunities for pupils with SEND

It is important that computing in schools is as inclusive as possible. Pupils with special educational needs and disabilities (SEND) are disproportionately likely to miss out on educational opportunities[48].

In our meetings, concerns raised by teachers included the academic nature of computing, particularly the higher order computational thinking skills and sensitivity of syntax, potentially making much of the curriculum in secondary schools inaccessible for less able pupils and those with learning difficulties.

TABLE 9

A level subjects taken by major ethnic groups in England (base: Key Stage 5 pupils in year 12 and year 13 in 2014 – 2015).

	White	Mixed	Black	Asian	Chinese	Other
Mathematics	79,562 12.7%	5,077 15.1%	5,428 12.0%	18,224 21.7%	2,413 49.8%	2,153 19.6%
Biology	57,822 9.2%	3,752 11.1%	4,573 10.1%	15,049 17.9%	947 19.6%	1,648 15.0%
Chemistry	42,762 6.8%	3,112 9.2%	4,396 9.7%	14,716 17.5%	1,205 24.9%	1,608 14.6%
Physics	35,189 5.6%	2,036 6.0%	1,555 3.4%	5,138 6.1%	860 17.8%	671 6.1%
Computing	7,082 1.1%	357 1.1%	288 0.6%	869 1.0%	135 2.8%	99 0.9%
Totals	**626,639**	**33,693**	**45,260**	**84,102**	**4,842**	**11,010**

Source: Kantar Public.
Note: Percentages represent the proportion of the ethnic group undertaking the subject.

48. Tes. 2016. SEND pupils don't get enough support because of limited funding and training, school staff say. See www.tes.com/news/school-news/breaking-news/send-pupils-dont-get-enough-support-because-limited-funding-and (accessed 31 July 2017).

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Conventional styles of teaching or resources may not be suitable for SEND pupils as resource developers have focused on creating resources for mainstream education. Technology itself can be highly inaccessible and may become more so as more complex tools and interfaces are developed. For example, partially sighted pupils need screen readers to work with programming tools if they are to be able to learn to program. While traditional text-based languages work naturally with screen readers, tools such as Scratch Jr., which are popular as a primary programming language, use explicitly visual metaphors and, therefore, do not necessarily transfer.

Conclusion

Computing needs to reflect the diversity that is prevalent in society and become a valuable subject for female pupils and disadvantaged groups including pupils from low socio-economic backgrounds and ethnic minorities. Improving the gender balance should remain a priority and will help increase the number of young people with skills in computing. Schools need to ensure that the learning environment does not allow stereotypical perceptions to have a negative influence on pupils' subject choices. Ultimately, widening the pool of young people choosing to study computing will require a range of approaches. Computing teachers must address biases and provide opportunities for all pupils.

TABLE 10

Full-time HE student enrolments for selected subjects by ethnicity 2015/16.

Course involves...	White	Black	Asian	Other	Unknown ethnicity
Business and administrative studies	91,680 10.0%	15,280 17.9%	24,005 17.6%	8,310 11.5%	1,285 10.0%
Medicine / Dentistry	25,790 2.8%	1,275 1.5%	9,815 7.2%	2,675 3.7%	475 3.7%
Subjects allied to medicine	100,390 11.0%	14,855 17.4%	18,585 13.6%	5,990 8.3%	1,015 7.9%
Computer sciences	39,705 4.3%	4,195 4.9%	9,310 6.8%	2,890 4.0%	545 4.2%
Creative arts and design	104,030 11.4%	5,625 6.6%	5,335 3.9%	7,140 9.8%	940 7.3%
Totals	**915,030**	**85,275**	**136,585**	**65,410**	**9,755**

Source: HESA.
Note: Percentages represent the proportion of the ethnic group undertaking the subject.

Chapter three
The importance of confident, well-qualified computing teachers

Left
© sturti.

The importance of confident, well-qualified computing teachers

"The discipline is completely new to me. It's like a linguist having to teach a different language but with no resources or preparation time."

Head of ICT and Computer Science, Secondary School

Introduction

- The experience, confidence and qualifications of computing teachers varies significantly across the UK.
- Over the last 10 years, Scotland has seen a greater drop in the number of computer science teachers (25%) than the drop in the number of secondary school pupils (11%).
- England has not met its recruitment targets for computer science and this was the biggest shortfall of all the English Baccalaureate subjects.
- In England, existing teachers have been asked to teach the new computing curriculum, with minimal support.

Inspirational teaching begins with 'teachers who know and love their subject'[49]. For pupils to thrive, knowledgeable, highly skilled teachers need support from the school community. This includes more opportunities for training, dedicated time for CPD, and specialist expert advice to assist teachers with subject knowledge[50].

In our discussion groups and evidence gathering, we found that the overwhelming majority of the teachers are deeply committed to developing pupils' knowledge and understanding of computing. They welcome the opportunities opened up by the new computing curriculum, and they are determined to adopt it, and to acquire the necessary subject knowledge and pedagogy to succeed.

However, shifting from computing curricula dominated by information technology to new curricula with a stronger computer science focus is a difficult transition to make. Many teachers feel that computing was introduced with insufficient guidance and support for teachers[51]. They are working extremely hard, but they often have no background in computer science and feel under-supported.

In this chapter, we examine the profiles of current computing teachers and look at the challenges of recruiting and retaining teachers who have expertise that is in demand elsewhere in the economy.

49. Department of Business, Innovation & Skills. 2010. Science and mathematics secondary education for the 21st century. Report of the Science and Learning Expert Group. London: DBIS.
50. Pye Tait. 2017. After the Reboot: The State of Computing Education in UK Schools and Colleges. p12.
51. Pye Tait. 2017. After the Reboot: The State of Computing Education in UK Schools and Colleges. p14.

CHAPTER THREE

Teachers in the computing classroom

Computing is the newest curriculum subject in primary and secondary education – the current cohort of teachers have had little practical experience of teaching computing and are facing a series of challenges. Computing is a unique subject where in many cases pupils and teachers are learning together[52].

To understand how computing is being taught in the UK we surveyed 341 primary school teachers and 604 secondary school teachers with some responsibility for computing education over a two-month period[53,54].

Despite efforts to obtain an unbiased view, due to the self-selecting nature of a survey, a significant number of the responses were from teachers who hold a degree-level qualification in a STEM subject or ICT (62%). Respondents were also broken down into those that had undertaken computing-related CPD in 2015 – 2016 with Computing At School, which made up 17% of those respondents (see Box 7). Other data sources suggest that a lower proportion of computing teachers have a related qualification[55]. We therefore caution the reader that our survey data is unavoidably vulnerable to selection bias, and may represent an over-optimistic view of the true situation.

Our survey responses indicated that many teachers in England believe that the Government has changed the subject they teach, without providing them with sufficient support to teach it effectively (See Chapter 4).

Through our survey we found there is a diversity of computing teachers with varying levels of knowledge and experience. Due to this diversity, teachers require different levels of support, and governments, head teachers and resource providers must recognise this.

One group of teachers we identified are confident in teaching computing and are quite favourably inclined to the new English computing curriculum. These teachers typically hold qualifications in computer science at secondary school and generally have ample opportunities to undertake continuous professional development courses. These teachers are often driving the subject within their schools and providing support to other teachers who may not be as confident as them.

A second group of teachers are strong supporters of computing and want to see the subject thrive; however, they feel inadequately trained. These teachers can have varied CPD needs and may want the help of more experienced teachers to provide support.

However, the shift from ICT to computing has resulted in a large cohort of teachers that do not feel confident in teaching computing[56]. These teachers believe they need significant support to help them to be effective in their roles.

Headline teacher confidence at different stages of the curriculum

32%

of primary teachers feel more confident teaching the earlier stages of the curriculum than the latter.

44%

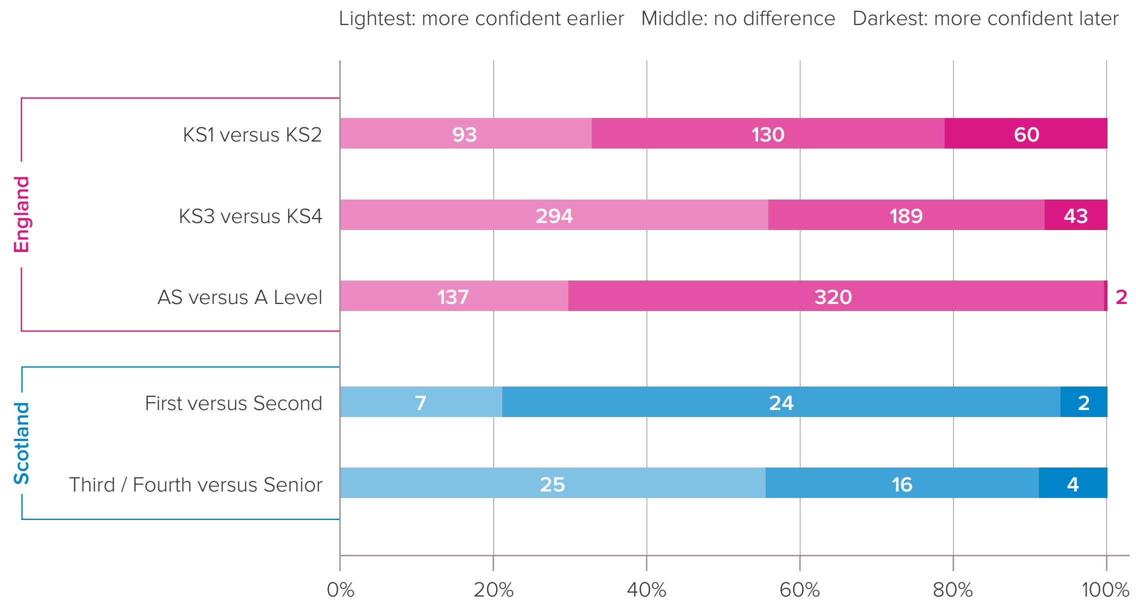
of secondary teachers feel more confident teaching the earlier stages of the curriculum than the latter.

Source: Pye Tait. 2017. *After the Reboot: The State of Computing Education in UK Schools and Colleges.*

52. Pye Tait. 2017. After the Reboot: The State of Computing Education in UK Schools and Colleges. p35.
53. Pye Tait. 2017. After the Reboot: The State of Computing Education in UK Schools and Colleges. p18.
54. There are approximately 21,000 primary schools and 6,000 secondary schools in the UK.
55. Department for Education. 2017. School workforce in England: November 2016. See https://www.gov.uk/government/statistics/school-workforce-in-england-november-2016 (accessed 22 September 2017).
56. Pye Tait. 2017. After the Reboot: The State of Computing Education in UK Schools and Colleges. p43.

FIGURE 7

Teacher confidence at different stages of the curriculum, presented as a series of contrasts.



Source: Pye Tait.

Teacher confidence

As part of the survey we asked teachers to rate their confidence at each stage of the curriculum on a 10-point scale, with 1 being the least confident and 10 being the most confident. 48% of the surveyed teachers gave a score below 7 and were asked to provide explanations for the low confidence scores. A common response from these teachers was that they were lacking sufficient theoretical and technical knowledge of computing that included aspects of programming and coding[57].

When comparing confidence ratings at different stages of the curriculum, perhaps unsurprisingly it is evident that teachers are more confident with the earlier stages than with the later stages where the subject can have a greater focus on computer science.

This was further demonstrated when we asked teachers for their confidence in delivering specific aspects of computing education. Many indicated that they were most confident with the elements of the curriculum that were inherited from the previous ICT courses, for example using technology safely, responsibly and securely, and creating digital content for a given audience[58].

57. Pye Tait. 2017. After the Reboot: The State of Computing Education in UK Schools and Colleges. p44.

58. Pye Tait. 2017. After the Reboot: The State of Computing Education in UK Schools and Colleges. pp34–35.

CHAPTER THREE

Pedagogies for computing are less developed than those for other subjects, as computing education research in the past has focused on higher education[59]. The lack of evidence-based advice on how to teach computing can fundamentally undermine teacher confidence. In Chapter 5, we discuss how research to develop improved computing pedagogies is essential to supporting effective teaching and the work and well-being of teachers.

There is an additional challenge in that teachers may perceive that their pupils are more confident with technology than they are[60]. Through our discussion groups, some teachers felt that many of today's pupils have grown up with technology embedded in their lives which creates the image of a tech-savvy generation. However, while prolific users of technology, this does not mean they understood that technology or the computer science behind it, or even that they could use it outside narrow boundaries.

Who teaches computing?

Specialist knowledge is vital to a subject such as computing. The teachers who completed our survey had a wide mix of educational backgrounds. In our sample, 36% of computing teachers in secondary schools were computer science graduates (see Figure 9). Our sample was self-selecting, so we also examined the DfE workforce dataset. The DfE workforce data shows that 30% of ICT teachers hold a relevant ICT degree or higher. It should be noted that the overlap between an ICT-related degree (for example business studies) and a computing degree may be quite limited, which means an ICT-related degree may not cover the relevant computer science aspects of the new computing curriculum necessary to teach it. This suggests that the sample responding to the survey had a different range of backgrounds to the wider population of computing teachers.

For comparison, in 2016, 51% of physics teachers and 46% of mathematics teachers held a relevant degree or higher[61]. In Scotland, computing teachers are required to hold a computer science degree or have studied a related subject at university.

Similarly, 7% of primary school respondents had a background in computing, which is larger than the proportion of primary teachers with specialist mathematics or science degrees (3% and 5%, respectively)[62]. At the primary level, the most common highest qualification teachers held was in education (41%), reflecting the generalist nature of the role[63] (see Figure 8). This also suggests there may be a slight bias in the sample of teachers towards those with stronger computing backgrounds.

59. Hubwieser P, Magenheim J, Mühling A, Ruf A. 2013. Towards a conceptualization of pedagogical content knowledge for computer science. In Proceedings of the ninth annual international ACM conference on International computing education research. pp1–8. ACM.

60. ComputerWeekly.com. 2017. Teachers unprepared for 2014 computing curriculum. See www.computerweekly.com/news/2240207786/Teachers-unprepared-for-2014-computing-curriculum (accessed 8 June 2017).

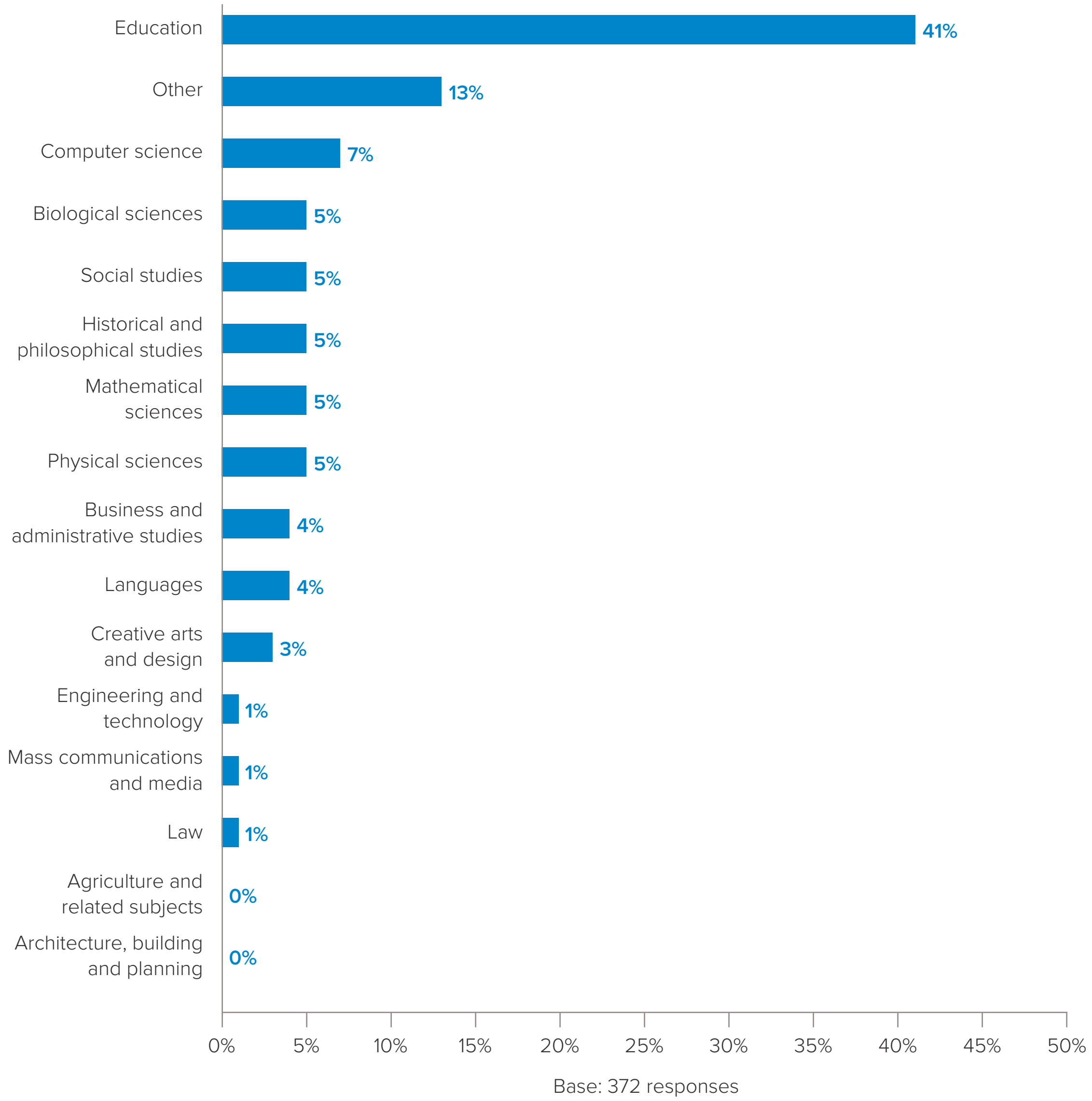
61. Department for Education. 2017. School workforce in England: November 2016. See www.gov.uk/government/statistics/school-workforce-in-england-november-2016 (accessed 8 September 2017).

62. The Royal Society. 2014. Vision for Science and Mathematics Education.

63. Pye Tait. 2017. After the Reboot: The State of Computing Education in UK Schools and Colleges. pp37–38.

FIGURE 8

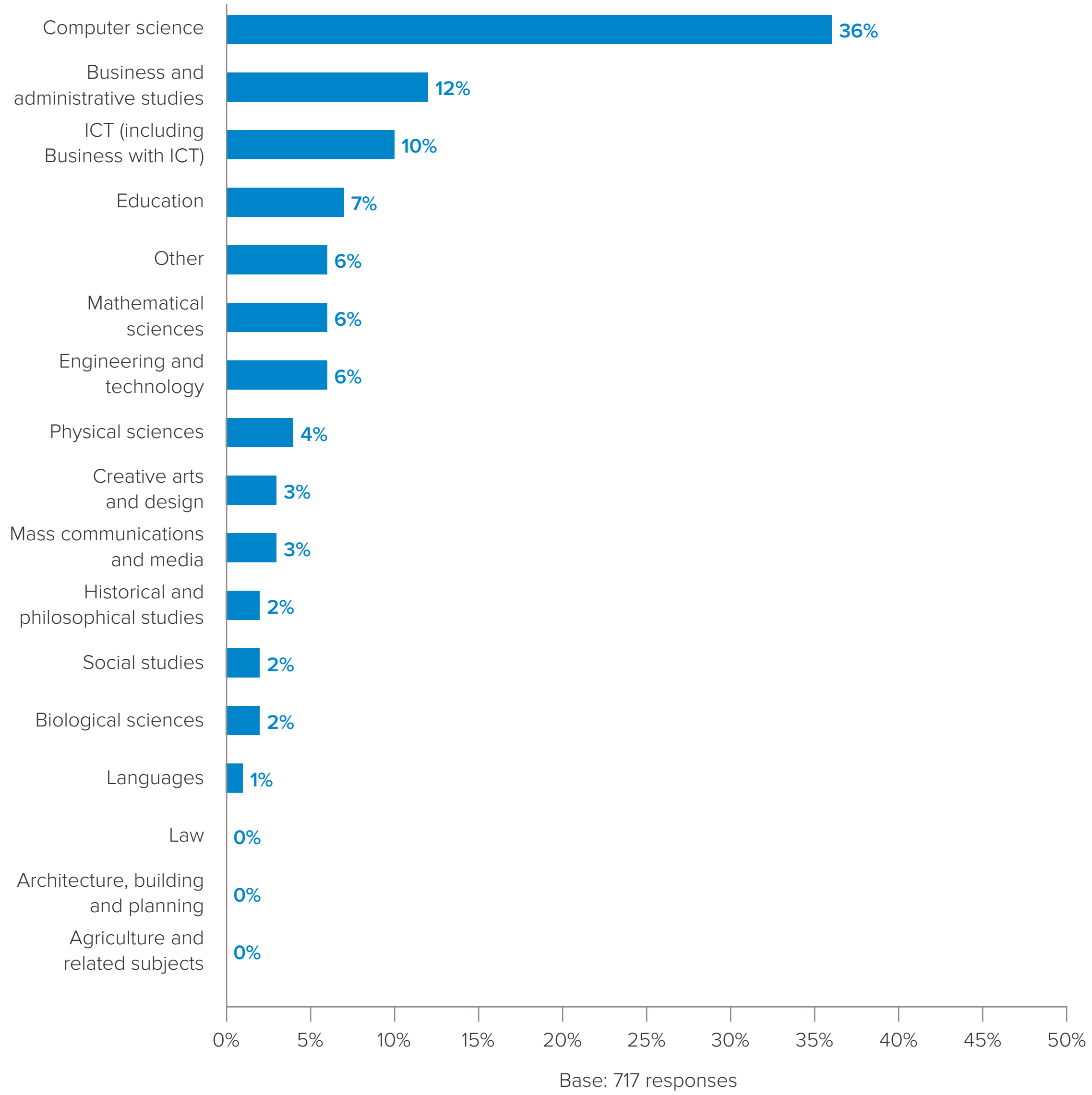
Share of highest qualifications by discipline – primary schools.



Source: Pye Tait.

FIGURE 9

Share of highest qualifications by discipline – secondary schools and colleges.



Source: Pye Tait.

What are the backgrounds of computing teachers?

The backgrounds of primary and secondary teachers in our sample tended to be different. A large number of secondary school computing teachers had industry experience, having previously worked in an IT role (42%), while a further 20% had worked in industry in a non-IT role. We found that 40% of primary school teachers had some form of industry experience[64].

CASE STUDY 5

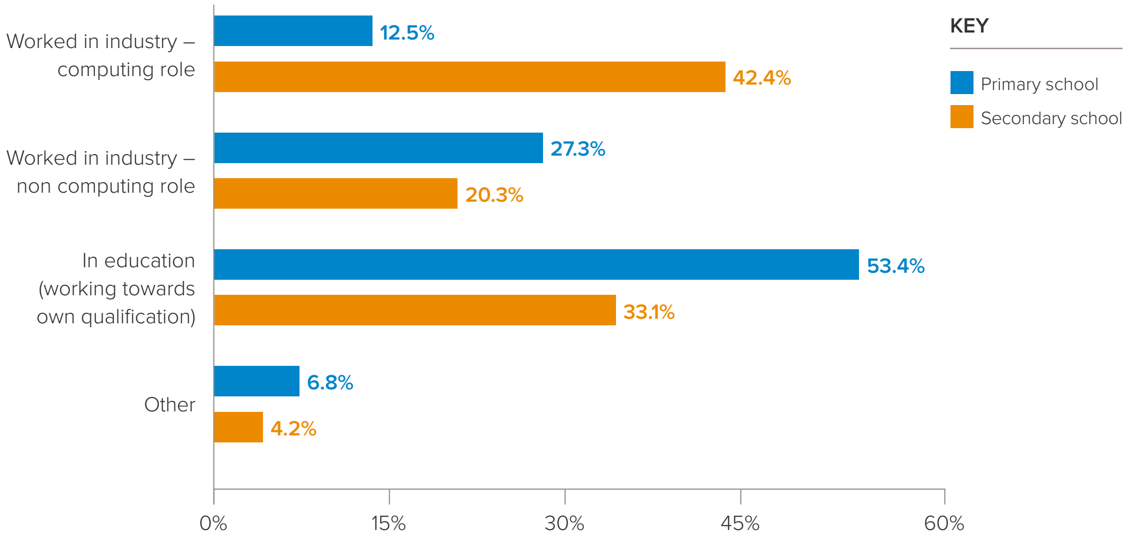
Swanwick School and Sports College

Matthew Parry, Head of Computing at Swanwick School and Sports College, Derbyshire, has an industry background in computer programming.

To make the most of Matthew's expertise, other members of staff at the school focus on teaching aspects of ICT, to free up Matthew's time to deliver the core elements of computer science. Matthew secured a £5,000 grant from the British Computer Society which funded the purchase of PicoBoards (interface for the Scratch programming language) and Lego Mindstorms kits. Other resources have been obtained from Computing At School[65].

FIGURE 10

Position prior to teaching.



Percentage of respondents

Base: Primary (88 respondents) and Secondary (118 respondents)

Source: Pye Tait.

64. Pye Tait. 2017. After the Reboot: The State of Computing Education in UK Schools and Colleges. p39.
65. Pye Tait. 2017. After the Reboot: The State of Computing Education in UK Schools and Colleges. Annex 1: Case Study Schools. p41.

Although computing may be the primary subject that a teacher is responsible for, computing teachers often have responsibilities in other subjects. Some surveyed teachers and discussion group participants felt there is a danger of an 'expectation' or 'inevitability' that computing will be taught by non-specialists[66]. In surveyed secondary schools, business studies (23%), mathematics (16%) and design and technology (12%) were the top three subjects outside of computing that computing teachers also taught.

Are we recruiting enough new computing teachers?

Finding skilled and enthusiastic computing teachers is a challenge that many schools face. When the Government introduced the computing curriculum, the initial teacher training community had to adapt quickly. Since 2013/14, universities have offered the new Postgraduate Certificate in Education (PGCE) in Computer Science, rather than ICT, and four cohorts of teachers have emerged from these universities. However, these numbers have not been reaching the targets required.

In England, the Government met only 68% of its recruitment target for new entrants to computing postgraduate and undergraduate initial teacher training courses from 2012 to 2017[67]. This was the biggest shortfall of all the English Baccalaureate (Ebacc) subjects[68].

In an analysis for this report conducted by TeachVac, 489 computing/IT teacher job advertisements in England were identified from the period 1 September 2016 to 21 March 2017. Of these jobs, 235 (48%) required an IT qualification that was a degree or higher.

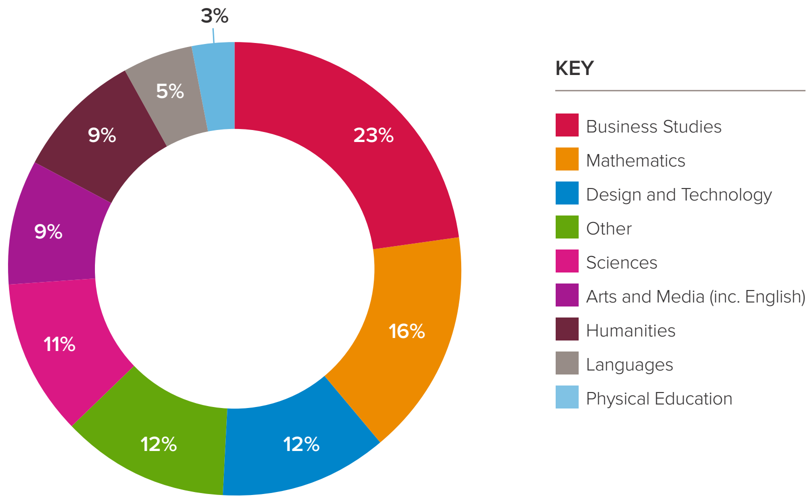
Scotland is also facing a similar problem with teacher recruitment. The number of computer science teachers has decreased from 802 in 2005 to 598 in 2015. This is a decrease of 25% over the last ten years, disproportionate to the 11% decrease in secondary school pupils over that same period. This has resulted in 17% of secondary schools having no computing subject-specialist[69].

Due to the technical nature of computing, prospective teachers must have a strong level of subject knowledge in advance so that their training can focus on pedagogy and curriculum knowledge. However, there are not enough candidates with this subject knowledge who want to become computing teachers. In England, pre-service subject knowledge enhancement courses are currently available to prospective teachers; however, there are some concerns regarding the quality of these courses leading to teachers with inconsistent knowledge. An accreditation mechanism is needed to ensure quality.

66. Pye Tait. 2017. After the Reboot: The State of Computing Education in UK Schools and Colleges. p77.
67. House of Commons Education Committee. 2017. Recruitment and retention of teachers: Fifth Report of Session 2016 – 17.
68. The English Baccalaureate (EBacc) is a school performance measure. It allows people to see how many pupils get a grade C or above in the core academic subjects at Key Stage 4 in any government-funded school. The EBacc is made up of: English, mathematics, history or geography, the sciences, and a language. Source: The Department for Education. 2017.
69. Computing At School Scotland. 2016. Computing Science Teachers in Scotland 2016.

FIGURE 11

Mix of other subjects taught by computing teachers – secondary schools and colleges.



Base: 811 responses.

Source: Pye Tait.

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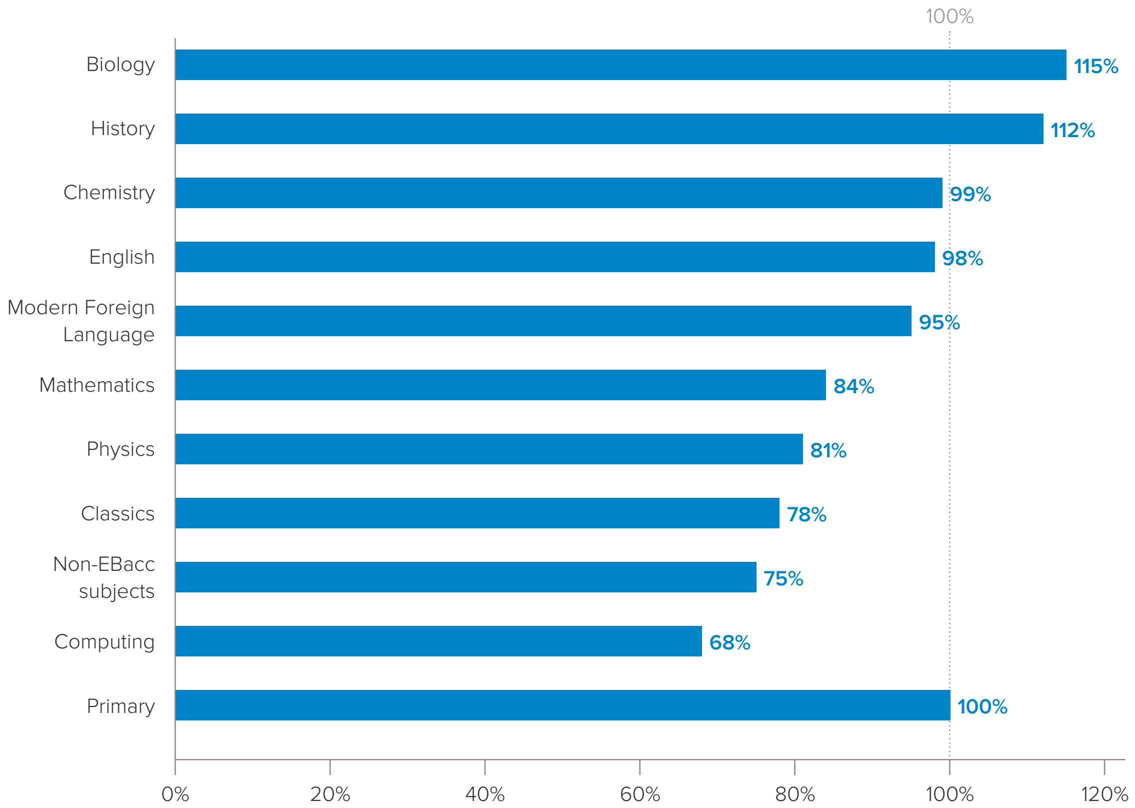
FIGURE 12

Percentage of recruitment against Teacher Supply Model* targets.

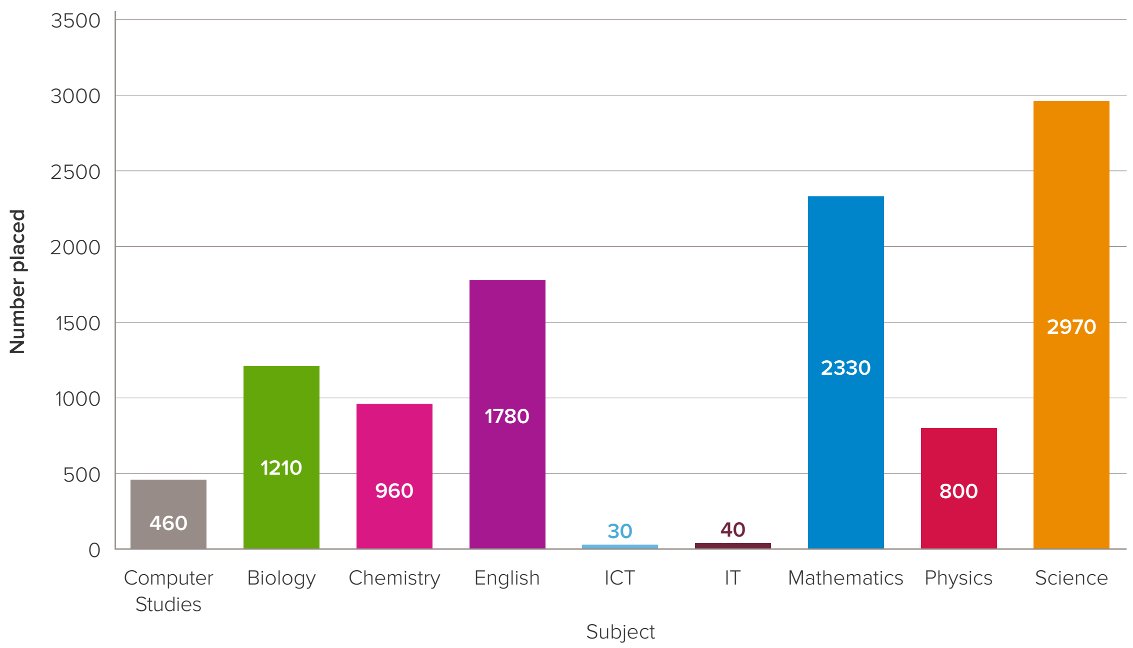


* The Teacher Supply Model is used to estimate the number of teachers needed in the system and therefore the recruitment targets for initial teacher training.

Source: House of Commons Education Committee.

FIGURE 13

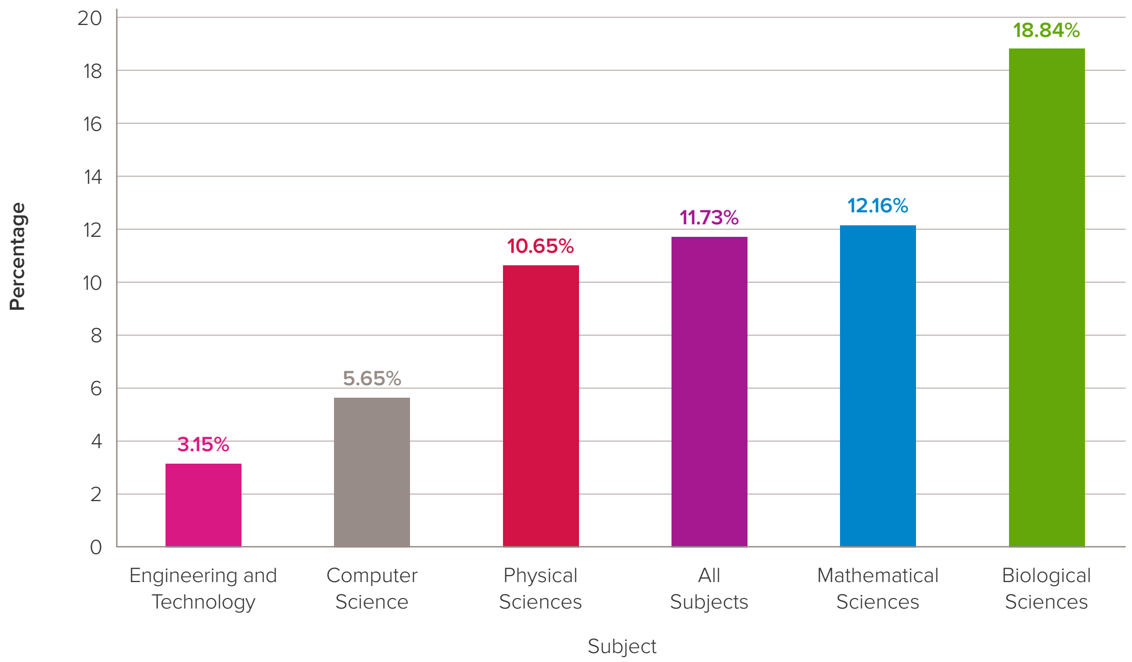
UCAS Teacher Training applications at End of Cycle 2016.



Note: Subject classifications are based upon the course title.
Source: UCAS.

FIGURE 14

Percentage of full-time first-degree leavers working in education post-graduation by subject area (2011/12 to 2015/16).



Source: HESA.

In-service conversion courses for computing are not available for primary or secondary teachers, but these could help increase the pool of computing teachers.

UCAS admissions data for teacher training applications in 2016 (see Figure 13) show that applications for computing (computer studies) courses are significantly lower than other subjects, including mathematics, English, chemistry, and biology[70].

In Scotland, the number of first-year students on computing initial teacher training courses has dropped by 80% over the last nine years[71]. As a result, this has impacted on training colleges, with a number of universities dropping their PGCE in computer science.

RECOMMENDATIONS

Governments should introduce quality-assured computing conversion courses for existing teachers, equivalent to those in physics and mathematics. Individual teachers or schools should not have to contribute to the costs of this training.

Governments should work with higher education providers and the British Computer Society to develop and accredit pre-service subject content courses to enable more people from a wider variety of backgrounds to become computing teachers. Existing initiatives to support and develop computing degree courses with qualified teaching status should be continued and, if successful, expanded.

0

Teacher Subject Specialism Training courses available for computing.

65

Teacher Subject Specialism Training courses available for physics.

93

Teacher Subject Specialism Training courses available for mathematics.

Source: Department for Education, Institute of Physics.

70. UCAS. 2016. UTT monthly statistics: Applications. Report B: UCAS Teacher Training applications at End of Cycle 2016. See www.ucas.com/corporate/data-and-analysis/ucas-teacher-training-releases (accessed 5 July 2017).

71. General Teaching Council for Scotland (GTCS). Freedom of information request response, dated 28 October 2016.

Some consequences of qualified teacher shortages

The shortage of qualified teachers has also made it difficult for initial teacher trainers to find suitable placements for their students where there are sufficiently trained and knowledgeable mentors in situ. Some schools in their area may not even offer GCSE and A level computer science, providing further challenges for initial teacher trainers in finding placements.

This shortage of qualified teachers limits the ability of schools to teach computing and tends to have a disproportionate effect on schools in disadvantaged areas. Some schools have been unable to offer computing qualifications as they cannot find a suitable computing teacher.

Why is it difficult to recruit and retain new computing teachers?

The skills needed to teach computing are widely sought after; this makes it necessary for schools to compete with other employers and with each other when they try to attract computing teachers.

Current incentives in England to recruit new teachers into computing with bursaries and scholarships, including the availability of a non-taxable scholarship award of up to £25,000, have had limited impact[72]. Due to the tax-free nature of the bursaries, when trainees transition from the bursary to a taxable salary when they secure a teaching role, they often see their real income fall; this has led to some completing training then returning to, or taking jobs in, industry. However, due to a shortage of computing teachers, newly qualified computing teachers face few issues finding employment and can get multiple job offers, which allows them the luxury of being selective.

Graduates who enrol on teacher training courses drop out for a variety of reasons. Some find that teaching is more challenging than they anticipated[73]. The pressures of initial training can put a strain on any trainee due to the heavy workload of planning, delivery and assessment. However this isn't isolated to just computing and is a problem experienced by those teaching other subjects. Teachers need support to reduce their workload once they start teaching to ensure that they stay in the profession for longer than just a year or two.

Figure 14 indicates that only 6% of computer science graduates have embarked on a career in education, compared with 11% for physics and 12% for mathematics. More initiatives need to be put in place to promote a teaching career to computer science students in higher education.

The impact of reduced teaching time for computing

A further challenge that teachers face is the reduction of teaching hours dedicated to computing. Our survey indicated that 30% of secondary schools had seen a decrease in total teaching time for computing education, while 22% saw an increase[74]. Schools that have reduced the time allocated to computing place additional stress on teachers who must still meet the requirements of the curriculum and qualifications.

A further effect of reduced teaching time is that teachers gain less hands-on experience of teaching the new subject. This will disproportionately affect teachers with lower confidence or those less familiar with computing. A reduction in teaching hours will also make on the job experience harder to gain for new teachers.

72. National College for Teaching and Leadership. 2017. Initial teacher training bursary guide Academic year 2015/16. See www.gov.uk/government/uploads/system/uploads/attachment_data/file/501510/Training_Bursary_Guide_AY_2015-2016.pdf (accessed 29 June 2017).
73. The Royal Society. 2017. Computing Initial Teacher Training round table note.
74. Pye Tait. 2017. After the Reboot: The State of Computing Education in UK Schools and Colleges. p57.

The roles and responsibilities of business and academia

The whole computing community has a role to play in recruiting and supporting teachers. There are not enough teachers with computing expertise, but there is a strong level of expertise in businesses and industry around the country. Teachers responding to our survey indicated that they would welcome more collaboration opportunities with subject specialists, industry experts and computer science graduates in order to improve their knowledge[75]. Schools and teachers need ready and easy access to the expertise in industry and academia. They need computing experts to give them advice about the curriculum. They need people willing to spend time in the classroom, supporting their teaching.

RECOMMENDATIONS

Higher education providers need to promote careers in computing education to a wide range of students.

Industry and academia should support and encourage braided careers[76] for staff who want to teach as well as work in another setting.

Conclusion

The shortage of computing teachers is extremely worrying and the recruitment of new teachers into the profession is not meeting demand. Governments need to do much more to address the shortages if pupils are to gain the computing skills required.

Despite the challenges computing teachers are facing, they have shown remarkable resilience and willingness to adopt computing as a subject. To bridge this gap from the old ICT curriculum, governments must commit significant investment to the existing teachers, so they can gain the knowledge and confidence they need to teach the subject effectively. Gaining knowledge will not happen overnight and there needs to be a recognition that teachers cannot learn the subject in a few days or even months.

75. Pye Tait (2017). After the Reboot: The State of Computing Education in UK Schools and Colleges. p.48.
76. A braided career describes someone who is working in two sectors simultaneously, for example working part-time in an academic position and part-time in an industry position.

Chapter four
Continued professional development, resources and the broader context

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Continued professional development, resources and the broader context

Introduction

- Continued professional development (CPD) needs to be sustained over time, and computing teachers cannot be expected to deliver a new subject with only a few hours of training.
- Since the introduction of the computing curriculum in 2014, there has been an abundance of resources available; however, some teachers have found this to be overwhelming.
- Opportunities are available beyond the classroom for pupils to enhance their experience of computing.

In computing, teachers are teaching a new subject in the school curriculum. Since the introduction of computing in England in 2014, and the curriculum changes for computing in Scotland, Wales and Northern Ireland, the volume, richness and diversity of resources and professional development opportunities for teachers have grown.

Good teaching resources are essential to help teachers deliver a comprehensive computing education to their pupils. These resources include educational programmes, online media, support networks and lesson plans. These resources can help to enhance the learning experience for students while allowing teachers to improve their subject knowledge.

Passionate groups and individuals with the intention of improving the subject and raising its profile have championed many of these resources. This chapter explores the resources and professional development support available to teachers, with a view to identifying priorities for further action.

Teachers need high-quality CPD

Computing as a school subject is new and continues to evolve. Teachers across the UK urgently need to have access to, and to take part in, CPD. As described in Chapter 3, these teachers may need to gain expertise in the subject knowledge included in the computing curriculum and in the pedagogical approaches to teaching this curriculum.

The Department for Education's standard for professional development recognises that effective teaching requires both considerable knowledge and skill that develop as teachers' careers progress[77]. The standard also identifies that effective teacher professional development is dependent on strong partnerships between head teachers, teachers and providers of professional development expertise. To ensure these partnerships are effective, there are five supporting aims:

1. Professional development should have a focus on improving and evaluating pupil outcomes;
2. Professional development should be underpinned by robust evidence and expertise;

77. Department for Education. 2016. Standard for teachers' professional development.

3. Professional development should include collaboration and expert challenge;
4. Professional development programmes should be sustained over time; and
5. Professional development must be prioritised by school leadership.

Points 1 to 4 are underpinned by, and require, point 5.

If schools and the Government apply these standards to professional development for computing they should help to maximise the impact of their investment in computing teachers.

To understand the range of professional development provision in computing, we asked survey respondents what types of activity they had participated in. Teacher network meetings were the most popular form of CPD undertaken with both primary and secondary teachers, closely followed by external training courses (see Figure 15). The difference in uptake between primary and secondary teachers with respect to Massive Open Online Courses (MOOCs) was larger than any other form of CPD.

From our survey there are three noticeable gaps in professional development provision for computing teachers: mentoring, action research, and self-study:

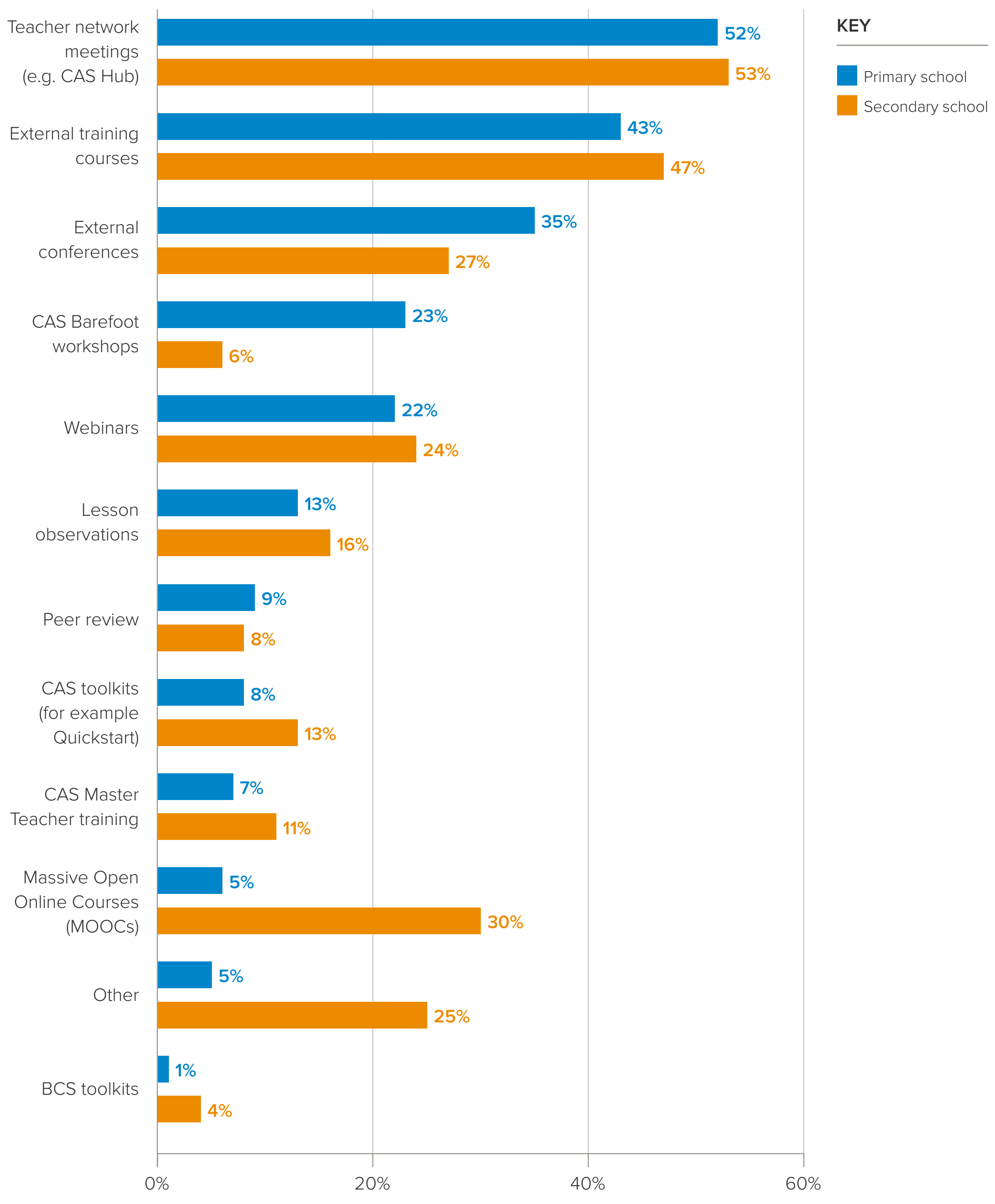
- **Mentoring** can play an important role in a teacher's professional development and provides teachers with opportunities to learn from experts who can provide guidance and support when required.
- **Action research** empowers teachers to investigate changes in teaching and learning and measure the impact of those changes, rather than having them dictated to them during an inset day formal delivery session. It enables teachers to gain confidence in decision-making, based upon the needs of their pupils and schools[78].
- **Self-study** provides teachers with time to read around the subject, improve pedagogical knowledge, further their understanding of concepts such as abstraction, logic and algorithms, and to practise their programming skills[79]. Helping teachers identify proven reading materials and the best places for programming support is crucial to any teacher's professional development.

78. Burbank M. 2003. An Alternative Model for Professional Development: Investigations into effective collaboration. Teaching and Teacher education. 19, pp499–514.

79. Pye Tait. 2017. After the Reboot: The State of Computing Education in UK Schools and Colleges. p48.

FIGURE 15

Types of CPD activity.



Base: Primary (221 respondents) and Secondary (420 respondents)

Source: Pye Tait.

Professional development aimed at improving pupil outcomes and underpinned by robust evidence

There is relatively little evidence about what works in computing education at school level (see Chapter 5). Due to a lack of evaluation, there is even less evidence about the impact of professional development programmes in computing, and we have summarised evidence about individual projects below. Government and industry-funded interventions in computing education should contribute to the evidence base, with results feeding into CPD provision.

As evidenced through our survey, Computing At School (CAS) and its Network of Excellence (see Box 7) has proven to be a popular channel for providing teacher support, especially through the abundance of teacher-created resources available online[80].

Development activities delivered by the Network of Excellence have focused on improving and evaluating pupil outcomes. The Network surveys teachers taking part in its activities on the first day of training and ten weeks later, to understand if intended learning outcomes have been achieved. Building the CAS Network of Excellence hubs through universities enables its CPD courses to incorporate best practice backed by robust evidence where available.

BOX 7

Computing At School and the Network of Excellence

Computing At School (CAS) is the subject association for computer science and part of the British Computer Society (BCS). CAS develops and articulates a vision for the subject of computing at the national level. CAS is also a grassroots community of professional practice, which brings teachers together as professionals who help one another develop and share good practice. In England, through DfE core funding, CAS runs the Network of Excellence (NoE) in computing, which is recognised by the Government as a key part of their digital skills strategy[81].

Using universities as regional centres, the NoE works with schools and teachers in the local area to promote and support relevant teacher engagement and CPD activities[82]. The Network has certified over 470 Master Teachers as subject experts, to deliver this support in collaboration with the universities[83].

80. Pye Tait. 2017. After the Reboot: The State of Computing Education in UK Schools and Colleges. p65.

81. Department for Digital, Culture Media & Sport. 2017. Digital skills and inclusion – giving everyone access to the digital skills they need. See www.gov.uk/government/publications/uk-digital-strategy/2-digital-skills-and-inclusion-giving-everyone-access-to-the-digital-skills-they-need (accessed 19 April 2017).

82. CAS Regional Centres. 2017. Computingatschool.org.uk. See www.computingatschool.org.uk/crcs (accessed 29 June 2017).

83. Master Teachers. 2017. Computingatschool.org.uk. See http://community.computingatschool.org.uk/master_teachers (accessed 12 September 2017).

CHAPTER FOUR

Collaboration and expert challenge

Collaborative learning can help teachers to continually develop and build knowledge about their subject[84,85]. Collaborative learning groups involve teachers working together, reviewing and working on their subject, reflecting on their practice between lessons and the learning that took place[86]. Collaboration also helps those who might feel isolated in their roles to know that they are part of a community. Collaborative learning groups need support from experts. This expertise may be internal or external, but will typically involve higher education institutions, professional learning providers, industry, and other schools and colleges[87].

The Network of Excellence regional centres aim to develop strong relationships with schools. In addition, they seek to facilitate the building of strong relationships between schools and higher education providers, while also providing opportunities for formal training.

CAS Master Teachers are expert teachers who volunteer to support others as part of the Network of Excellence. They receive sustained training to become experts in computing education through up to 120 hours of guided learning within the first year, depending on their subject knowledge needs. In their second year, they receive mentoring and coaching opportunities. There are over 470 current Master Teachers, but they cannot be expected to support all of the 4,000 secondary schools and 21,000 primary schools in England. For the Network to support all the teachers required to teach the new subject of computing, it would need to recruit many more Master Teachers. Governments in the devolved nations also need to support CAS and grow the Network across the UK.

In the current model, Master Teachers require significant support from their school leadership. Unlike similar models for physics and mathematics, schools do not receive additional funding to release Master Teachers for their training, or to support other teachers.

BOX 8

PLAN C

Launched in 2013, PLAN C (Professional Learning and Networking in Computing) was developed in collaboration with the British Computer Society and Computing At School Scotland with a focus on providing continuous professional development for computing teachers throughout Scotland[88].

PLAN C provides a free set of sustained professional learning opportunities while also enabling teachers to have more collaborative methods of teaching through local hubs. Rather than training teachers in specific technologies, PLAN C aims to develop computational thinking skills and pedagogical knowledge. The hubs also allow teachers to share learnings and teaching materials in a collaborative environment[89].

84. Advisory Committee on Mathematics Education. 2016. Professional Learning for all teachers of mathematics. p10.
85. Wenger E. 2000. Communities of practice and social learning systems. Organisation. 7(2). pp225–24.
86. In the academic literature these are often referred to as professional learning communities. See Vescio, Ross and Adams 2008. A review of research on the impact of professional learning communities on teaching practice and student learning. Teaching and Teacher Education 24(1).
87. Advisory Committee on Mathematics Education. 2016. Professional Learning for all teachers of mathematics.
88. Cutts Q, Robertson J, Donaldson P. and O'Donnell L. 2017. An evaluation of a professional learning network for computer science teachers. Computer Science Education, 27(1).
89. About PLAN C. 2017. Computing At School Scotland. See www.cas.scot/plan-c/ (accessed 12 September 2017).

In our Birmingham teacher meeting, a teacher spoke of his interest in becoming a Master Teacher. Unfortunately, he was unable to take on the role, as his head teacher was unable to release him to provide support to local teachers. Without support from senior leadership teams, it would prove too difficult for others in similar situations to become Master Teachers.

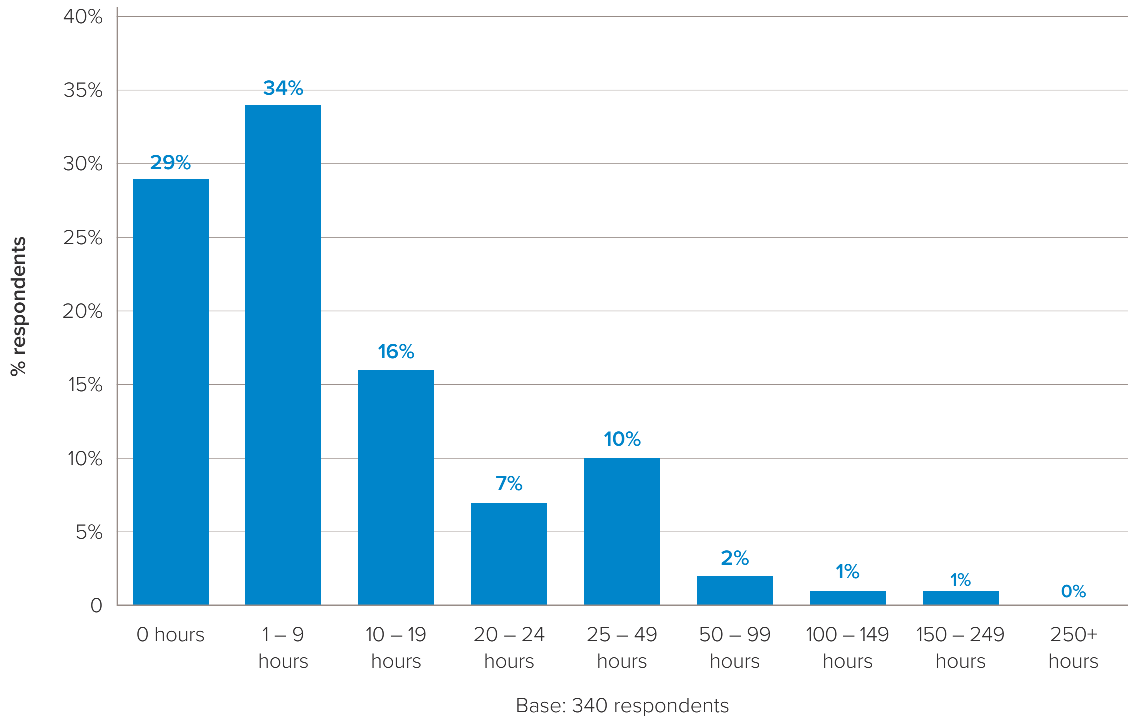
Sustained professional development

Teachers need to gain a background in all three aspects of computing, and attending a one-day course simply cannot achieve this. We have found it hard to assess the extent to which computing teachers are taking part in sustained professional development. Through the university-led regional centres, Master Teachers run ongoing professional development courses for local schools at least once a term. However, these courses are not centrally structured, and because the Master Teachers are volunteers, the focus of the courses varies across the country. The Network of Excellence and other professional development providers could use our survey results to prioritise topics for future programmes.

Our survey results point to wide variations in the amount of computing-related CPD undertaken in 2015/2016. In primary schools, 29% indicated having undertaken zero hours of CPD during this period, and over 60% had less than nine hours. In secondary schools 26% of the respondents indicated that they have undertaken zero hours of CPD, and over 40% had less than nine hours (see Figure 17).

FIGURE 16

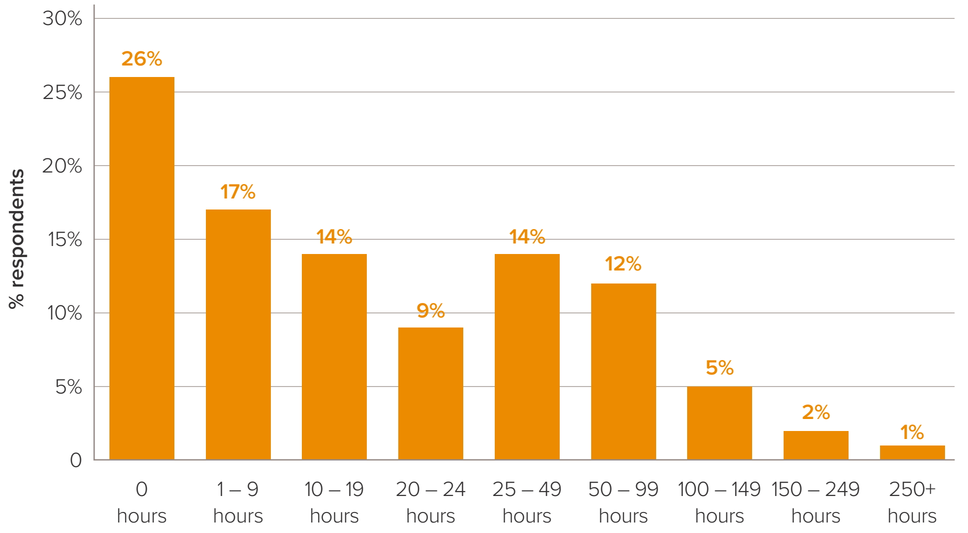
CPD banded hours in 2015/16 – primary schools.



Source: Pye Tait.

FIGURE 17

CPD banded hours in 2015/16 – secondary schools.

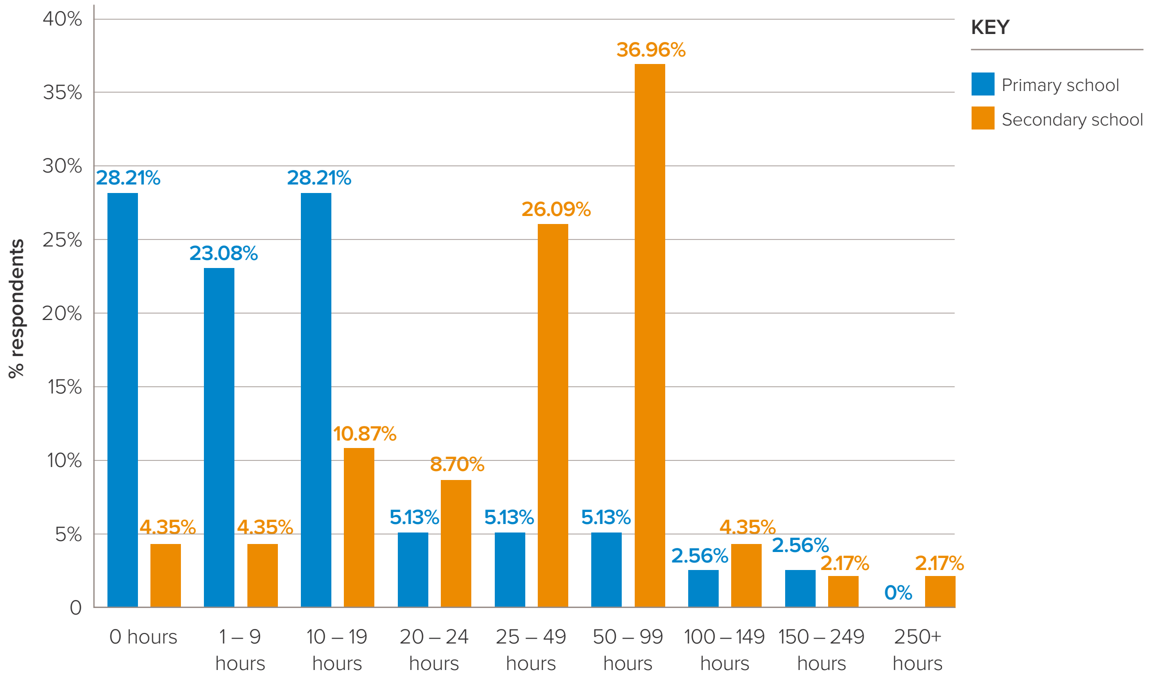


Base: 599 respondents

Source: Pye Tait.

FIGURE 18

Computing-related CPD banded hours in 2015/16 – Scotland.



Base: Primary (39 respondents) and Secondary (46 respondents)

Source: Pye Tait.

The high proportion of teachers who undertake little or no computing-related CPD is very concerning, especially for a subject recently introduced into the curriculum. Scottish teachers are required to undertake 35 hours a year of CPD, though this does not have to be subject related.

Teachers based away from city hubs can feel isolated, making it harder for them to attend CPD courses and networking meetings where they could connect with other teachers. Similarly, teachers with caring responsibilities, disabilities or other commitments may not be able to realise the full potential of the support that is on offer to them. MOOCs are proving popular, with 30% of our surveyed secondary school teachers accessing them, but they do not necessarily enable collaboration. Isolated teachers require other ways of connecting to support networks.

The Further Mathematics Support Programme (FMSP) is an example of another subject which does provide support to pupils and teachers in isolated areas. FMSP Area Coordinators cover the whole of England to provide training and support to other teachers while also arranging further mathematics tuition for students without access to the subject[90]. The Government could consider a similar model for computing.

Investing in a national infrastructure for computing CPD

The Network of Excellence for computing teachers has proved itself effective, despite operating within the constraints of its limited budget. For example, secondary schools reached by the Network generally have larger student cohorts taking computer science at GCSE, and they achieve higher grades than schools not reached by the Network[91]. To truly transform computing education over the next five years, a significantly scaled-up training network is required and this should build on the existing infrastructure.

Within the existing funding constraints, the current model of professional development does not have adequate regional coverage and is largely reliant on volunteer support. Schools and teachers are not funded to take part in the training programme, CAS Master Teacher support is voluntary and entirely unfunded, and this has limited the possibility of participation in the Network. The Network currently is not funded to evaluate its impact on student outcomes, making it difficult to improve the support it provides since current evaluation is reliant on publicly available school-level GCSE data. As the programme expands, it will need to maintain strong links with universities, while maintaining the ethos of a community of practice, and seek funding for an independent evaluation of the impact of this network on pupil outcomes.

At Western Primary School in Harrogate, North Yorkshire, head teacher Cheryl Smith supports her computing teachers in undertaking CPD as and when required, to maintain and build their computing expertise.

"CPD training is vital. First and foremost it's about boosting the confidence and ability of the computing teachers."

Suzanne Brooke – Year 5/6 Teacher[92]

90. Furthermaths.org.uk. 2017. The Further Mathematics Support Programme. See www.furthermaths.org.uk/ (accessed 29 June 2017).

91. British Computer Society. 2017. Evaluating the impact of the Network of Teaching Excellence in Computer Science. See https://community.computingatschool.org.uk/files/8772/original.pdf (accessed 19 September 2017).

92. Pye Tait. 2017. After the Reboot: The State of Computing Education in UK Schools and Colleges. Annex 1: Case Study Schools. p21.

The existing budget of £1.2 million a year allocated by DfE to upskill existing primary and secondary teachers will not cover the costs of training over 8,000 secondary teachers that need significant upskilling in order to successfully deliver GCSE computer science. Based on the figures for comparable programmes in mathematics[93], funds of £60 million over five years are needed to train that many secondary computing teachers.

RECOMMENDATION

Governments and industry need to play an active role in improving continuing professional development (CPD) for computing teachers, such as exemplified by the Network of Excellence. Investment in a national network needs at least a tenfold increase to expand the reach, and to have rigorous evaluation measures in place to strengthen the offer of such networks. Importantly, financial support should be made available to schools to release staff to attend professional development opportunities.

Prioritisation by school leadership

The amount of investment a school makes in CPD indicates the priority placed on professional development by its school leaders. When asked about school investment changes between 2013/14 and 2015/16, 30% of respondents in secondary schools indicated that there had been a decrease in investment in CPD, and 37% experienced a decrease in time allocated for CPD.

Schools with shortages of expert computing teachers cannot easily provide for teachers undertaking CPD during school hours, so it is not surprising that the results indicated that teachers are undertaking CPD in their own time. The average time spent on computing-related CPD in personal time was 22 hours for secondary school teachers and six hours for primary during 2015/16[94]. It is not acceptable for teachers of a brand new subject to have to fund their own professional development courses or to have to do substantial professional development in their own time.

Helping teachers deliver the curriculum

With the introduction of computing in England in 2014, the number of organisations providing resources to help teach and assess the curriculum has grown rapidly (see Boxes 9 – 14 for examples). Many teachers have also adapted existing resources, or created their own (for example Case studies 6 and 7). Sustaining the enthusiasm of these organisations and teachers will support the development of the subject.

93. The DfE-funded Maths Mastery Programme will retrain 8,000 primary teachers by 2020 to teach the new mathematics curriculum, at a cost of £40 million over four years. The DfE is currently tendering for a new Level 3 mathematics support programme that will train post-16 teachers to teach new core mathematics and A level curriculum. The budget allocated by DfE for this programme is currently £16 million over two years.

94. Pye Tait. 2017. After the Reboot: The State of Computing Education in UK Schools and Colleges. p54.

Finding and choosing classroom resources

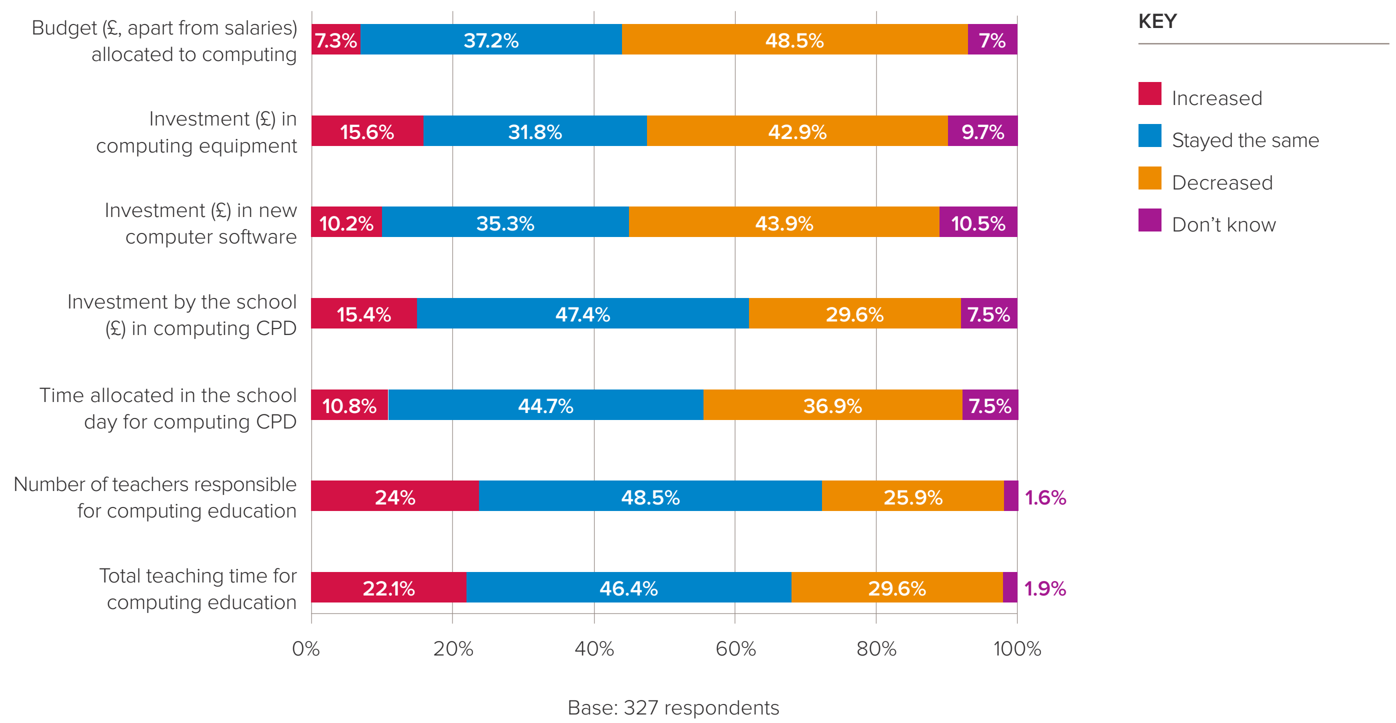
Despite the best of intentions, teachers can find the landscape of computing resources hard to navigate. A common refrain in the responses from teachers was that they felt overwhelmed by the abundance of resources and were often unsure of their suitability[95]. It is important that resource developers and others provide teachers with evidence of the impact of teaching resources to enable them to select the best quality resources available.

New assessment tools

Automated tools are now available to help teachers understand pupil progression. For example, teachers can use Dr. Scratch to save time and mark pupils' work. This tool allows users to upload Scratch projects and it will provide feedback for users to improve their coding skills. Other online quiz tools such as Kahoot and Socrative enable teachers to run class quizzes to informally test pupil understanding and progression.

FIGURE 19

Investment change between 2013/14 and 2015/16 – secondary schools and colleges.



Source: Pye Tait.

95. Pye Tait. 2017. After the Reboot: The State of Computing Education in UK Schools and Colleges. p65.

Equity of access

Poor access to resources inside and outside the classroom and a lower probability of access to specialist teachers can have a negative impact, disproportionately so, on the outcomes of pupils from disadvantaged backgrounds.

Regarding resourcing, a focus on equity is essential. Products such as the BBC micro:bit (see Box 13) and the Raspberry Pi (see Box 14) have provided a low-cost alternative on the market. For under £30 these products have enabled pupils to have access to computing equipment (although a monitor, keyboard and mouse are also required), and may go some way to addressing imbalances.

RECOMMENDATION

Industry and non-profit organisations need to work with and through the British Computer Society and STEM Learning to provide a coherent offer of teaching support to teachers and schools.

BOX 9

Barefoot Computing

The Barefoot Computing project[96] was originally funded by the DfE for English primary schools in 2014, before being adopted by BT, and is now available free of charge to primary schools in all UK regions.

The project provides computer science teaching resources for primary teachers with no prior expertise, which are designed to be cross-curricular, and most of the resources are unplugged to be as accessible as possible. The project also provides free workshops for schools to showcase the resources, which are delivered by volunteer IT professionals.

To date over 40,000 primary teachers across the UK have benefited from the project. According to an independent Ipsos MORI survey[97] of 400 primary schoolteachers, 96% of teachers felt their pupils' learning in numeracy improved as a result of Barefoot resources, and 69% of teachers felt their pupils' learning in literacy improved.

BOX 10

Tes: Times Educational Supplement

The Tes website provides an extensive online catalogue that enables teachers to upload and download shared resources. Further demonstrating the goodwill of the community, many of these resources are created by teachers themselves. With approximately 13,000 resources tagged as 'computing', there is an abundance of lesson plans and guides available. Tes provided a list of their most popular resources and this included:

- Computing Planning for 2014 National Curriculum
- 6-Week Key Stage 2 Scratch Primary Scheme of Work
- Primary ICT Curriculum / Scheme of Work

Compared to other subjects, computing ranked 25th out of 75 subjects in terms of resources available. The top subjects are English, mathematics and history.

96. Barefoot Computing. 2017. Computing At School. See www.barefootcas.org.uk (accessed 12 September 2017).

97. BT and Ipsos MORI. 2016. Tech Literacy: A new Cornerstone of Modern Primary School Education.

CASE STUDY 6

Kings Priory

At Kings Priory in Tynemouth, computing teachers Jeanette, Laura and Nik create the majority of teaching resources themselves, which are tailored to the abilities of students. Some online resources have been found to be better than others, so these are sometimes adapted[98].

CASE STUDY 7

Bengeworth CE Academy

Bengeworth CE Academy, Worcester uses a curriculum and assessment framework called Epiphany (designed by Natalie Snowdon, Year 2 teacher) which is shared by a cluster of schools across the area. This breaks down curriculum content by year group, and provides teachers with information on the types of resources to use and where they can find them, as well as progression and cross-curricula learning opportunities. Greg Satterley (Year 4 teacher) has plans to develop and expand on this framework for computing, which will also help teachers to identify areas where they feel less confident[99].

TABLE 11

Top 10 supporting organisations as indicated by surveyed teachers.

Primary		Secondary	
Barefoot	17.7%	Computing At School	36.5%
Computing At School (CAS)	15.3%	OCR	5.2%
Scratch	11.4%	TES	5.2%
Rising Stars	6.5%	Teach ICT	4.1%
Purple Mash	5.3%	PG Online	3.4%
Code.org	2.9%	Facebook Groups	3.3%
Espresso	2.9%	BBC (Micro:bit / Bitesize)	3.1%
Code Club	2.7%	Zig Zag	2.1%
Switched On Computing	2.7%	Code Academy	1.8%
Hour of Code	2.4%	Raspberry Pi	1.7%

Source: Pye Tait.

98. Pye Tait. 2017. After the Reboot: The State of Computing Education in UK Schools and Colleges. Annex 1: Case Study Schools. p37.

99. Pye Tait. 2017. After the Reboot: The State of Computing Education in UK Schools and Colleges. Annex 1: Case Study Schools. p15.

Extracurricular computing

Pupils' experience of computing in schools is not restricted to the classroom. Schools often further their pupils' interest in the subject by attending computing-related events or offering extracurricular computing clubs held at lunch breaks or after school. Participation in extracurricular activities has the added benefit of influencing young people's decisions[102] on subject choices.

From our surveyed schools, 62% of primary schools and 77% of secondary schools offered extracurricular computing activities. The most popular weekly activities are computing clubs offered by 80% and 71% respectively of those primary and secondary schools that had indicated they offered extracurricular activities.

Table 12 and Table 13 contain a breakdown of these activities.

Annually, for those primary schools that offered extracurricular activities, industry visits proved popular, undertaken by 95%, while guest speakers attended 86% of those schools. For secondary schools that offered extracurricular activities, 74% of these schools undertook annual industry visits, with 58% having guest speakers. This demonstrates that schools value industry involvement in the classroom and more organisations should make themselves available for schools.

CASE STUDY 8

Bengeworth CE Academy

Stefan Delorenzo runs an after-school computing club at Bengeworth CE Academy located in Worcester. In this club, pupils learn and practise Pyonkee, a Scratch-based iPad app, as well as Tynker, a complete learning system that teaches children how to code. This includes experimenting with visual blocks and text-based coding which can help in designing games and other projects[103].

BOX 11

Project Quantum

Project Quantum is currently underway in the UK and is developing a crowdsourced question bank for computing assessment in schools. The platform enables teachers to generate quizzes using the stored questions and check pupils' understanding. The question bank will be used by researchers to improve teaching and learning in the curriculum[100].

100. Oates T, Coe R, Peyton Jones S, Scratcherd T. and Woodhead S. 2017. Quantum: tests worth teaching to. See http://community.computingatschool.org.uk/files/7256/original.pdf (accessed 25 April 2017).

101. BBC. 2017. The BBC micro:bit. See www.bbc.co.uk/programmes/articles/4hVG2Br1W1LKCmw8nSm9WnQ/the-bbc-micro-bit (accessed 4 August 2017).

BOX 12

The Duke of York Inspiring Digital Enterprise Award

The Duke of York Inspiring Digital Enterprise Award (iDEA) is an innovative Badge Store concept that helps people develop skills for free. 'Badges' can be online or real world experiences which unlock points towards the Bronze, Silver or Gold Award.

iDEA is the digital and enterprise equivalent of The Duke of Edinburgh Award. The programme is completely free and accessible on any device.

People can gain iDEA badges with their friends, on their own, or in facilitated environments. Badges have been mapped against the National Curriculum and the Skills Framework for the Information Age. This helps support teachers across a range of curriculum subjects including the three core areas of formal computing education: digital literacy, computer science and IT. They include badges, which are useful for teachers to be able to demonstrate to Ofsted that schools are meeting safeguarding requirements. All the key resources are available on Tes.

BOX 13

BBC micro:bit

The BBC micro:bit is a small pocket-sized programmable device that has a huge range of capabilities for its size and cost. It has a 5x5 grid of individually programmable LEDs, connecting input and output pins and a range of onboard sensors including an accelerometer and compass. It can send and receive data and programs via USB or Bluetooth.

As part of the BBC's Make it Digital initiative, in 2016 every child in year 7 across the UK was given a device through their school. Following the BBC distribution, the not for profit Micro:bit Educational Foundation was created to make the BBC micro:bit and its supporting resources available for purchase to all, not just in the UK but around the globe.

The micro:bit aims to inspire young people to begin coding and become creative with digital technology. Using the software on microbit.org, users can easily program each element of the device. It also connects easily to other devices such as mobile phones and Raspberry Pis[101].

102. Department of Education & Professional Studies, Kings College London. 2013. ASPIRES: Young people's science and career aspirations age 10–14. p13. See www.kcl.ac.uk/sspp/departments/education/research/ASPIRES/ASPIRES-final-report-December-2013.pdf (accessed 17 July 2017).

103. Pye Tait. 2017. After the Reboot: The State of Computing Education in UK Schools and Colleges. Annex 1: Case Study Schools. p16.

TABLE 12

Frequency of extracurricular computing activities – primary schools.

Activity type (and Base respondents)	Daily/ twice weekly	Weekly	Twice monthly	Monthly	Every 2 – 3 months	Every 4 – 6 months	Annually
Computing clubs / code clubs (93)	10%	80%	–	2%	4%	2%	2%
Visits to other computing-related events (40)	–	–	–	–	5%	18%	78%
Cross-curricular projects (33)	–	6%	–	9%	18%	15%	52%
Guest talks in school (28)	–	–	–	–	4%	11%	86%
Entrants to computational thinking challenges (23)	–	4%	–	9%	–	4%	83%
Visits to industry (20)	–	–	–	–	–	5%	95%
Whole school 'super learning days' (20)	–	–	–	–	15%	5%	80%
University Ambassador Schemes (11)	9%	9%	–	9%	9%	9%	55%

Source: Pye Tait.

TABLE 13

Frequency of extracurricular computing activities – secondary schools / colleges.

Activity type (and Base respondents)	Daily/ twice weekly	Weekly	Twice monthly	Monthly	Every 2 – 3 months	Every 4 – 6 months	Annually
Computing clubs / code clubs (93)	22%	71%	3%	1%	2%	1%	1%
Visits to other computing-related events / exhibitions (40)	–	–	–	–	14%	15%	72%
Entrants to computational thinking challenges (120)	1%	1%	1%	2%	5%	17%	74%
Visits to industry (120)	–	–	–	3%	8%	15%	74%
Guest talks in school (119)	–	–	2%	2%	8%	30%	58%
Cross-curricular projects (96)	1%	13%	2%	4%	15%	15%	51%
University Ambassador Schemes (64)	–	2%	–	–	13%	17%	69%
Whole school 'super learning days' (55)	–	–	–	–	6%	6%	89%

Source: Pye Tait.

CHAPTER FOUR

BOX 14

Extracurricular computing initiatives

The Raspberry Pi Foundation
The Raspberry Pi Foundation is a UK-based charity that aims to advance computing education through the Raspberry Pi, a credit-card-sized, low-cost computer that allows pupils to learn how to program.

Complementing the Raspberry Pi is an abundance of educational resources for pupils and teachers, which includes lesson plans that provide cross-curricular learning with other subjects.

They also run a number of outreach programmes, such as the Raspberry Jam, a regular meetup for pupils to learn more about using the Raspberry Pi. In collaboration with Computing At School, the Raspberry Pi Foundation launched *Hello World* in 2016, a magazine for educators to share experiences and learn from each other.

Code Club
Founded in 2012, Code Club provides pupils with further opportunities to code through extracurricular sessions typically held in after-school hours, with approximately 6,000 code clubs across the UK for 9–13 year olds. Volunteer IT professionals originally led the organisation, but teachers are increasingly leading clubs and using the resources. Volunteers make a minimum commitment of 12 weeks and they typically stay in the programme for around 1.5 years.

A study conducted by the National Foundation for Educational Research (NfER) to assess the impact of attending Code Club, was the first randomised control trial of an after-school computing programme. It showed a significant positive impact on children's programming ability in all of the languages used. Teachers reported improvements in children's skills and confidence in programming, general ICT skills and problem-solving, and wider school impacts. The study didn't show any effect on the Bebras test, which was used to assess computational thinking.

In 2015, Code Club merged with Raspberry Pi to create more opportunities for young people to learn how to code and create.

CoderDojo
Joining Raspberry Pi and Code Club in 2017, CoderDojo is a grassroots-led organisation that focuses on providing volunteer-led programming clubs, called dojos, for young people to learn more about programming outside the classroom and to be exposed to the subject at an early age. Started in 2011, CoderDojo has now expanded to over 1,100 Dojos in 63 countries[104].

104. CoderDojo. 2017. CoderDojo Movement. See https://coderdojo.com/movement/ (accessed 29 June 2017).

> "Room layouts needed to change as there has been a pedagogical shift and IT rooms were not designed for this. Computing students need access to computers, but they also need space for other types of unplugged activities, and sometimes the computers are a distraction[107]."

Feedback received from a secondary school Head of Computing.

Cross-curricular computing

Teachers of other subjects can integrate computing within their lessons and vice versa. Mathematics, for example, is a subject that links well with computing, especially within the coding aspect. ScratchMaths, a project developed by University College London (UCL) and funded by the Educational Endowment Foundation (EEF) is exploring this further by understanding how pupils can engage with mathematics through coding[105]. Modelling the brain during a computing lesson can teach pupils how the brain functions, while they also learn valuable computer science concepts.

A number of national initiatives promote the cross-curricular links of computing under the umbrella of STEM such as Bloodhound and the TeenTech Awards. These projects enable pupils to understand the impact computing can have in real-world contexts.

Despite the potential for teachers to create cross-curricular links to and from computing (particularly in primary schools), our survey results suggested that some school senior leadership teams still consider the curriculum to be quite narrow and miss the opportunity to forge links with other subjects. (Also see Case Study 9.)

BOX 15

TeenTech

Founded in 2008, TeenTech aims to inspire teenagers to see the wide range of career possibilities in science, engineering and technology. Their event, the TeenTech Awards, is aimed at UK pupils aged 11 – 16 and 17 – 18, working in groups of three to explore how science and technology can be applied to real-world problems. Each year, the best projects go forward for judging at an event hosted by the Royal Society.

CASE STUDY 9

Western Primary School

Western Primary School in Harrogate, North Yorkshire, takes every opportunity to make cross-curricular links between computing and other subjects. iPads have been introduced into classrooms, allowing pupils to carry out research. For example in geography lessons pupils use Google Earth to look at maps and research different countries. In English and drama lessons, slow-motion video is used[106].

105. University College London. 2017. ScratchMaths. See www.ucl.ac.uk/ioe/research/projects/scratchmaths (accessed 30 June 2017).

106. Pye Tait. 2017. After the Reboot: The State of Computing Education in UK Schools and Colleges. Annex 1: Case Study Schools. p47.

107. Pye Tait. 2017. After the Reboot: The State of Computing Education in UK Schools and Colleges. p82.

CASE STUDY 10

Craigmount High School

Sara Hendrie, Curriculum Leader at Craigmount High School, West Edinburgh, believes that delivering computing education is a continuous journey. The key to maintaining momentum has been buy-in from the senior leadership team to the importance of digital literacy and computing skills to the local economy.

To help with the journey, Craigmount has built relationships with computing firms and nearby Edinburgh Napier University. For example, students go on visits and industry representatives visit the school to give talks and work with the students[108].

The physical classroom

Computing classrooms should be flexible learning spaces where pupils can easily interact with computers, teachers and their peers. Many school computing classrooms are set up in rows or islands, meaning pupils are restricted to a limited number of peers around them and are not able to collaborate on practical group activities.

Schools are increasingly using mobile devices such as laptops and tablets, and this is a step towards creating a flexible environment. A flexible classroom can also support a hybrid of unplugged and plugged learning and allow the teacher to configure the class differently for each aspect of the curriculum. Senior leaders should consult teachers on equipment upgrades to ensure future classrooms meet the needs of the subject.

Conclusion

The changes to computing curricula have resulted in teachers being asked to teach a subject they have not learned themselves. In the future, providing quality-assured and in-depth subject knowledge courses for non-specialist teachers should remain a priority. These should be delivered by higher education providers, and be consistent with mechanisms used to provide subject knowledge courses in other disciplines.

The Computing At School Network of Excellence has played an important role supporting the development of the subject and pedagogical content knowledge of in-service computing teachers. Building the Network through universities provides Master Teachers and teachers with ready access to expertise in computing. There is potential for this Network to scale-up both in terms of reach and funded support available in each region.

The value of suitable resources for teachers and pupils cannot be underestimated; however, there is a complex landscape of resources available. Resources need to align with the curriculum and to support teachers who have differing levels of knowledge.

Industry is also responsible for playing an active role in supporting teachers and needs to provide collaborative opportunities that can extend the classroom into the working world. By doing so, they can not only improve a teacher's subject knowledge but also provide an understanding of how concepts in the classroom can be applied. This can lead to increased pupil engagement and ensure a healthy pipeline of talent for generations to come.

108. Pye Tait. 2017. After the Reboot: The State of Computing Education in UK Schools and Colleges. Annex 1: Case Study Schools. p20.

Chapter five
Improving computing education through research

Left

Improving computing education through research

Introduction

- Most existing research in computing education has a focus on higher education so further research is required at the school level to improve pupil outcomes.
- For further research to take place, the capacity for computing educational research within the UK needs to be increased.
- Funding will be required to support longitudinal and impactful research projects in computing education in schools.

The need for high-quality research into computing education is greater than ever before. Development of the subject pedagogy from the findings of robust research is important for pupils to gain the subject knowledge and conceptual understanding.

Although some investment has been put into implementing the computing curriculum in England and developing similar frameworks across the whole of the UK, there has been comparatively little consideration of how to teach the subject effectively. Unfortunately, the need for more evidence on what works in computing education comes at a time when there is evidence of a reduction in spending on educational research and decreasing UK capacity in the field of educational research[109].

In 2014, the Society published the report, *Vision for Science and Mathematics Education*, which highlighted the importance of evidence in education. One of the recommendations stated that education policy and practice are more effective when informed by evidence[110]. The report called for agreed standards for educational research to ensure good practice.

This chapter explores the research literature around computing pedagogy and assessment that was reviewed as part of our commissioned work. It also assesses the current capacity for computing education research in the UK and makes recommendations to strengthen research and the research base itself.

Research into computing education pedagogy

Research into effective teaching methods is important for ensuring that subjects are appealing to pupils, and such research has shown that high-quality teaching can have a positive effect on pupil engagement across all subjects[111].

Due to the relative newness of the subject, pedagogies for computing are less developed than other subjects. Today's passionate computing teachers are doing their best to teach the subject, but more evidence about the best available teaching methods would enable them to do their job even more effectively.

109. British Educational Research Association. 2015. The BERA Observatory of educational research. Final report. See www.bera.ac.uk/wp-content/uploads/2014/08/BERA-Observatory-FINAL.pdf?noredirect=1 (accessed 27 July 2017).

110. The Royal Society. 2014. Vision for science and mathematics education.

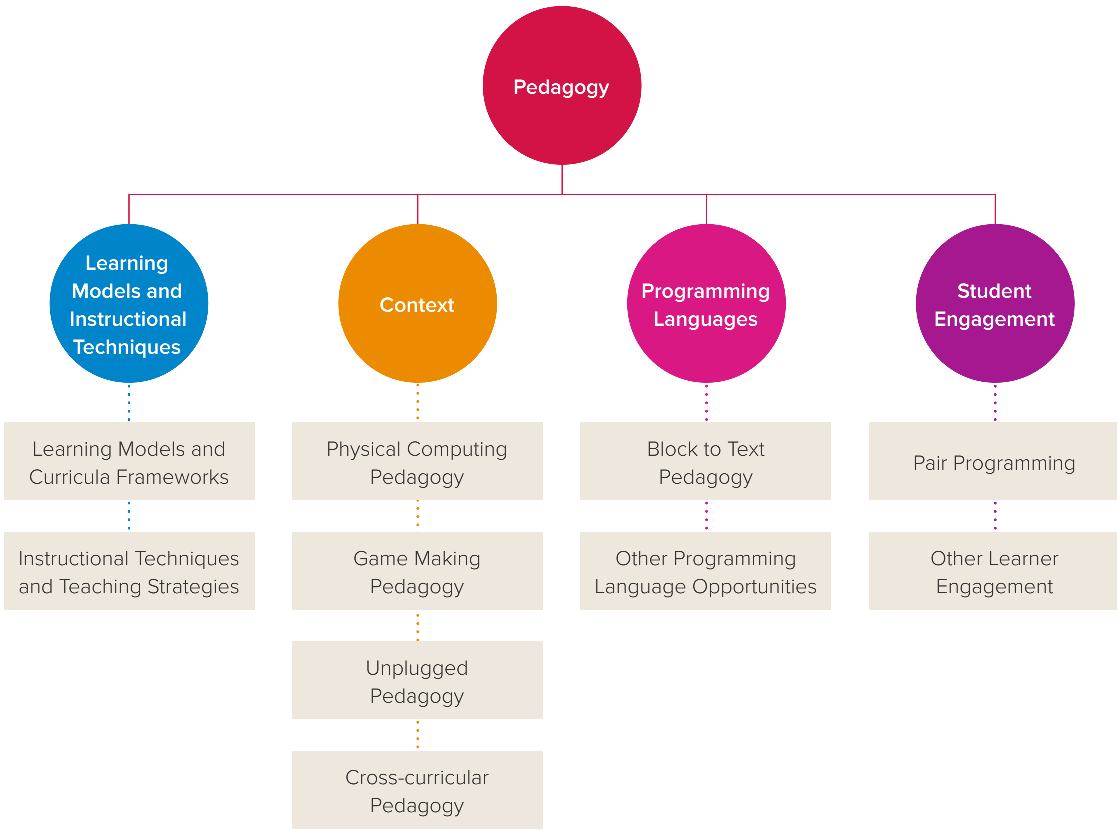
111. The Royal Society. 2014. Vision for science and mathematics education.

General pedagogical approaches do not specifically address the challenges that computing teachers face. The computing curriculum includes programming, which higher education research has demonstrated is difficult both to learn and teach. Teachers and researchers need to develop and evaluate computing-specific methods for primary and secondary schooling. This will enable teachers to teach confidently and educate their pupils effectively, and will result in improved pupil outcomes.

One of our literature reviews explored the area of computing pedagogy[112]. The review was based on 86 selected papers and divided pedagogy research into the following four areas shown in Figure 20.

FIGURE 20

Pedagogy literature review categories.



Source: Lr. 2.

112. Lr. 2.

Research into learning models and instructional techniques

Models of learning and theories of instruction should be central to any programme of computing education research. Although research in these areas is limited, there have been some attempts to model the learning process, such as representing the stages involved for understanding programming[113]. Researchers have evaluated various models of instruction including worked examples, tracing and reading code, and the use of discourse for understanding. Some of this research has taken place in school but the large majority is focused on higher education.

Research into context

Research on the environment or structure in which learning can best take place helps teachers to structure their classroom and decide which physical resources to use. An example included in our literature review[114] features a class using a programmable toy to deepen understanding about geometry, or creating a computer game that draws upon history topics to create cross-curricular learning opportunities. This research suggests that using games to learn how to programme can be highly motivational[115,116].

Physical computing devices are becoming more popular with pupils and teachers. Many different devices are available and the BBC micro:bit initiative saw the delivery of nearly a million small programmable devices for children in 2016. Although there is not a large body of research into physical computing, it is an area where research is emerging. This relates directly to use in schools and engagement in and out of the classroom. There are also unplugged resources that enable pupils to learn aspects of computing without hardware.

Research into programming languages

The reviewed evidence base that focused on teaching and learning programming languages focuses on the transition from block-based programming such as Scratch and Kodu to text-based languages that are widespread across primary and secondary computing classes.

Research into student engagement

Research into pupil engagement examines how learners can be active participants in teaching and learning. Evidence indicates that learning computing in an active environment benefits pupils beyond the impact on their formal attainment; for example, it can help create an inclusive learning environment that encourages the participation of a more diverse group of pupils in computing.

While an understanding of pedagogies is vital, we also need to understand what to teach and the appropriate age to introduce concepts[117].

113. Lr. 2.
114. Lr. 2.
115. Kafai, Y B & Burke, Q 2015 Constructionist gaming: understanding the benefits of making games for learning. Educ. Psychol. 50, 313–334. Repenning, A et al. 2015 Scalable game design: a strategy to bring systemic computer science education to schools through game design and simulation creation. ACM Transactions Comput. Educ. (TOCE) 15, 11.
116. Repenning, A et al. 2015 Scalable game design: a strategy to bring systemic computer science education to schools through game design and simulation creation. ACM Transactions Comput. Educ. (TOCE) 15, 11.
117. Lr. 1. p5.

Research into effective assessment techniques for computing

One of our literature reviews focused on assessment, identifying a range of different studies specifically relating to assessment in computing. The review did not include studies on particular aspects of summative assessment as these are country specific and can change with updates to the curriculum or qualifications. Formative assessment, also known as assessment for learning, is essential to enable teachers to monitor and guide progression and learning. The review highlighted that there is broad agreement among researchers that teachers need to take a multi-faceted approach to formative assessment[118].

The review summarises the evidence on a wide range of assessment strategies including concept maps, self and peer assessment, rubrics and multiple-choice questions. While most of the research focused on undergraduates in computer science, many of the findings are relevant to schools.

Research into assessment approaches tends to focus on self-assessment or peer assessment and where computing teachers can use them. Evidence from self-assessment research has revealed that pupils tend to work harder and are more motivated when self-assessment is used[119].

Some research studies assess the effectiveness of different assessment instruments. For example, rubrics, which provide teachers with a set of marking criteria for assessing programs, can be highly effective when assessing projects. The use of rubrics also allows pupils to recognise the standards required for their work.

Due to their increasing popularity, research into the effectiveness of automated assessment tools for assessing programming tasks and computational thinking is growing. Most of these studies are at an individual school level, so there is a need for more large-scale studies, particularly around assessing conceptual understanding and computational thinking[120].

Our literature reviews suggest that a number of other strategies might be useful in formative assessment of pupils' understanding of computing concepts. Concept maps graphically represent pupils' knowledge by mapping how they organise and represent knowledge. Research has identified that concept maps are also useful for teachers to identify gaps in pupils' knowledge[121].

118. Lr. 3. p40.
119. Lr. 3. p10 cited by Garcia-Beltrán and Martinez. 2006.
120. Lr. 3. p26.
121. Lr. 3. p32.

The computing research base in the UK

With the introduction of a mandatory computing curriculum for maintained schools in England, teachers might expect that UK researchers would be investigating computing pedagogies in order to improve pupil outcomes for ages 5 – 16. However, this is rarely the case, as computing education research has not been a funding priority.

The UK's computing education research community is small. There are just two named professors of computer science education in the UK, and no professors of computer science education in the education departments of the UK's higher education institutions[122].

In comparison, there are currently 27 active professors of mathematics education in England alone[123], most of whom are located in education faculties. Basing computing education researchers in computer science departments may restrict the capacity available to undertake educational research, but it may also be an opportunity[124].

A systematic review of over 2,000 computing education papers internationally from 2005 to 2014 revealed that most of the research was from the USA, with 1,231 papers, while the UK had only produced 128 during this period[125]. Within this review, the majority of school-level research was from the USA with 170 papers, while the UK only produced 24.

Despite the small number of computing education researchers in the UK, there is a growing community of teachers with an interest in computing education research. The Computing At School research working group was formed to encourage discussion between teachers and academics interested in research. And the Teaching Inquiry in Computing Education (TICE) project, funded by Microsoft and Google from 2015 to 2016, provided teachers with the opportunity to carry out small-scale action research projects of their choice.

Box 16 gives examples of current and recent UK research projects and these illustrate the breadth of research that is already underway in the UK despite the limited capacity.

Several conferences and journals relate to computing education but not many specifically focus on computing education in schools. However, a new UK-based journal, the *International Journal of Computer Science Education in School* (IJCSES)[126], is an open-access peer-reviewed journal that aims to publish computing education research that is also accessible to teachers.

A new strategy for computing education research

New research in computing education could help solve some of the problems this report has identified. For example:

- Gender imbalance in computing (see Chapter 2);
- Aspiration and image of the subject; and
- Teacher recruitment and retention (see Chapter 3).

These problems are difficult to solve and require broad-ranging interdisciplinary effort.

122. Dr Sue Sentance, personal communication, 13 June 2017.
123. Professor Jeremy Hodgen, personal communication, 13 June 2017.
124. Lr. 1.
125. Sentance S, Selby C. 2015. A classification of research into computer science education in school from 2005 – 2014: Initial report.
126. The *International Journal of Computer Science Education in School*. 2017. See http://ijcses.org (accessed 25 July 2017).

BOX 16

Examples of emerging school-based computing education research in the UK

Stride and programming language research
The Greenfoot team (Michael Kölling and colleagues, King's College London) have worked in the area of programming tool development for the past 15 years (previously at the University of Kent) and developed Greenfoot and Blue J for novice programmers. They have now developed an innovative 'frame-based' editor called Stride to support progression from block-based languages.

ScratchMaths and mathematical programming
This three-year EEF-funded research project completes in 2018. Through this project, research resources teach mathematics in primary school through programming have been developed and rigorously evaluated at University College London (UCL).

Torino
There has been much development in the UK relating to physical computing devices, including Raspberry Pi, the BBC micro:bit, and .NET Gadgeteer, that has been used to research the benefits of physical computing in the classroom. Torino is a new development by Microsoft Research that focuses on helping visually impaired children learn computer programming.

The Centre for Computing Science Education
Based in Glasgow University, the Centre for Computing Science Education has been established to bring together researchers in this field across Scotland to develop a coherent approach for future research. The centre aims to have a single academic discipline of computing science and to share best practice within the community.

PRIMM
There is currently little research in the UK around pedagogy specifically, but this new project from King's College London builds on existing research in the field and focuses on a scaffolding framework for teaching programming to children, independent of the tool or environment used.

The *Roehampton Annual Computing Education Report*
This project aims to report annually on the diversity of pupils choosing to take computer science as a GCSE subject. Over time, this will provide valuable information to assist research in increasing uptake of computing by under-represented groups.

Supporting computer science curriculum reform in Wales
As part of their work on developing computer science education and a Digital Competence Framework in the new Curriculum for Wales, researchers at Cardiff Metropolitan University (Professor Tom Crick and Professor Gary Beauchamp) and Technocamps based in Swansea University (Professor Faron Moller), have been working on computational thinking, effective pedagogies for programming and interventions to support teacher confidence and capability.

RECOMMENDATION

Education research funders, researchers, teachers and policymakers should develop a strategic plan that achieves:

- the establishment of a long-term research agenda for computing education in schools;
- a commitment to this programme by a number of stakeholders;
- the development of UK capacity to conduct the research; and
- the effective sharing of knowledge between researchers, teachers and teacher trainers.

A future research agenda

For research to have a high impact on educational outcomes for all pupils, it is important for teachers, school leaders and policymakers to be involved in discussions about research challenges, and for researchers to share their findings with teachers and policymakers. Research requires the active involvement of schools and teachers and the establishment of infrastructure to achieve research goals.

Based on the gaps and emerging research strengths identified in literature reviews, and the challenges identified within the evidence gathered for this project, we have proposed a framework to guide discussions about computing education research priorities with teachers, school leaders, researchers and policymakers. Our proposed framework has four strands:

1. Subject-specific pedagogies and assessment;
2. Computing for all;
3. Teacher education in computing; and
4. Understanding the impact of computing education over time.

This framework should be underpinned by research into learning models for computing, which may benefit from drawing on existing science and mathematics education research. It is important that new computing education research is established in a strong theoretical framework.

Subject-specific pedagogies and assessment

Teachers require teaching methods that embed pedagogy and practical strategies so they are able to understand the interrelatedness between them. Research needs to be accessible to teachers to enable them to make informed decisions when planning lessons for different stages of the curriculum. Teachers and examiners are assessing a new subject with very little evidence to support decisions about appropriate assessment methodologies.

There are a number of research questions to address in order to provide teachers with advice. A substantial research programme is required to address these, and other questions, so that computing education pedagogies and assessment methods are further developed. Some of the research questions that might be addressed include:

- What is the most effective, best-evidenced curriculum framework for computing?
- Which specific instructional techniques and teaching strategies are most effective for raising attainment in computing? For example, does teaching in situated contexts such as physical computing or unplugged computing improve pupil knowledge, skills and understanding?
- Which pedagogical approaches facilitate engagement, interest and motivation in computing?
- How can measures and rubrics for formative assessment play a role in identifying pupils' levels of learning and misconceptions?
- How do high-quality and reliable assessment instruments and tasks align with the learning objectives of the new computing curriculum?

Computing for all

Improving gender balance in computing must be a priority and understanding how to make the subject more attractive for girls is an important area of research. A multitude of social factors can affect uptake of computing and pupil engagement. Further research into these social factors to improve engagement within schools would be highly beneficial for the subject. We need to understand how the views, aspirations and experiences of young people affect their attitudes towards computing and their decision to study it. The forthcoming Royal Society and British Academy report on education research should identify computing education and gender balance in STEM subjects as priority research areas.

Teacher education in computing

As mentioned previously in the report (see Chapter 3), computing education is struggling to develop a strong pool of computing teachers. More research is required to understand how to make computing teaching careers more appealing, especially when the incentives within industry are so strong.

Research in teacher education is also required to support in-service teachers. As outlined in Chapter 4, teachers need sustained CPD opportunities and understanding best practice for delivering CPD would be highly beneficial. Research on the effectiveness of different CPD activities would help teachers improve their subject knowledge and supporting organisations to understand the most beneficial activities.

Understanding the impact of computing education over time

Given the increasing impact of data and computing in our society, understanding the long-term impact of the subject on the curriculum and on pupils is essential. Funders need to commission longitudinal studies (at least five years[127]) to understand pupil progression over time. Most of the studies identified in our literature reviews were only conducted over a short period.

At some stage in their education, pupils have to choose whether to study computing. Research into the factors that affect the uptake of the subject would help teachers and others understand how to make the subject more engaging to those pupils who might think otherwise. Understanding pupils' career choices and aspirations can provide insights into their decision to continue with computing or not.

RECOMMENDATION

The Economic and Social Research Council (ESRC) and other funders of education research should work to address the research priorities identified in this report.

Building research capacity

This should be an exciting time to be involved in computing education research due to the emergence of the subject in schools. The opportunities provided by new computing curricula coupled with advances in technologies and analytical tools with which to mine big datasets, and the increasingly interdisciplinary nature of educational research, offer enormous scope for advancing computing teaching and learning.

However, computing education research is nascent, and there is insufficient research capacity for establishing a sound evidence base[128]. To build capacity, multidisciplinary teams with expertise in workforce planning, diversity and inclusion, and economics, could be established to tackle some of the problems outlined in a new strategy for computing education research. However, pedagogic research requires an understanding of the discipline of computing.

It seems clear that the UK must find ways of improving the pipeline of computing education researchers in order to increase the capacity for computing education research. People enter education research from a diverse range of previous careers. In existing subjects, such as science and mathematics, it is common for education researchers to have been subject-specialist teachers with a strong grounding in their discipline. Clearly, that model does not work immediately for research in a new school subject, and this is not likely to change in the short term. Currently, there are few incentives or opportunities for those in taught higher education courses in computer science to adopt a more interdisciplinary position. Knowledge of social science methods and educational theory are not commonplace in either postgraduate taught or research computer science courses.

127. Technopolis. 2017. The role of EU funding for UK educational research. Case study for the Royal Society. (Forthcoming.)

128. The Royal Society. 2014. Vision for Science and Mathematics Education. p22.

Providing more opportunities for training in social science and interdisciplinary opportunities for research would be advantageous in incentivising more computer science graduates to consider educational research.

Moreover, education departments can begin to create structures to accommodate computing education research in the same way that they do for other science and mathematics education research. Scholarships and other PhD funding could be made available to encourage computing education research housed in education departments. Doctoral training partnerships could also provide new interdisciplinary and cross-institutional opportunities in computing education PhDs.

Another contributing factor for the lack of school-level research is due to a focus on higher education, as schools previously did not teach computing. Since the subject has become mandatory in English schools up to age 16, there is a great opportunity to undertake school-level research.

Teachers can have insights that researchers may not have. It is therefore useful for them to work together to develop in-depth research that benefits pupils over the long term. It also has another proven benefit of providing teachers with CPD[129].

The model of researcher-teacher collaboration found in many of the projects funded by the Education Endowment Foundation involves a process in which teachers are trained and supported to conduct the research themselves, which is then evaluated independently by academic researchers. We need a robust research programme where teachers are working with academics on education research in computing.

In the longer term, a centre for computing education research could help foster a critical mass of expertise, and systematically involve teachers in the co-creation and dissemination of research.

Conclusion

We need to increase the capacity of the existing computing education research base for the UK to produce high-quality research for schools. Without this research, the ability and speed with which we can advance our understanding of pedagogies and assessment for computing is limited[130]. Research will provide a strong theoretical base to improve pupils' learning outcomes.

We have outlined an ambitious, strategic programme for computing education research. The Society's 2014 report, *Vision for Science and Mathematics Education*, called for greater collaboration between education researchers, teaching professionals, policymakers and the public. Those involved in computing education need to collaborate on the research agenda, setting out clear priorities and strategies for delivering the required evidence in order to meet the programme's demands.

Funding for computing education research needs to increase now that computing has become a core component of the UK's education systems. This requires governments and employers to recognise that computing skills are now essential for life and are inextricably linked to economic prosperity. Without research, the teaching of the subject lacks a strong theoretical base to develop further and drive other initiatives. We cannot overlook the importance of research, as it will drive the future progress of the subject in schools.

129. Sentance S, Sinclair J, Simmons C. Csizmadia A. 2016. Teacher research projects in Computing.

130. Lr. 1.

Appendices

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Appendices

Working Group members

The members of the Working Group involved in this report are listed below. Members acted in an individual and not a representative capacity, and declared any potential conflicts of interest. Members contributed to the project on the basis of their own expertise and good judgement.

Chair	
Professor Steve Furber CBE FREng FRS	ICL Professor of Computer Engineering, School of Computer Science, The University of Manchester
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Review panel

This report has been reviewed by a panel of experts, before being approved by the Officers of the Royal Society. The Review Panel members were not asked to endorse the conclusions or recommendations of the report, but to act as independent referees of its technical content and presentation. Panel members acted in a personal and not a representative capacity, and were asked to declare any potential conflicts of interest. The Royal Society gratefully acknowledges the contribution of the reviewers.

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Participants

The Royal Society would like to thank all those who contributed to the development of this project through submission of evidence and attendance at events.

Commissioned research

To provide an evidence base for the report, three literature reviews, a school survey and an analysis of government data were commissioned and are available at **royalsociety.org/computing-education**

Reference in report	Title	Author
Lr. 1.	*Computing Education: An Overview of Research in the Field*	Professor Tom Crick MBE
Lr. 2.	*Pedagogy in teaching Computer Science in Schools: A Literature Review*	Jane Waite
Lr. 3.	*Assessment in Computer Science Courses: A Literature Review*	Maria Kallia
Pye Tait	*After the Reboot: The State of Computing Education in UK Schools*	Pye Tait
Kantar Public	*The Royal Society: Computing Education Analysis of administrative education data*	Kantar Public

APPENDICES

Data annex

TABLE 14

Types of career young people are interested in.

	All young people %	Males %	Females %
Medicine*	27	14	44
Engineer*	24	34	10
Computer scientist*	11	17	3
Psychologist*	8	3	16
Teacher / lecturer*	7	5	10
Veterinary science*	6	3	10
Sports science / physiotherapist	5	5	4
Chemist	5	4	5
Civil engineering / design	5	6	2
Biologist	4	3	6
Forensic scientist	4	1	7
Physicist	3	3	2
Armed forces	2	3	2
Other science career	13	12	14
Non-science career*	16	18	12
Unweighted base	1,495	807	683

*Indicates if significant difference between males and females.

Source: Wellcome Trust. 2017. Young people's views on science education. Science Education Tracker Research Report. See https://wellcome.ac.uk/sites/default/files/science-education-tracker-report-feb17.pdf (accessed 14 March 2017).

TABLE 15

Key Stage 2 mathematics profiles of 2016 GCSE subject cohorts. 45 largest subjects.

Subject	Mean	SD
Latin	4.89	0.33
Chemistry	4.68	0.51
Physics	4.68	0.51
Biology	4.67	0.52
Economics	4.61	0.57
German	4.53	0.61
Computing	4.44	0.67
Spanish	4.43	0.65
French	4.43	0.65
Music	4.36	0.72
Psychology	4.35	0.65
Statistics	4.34	0.72
Applications of Mathematics	4.31	0.75
Business Studies	4.30	0.68
English Language	4.28	0.73
History	4.27	0.72
Physical Education	4.27	0.70
Geography	4.26	0.73
Applied Engineering	4.24	0.73
English Literature	4.24	0.75
Religious Studies	4.23	0.75
D&T Graphics	4.21	0.75
Mathematics	4.16	0.77

TABLE 15 (continued)

Subject	Mean	SD
Sociology	4.16	0.70
ICT	4.15	0.76
Drama	4.14	0.77
ALL	4.14	0.80
Design and Technology: Product Design	4.13	0.78
Office Technology	4.12	0.75
Fine Art	4.11	0.82
Dance	4.10	0.76
Science Additional	4.07	0.73
Design and Technology: Textiles	4.06	0.79
Social Science: Citizenship	4.05	0.78
Media/Film/TV	4.05	0.75
Design and Technology: Resistant Materials	4.05	0.80
Art & Design	4.03	0.84
Home Economics: Food	3.97	0.82
Design and Technology: Food Technology	3.97	0.82
Art & Design (Textiles)	3.96	0.84
Photography	3.94	0.79
Science Core	3.91	0.79
Health & Social Care	3.85	0.76
Home Economics: Child Development	3.77	0.77
English Language and Literature	3.58	0.87

Source: Kemp P. 2017. The Royal Society Computing Project.

APPENDICES

TABLE 16

ICT and Computing qualifications taken in England, Wales and Northern Ireland (2007 – 2016).

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Entries for academic qualifications*										
ICT (full GCSE)	99,656	85,599	73,519	61,022	47,128	53,197	73,487	96,811	111,934	84,120
Computing (full GCSE)	–	–	–	–	–	–	–	16,773	35,414	62,454
ICT (GCSE short course)	96,056	80,840	61,443	44,891	29,931	15,223	11,908	8,215	6,221	5,466
ICT (GCSE double award)	27,656	16,062	9,158	5,810	3,383	1,998	2,393	1,844	1,379	656
Total academic qualifications	**223,368**	**182,501**	**144,120**	**111,723**	**80,442**	**70,418**	**87,788**	**123,643**	**154,948**	**152,696**
Registrations for vocational qualifications*										
Level 1 / 2										
Cambridge International	–	–	–	–	35	1,620	2,340	5,500	3,645	270
OCR Cambridge National	–	–	–	–	–	–	8,255	49,245	73,270	40,530
Level 2										
BCS	2,800	4,185	1,645	–	49,290	61,090	54,885	67,070	263,555	235,680
City & Guilds	3,880	6,080	7,080	–	–	–	–	–	–	–
OCR	18,105	18,935	4,855	10,350	131,320	479,285	61,860	31,090	9,300	7,095
Other	5,575	6,285	7,630	6,240	124,395	78,280	70,880	39,705	16,725	14,095
Total vocational qualifications	**30,360**	**35,485**	**21,210**	**16,590**	**305,040**	**620,275**	**198,220**	**192,610**	**366,495**	**297,670**

* Source (academic qualifications): JCQ examination results (GCSE and entry-level certificate results Summer [YEAR]). See www.jcq.org.uk/examination-results/gcses (accessed November 2016).

* Source (vocational qualifications): Ofqual Vocational qualifications dataset, 2006 to present – England, Wales and Northern Ireland. See www.gov.uk/government/statistical-data-sets/vocational-qualifications-dataset (accessed November 2016).

Level 1 / 2
Cambridge International: Includes Level 1 / Level 2 Certificates in ICT and computer science.

OCR Cambridge National: Includes Level 1 / Level 2 Cambridge National Certificate, Award and Diploma in ICT.

Level 2
BCS: Includes Certificates, Awards, Diplomas, NVQs in IT User Skills, IT Application Skills, Creative Digital Media.

City & Guilds: Includes NVQs for IT Users, Communication technologies practitioners, Contact centre operations, IT Practitioners.

OCR: Includes NVQs for IT Users, IT Practitioners, Contact centre operations; National Award, Certificate, First Award, First Certificate, Short Course Award in ICT; Award, Certificate, Diploma, Extended Certificate in IT user skills and systems and principles for practitioners; Award in ICT systems and principles for IT professionals; Cambridge Technical Certificate, Diploma, Extended Certificate in IT; Principal learning in IT; Diploma in ICT Professional competence.

APPENDICES

TABLE 17

Level 3 ICT and Computing qualifications taken in England, Wales and Northern Ireland (2007 – 2016).

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Entries for academic qualifications*										
Computing (GCE A level)	5,610	5,068	4,710	4,065	4,002	3,809	3,758	4,171	5,383	6,242
ICT (GCE A level)	13,360	12,277	11,948	12,186	11,960	11,088	10,419	9,479	9,124	8,737
Applied ICT (GCE A level single award)	12,076	13,618	13,580	12,291	11,045	9,594	8,753	7,384	6,283	5,481
Applied ICT (GCE A level double award)	3,051	2,609	1,835	1,328	833	587	472	356	267	202
Total academic qualifications	**34,097**	**33,572**	**32,073**	**29,870**	**27,840**	**25,078**	**23,402**	**21,390**	**21,057**	**20,662**
Registrations for vocational qualifications*										
BCS	70	135	45	–	830	1,385	990	515	395	710
City & Guilds	1,325	1,915	2,285	–	–	–	–	–	–	–
OCR	1,095	1,060	305	745	5,860	14,365	6,795	9,380	10,390	11,365
Other	1,700	1,845	2,260	1,595	24,655	1,130	2,015	1,430	865	890
Total vocational qualifications	**4,190**	**4,955**	**4,895**	**2,340**	**31,345**	**16,880**	**9,800**	**11,325**	**11,650**	**12,695**

* Source (academic qualifications): JCQ examination results (GCSE and entry-level certificate results Summer [YEAR]). See www.jcq.org.uk/examination-results/gcses (accessed November 2016).

* Source (vocational qualifications): Ofqual Vocational qualifications dataset, 2006 to present – England, Wales and Northern Ireland. See www.gov.uk/government/statistical-data-sets/vocational-qualifications-dataset (accessed November 2016).

APPENDICES

TABLE 18

Comparison of percentages of entries to Computing and ICT A levels with entries to selected science A levels across the UK by gender (2002 – 2016).

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Computing (%)															
Male	86	87	88	89	90	90	91	90	91	92	92	93	92	92	90
Female	14	13	12	11	10	10	9	10	9	8	8	7	8	8	10
ICT (%)*															
Male	65	66	65	65	64	63	62	61	62	61	61	62	64	64	64
Female	35	34	35	35	36	37	38	39	38	39	39	38	36	36	36
Mathematics (%)															
Male	63	63	61	62	61	60	60	59	59	60	60	61	61	61	61
Female	37	37	39	38	39	40	40	41	41	40	40	39	39	39	39
Physics (%)															
Male	77	77	78	78	78	78	78	78	78	79	79	79	79	79	78
Female	23	23	22	22	22	22	22	22	22	21	21	21	21	21	22
Chemistry (%)															
Male	49	48	49	51	51	50	51	52	52	53	53	52	52	51	50
Female	51	52	51	49	49	50	49	48	48	47	47	48	48	49	50

Source: JCQ examination results (A, AS and AEA results, Summer [YEAR]).
See www.jcq.org.uk/examination-results/a-levels (accessed November 2016).

TABLE 19

Gender uptake of computer science in Scotland at National 4, National 5, Higher, and Advanced Higher

	National 4					
	2015		2016		2017	
	Entries	%	Entries	%	Entries	%
Male	2,765	80	2,353	81	2,225	83
Female	691	20	540	19	470	17

	National 5					
	2015		2016		2017	
	Entries	%	Entries	%	Entries	%
Male	6,117	80	6,489	82	5,990	80
Female	1,546	20	1,438	18	1,452	20

TABLE 19 (continued)

	Higher					
	2015		2016		2017	
	Entries	%	Entries	%	Entries	%
Male	1,010	85	3,711	83	3,818	85
Female	172	15	743	17	658	15

	Advanced Higher					
	2015		2016		2017	
	Entries	%	Entries	%	Entries	%
Male	442	87	416	86	565	88
Female	67	13	69	14	76	12

Source: Scottish Qualifications Authority. 2017. Statistics 2016.
See www.sqa.org.uk/sqa/63001.8312.html (accessed 2 October 2017).

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TABLE 20

English local authority uptake of computer science at Key Stage 4.

Local authority (LA)	Total KS4 pupils	Total computer science students	% of KS4 in LA undertaking computer science	No. of schools in LA	No. schools not offering GCSE computer science	No. schools offering GCSE computer science	% of schools offering GCSE computer science	Avg. KS4 cohort Size
Top 5 Local Authorities with the highest percentage of total Key Stage 4 pupils undertaking GCSE computer science								
Bournemouth	1,732	394	22.75	18	10	8	44.44	96.22
Central Bedfordshire	2,648	584	22.05	19	11	8	42.11	139.37
Hartlepool	1,073	231	21.53	7	2	5	71.43	153.29
Knowsley	1,149	234	20.37	10	5	5	50.00	114.90
Slough	1,657	330	19.92	14	6	8	57.14	118.36
Bottom 5 Local Authorities with the lowest percentage of total Key Stage 4 pupils undertaking GCSE computer science								
Rutland	846	44	5.20	7	5	2	28.57	120.86
Calderdale	2,639	137	5.19	20	14	6	30.00	131.95
Kensington and Chelsea	1,152	58	5.03	17	14	3	17.65	67.76
Blackburn with Darwen	1,952	94	4.82	20	14	6	30.00	97.60
City of London	229	10	4.37	2	1	1	50.00	114.50
Top 5 Local Authorities with the highest percentage of schools offering GCSE computer science								
Isles of Scilly	23	4	17.39	1	0	1	100.00	23.00
Hartlepool	1,073	231	21.53	7	2	5	71.43	153.29
Harrow	2,531	447	17.66	18	6	12	66.67	140.61
Bracknell Forest	1,457	181	12.42	12	4	8	66.67	121.42
Thurrock	1,721	176	10.23	12	4	8	66.67	143.42
Bottom 5 Local Authorities with the lowest percentage of schools offering GCSE computer science								
Greenwich	2,439	179	7.34	24	17	7	29.17	101.63
Rutland	846	44	5.20	7	5	2	28.57	120.86
Shropshire	3,565	208	5.83	41	30	11	26.83	86.95
Tower Hamlets	2,769	181	6.54	30	22	8	26.67	92.30
Kensington and Chelsea	1,152	58	5.03	17	14	3	17.65	67.76

Source: The Department for Education. 2017. Find and compare schools in England.
(see www.gov.uk/school-performance-tables, accessed September 2017).

Glossary

A level	GCE Advanced Level
AQA	Assessment and Qualifications Alliance
BBC	The British Broadcasting Corporation
BCS	British Computer Society
C&G	City & Guilds
CAS	Computing At School
CPD	Continuing Professional Development
cs4fn	Computer Science for Fun
DfE	Department for Education
EBacc	English Baccalaureate
EEF	Educational Endowment Foundation
ESRC	Economic and Social Research Council
FE	Further Education
FMSP	The Further Mathematics Support Programme
GCSE	General Certificate of Secondary Education
HE	Higher education
HEIs	Higher education institutions
ICT	Information Communication Technology
IDACI	Income Deprivation Affecting Children Index
iDEA	The Duke of York Inspiring Digital Enterprise Award
IJCSES	International Journal of Computer Science Education in School
IoP	Institute of Physics
IT	Information Technology
JCQ	Joint Council for Qualifications
MOOCs	Massive Open Online Courses
NoE	Network of Excellence
NPD	National Pupil Database
OCR	Oxford, Cambridge and RSA Examinations
Ofqual	Office of Qualifications and Examinations Regulation
Ofsted	Office for Standards in Education, Children's Services and Skills
PGCE	Postgraduate Certificate in Education
PhD	Doctor of Philosophy
PLAN C	Professional Learning and Networking in Computing
QMUL	Queen Mary University of London
SEND	Special educational needs and disabilities
SET	Science Education Tracker
SQA	Scottish Qualifications Authority
SQL	Structured Query Language
STEM	Science, technology, engineering and mathematics
STEMNET	Science, Technology, Engineering and Mathematics Network
Tes	Times educational supplement
TICE	Teaching Inquiry in Computing Education
UCAS	The Universities and Colleges Admissions Service
UCL	University College London
UKForCE	UK Forum for Computing Education

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Registered Charity No 207043

ISBN: 978-1-78252-297-3
Issued: November 2017 DES4633