A critical evaluation of the impact of government STEM policy and curriculum reform on Computer Science A Level

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Introduction

Only in the last 5-7 years has UK Computing education been given due attention, and government changes to the system since have been far more drastic than for the rest of Science, Technology, Engineering & Mathematics (STEM). This essay begins by looking at some of the changes brought about through government STEM policy and, more specifically, at the introduction of a new Computer Science curriculum. By following three identified issues in STEM education of student numbers, teacher recruitment and gender balance, it examines the impact on FE institutions offering A Level Computer Science, as well as on their teachers and students.

Context

'STEM' abbreviates the set of subject areas (Science, Technology, Engineering and Mathematics) which are grouped together because of their shared quantitative approach and strong links to driving and futureproofing economic growth. STEM describes taught subjects as well as the high skilled, technical industries that they can all lead to. "The nations that can thrive in a highly competitive global economy will be those that can compete on high technology and intellectual strength" (HM Treasury, 2004, p.1). The technological boom of the last few decades has brought with it many new opportunities for the British and global economy. Whether or not it is helpful to group such a large set of subjects together, the government is using STEM to talk about improving innovation and productivity for the future.

The driving factors behind the government's focus on STEM are certainly economic. According to them, the country's science base is "the bedrock of our economic future" (HM Treasury, 2004, p.1). The government believes that investing in STEM is essential for the country's economy and that one of the most effective targets for that investment is STEM education (HM Treasury, 2004). One of education's main purposes is to drive economic growth, and it appears that the government thinks STEM education drives it the most.

The government's investment framework from 2004 was partly motivated by Sir Gareth Roberts' review in 2002. It identified a skills shortage in many science and engineering industries and made recommendations for dealing with it. Although there was a higher demand for graduates with STEM skills, there was a lower supply of them, particularly from Physics and Mathematics degrees (Roberts, 2002). This deficit of graduates was linked back to Further Education. The number of students taking up STEM A levels is important, because level 3 study is a crucial transition period from school to Higher Education. If the government wants to increase the number of STEM graduates, increasing the numbers of those taking relevant A Levels is a good idea. However, the review found an 18% drop in Mathematics A level passes from 1995 to 2000 and a 16% drop in Physics (Roberts, 2002).

As well as student numbers, teacher recruitment was identified as a significant issue. According to the review, "this is evident in the consistent failure to recruit sufficient numbers specialising in these [STEM] subjects" (Roberts, 2002, p.4). This could have been partly due to the lower supply of graduates. However, the decrease in student numbers felt by Physics and Mathematics was not felt by Computer Science, with a 30% increase in A level passes and an increase in the number of students taking it as a first degree (Roberts, 2002). Yet, the teacher shortage was just as prevalent in Computing (mostly ICT at that time). A more likely cause would have been attractive private STEM industry salaries, which were much higher than those in the public education sector. Related to this issue was that of recruiting suitably specialised teachers. In both secondary and FE, those teaching STEM subjects commonly did not have a relevant degree and some not even A levels (Roberts, 2002).

Roberts' Review mentioned gender imbalance as another problem faced by STEM education. It talked of the issue of "the ability of these [STEM] subjects' courses to inspire and interest pupils, particularly girls" (Roberts, 2002, p.3). Although this issue is difficult to find causes and solutions for, it is easy to see the scale of it in data. 2016 salary data for the 2009/10 graduating cohort showed that 93% of Computer Science degree courses had a higher median graduate salary for males than females, 5 years after graduation (DfE, 2018). This placed Computer Science as the third most unequal out of 23 subjects reviewed. The students in this cohort would be likely to have started Year 9 in 2002, at the time of Roberts' review. This data firstly implies that incentives and opportunities for women in the Computer Science industry are significantly unequal. Secondly, and perhaps most importantly, it highlights how measuring the effects of educational policy change is slow because of the length of time a person can be in education. To put this into perspective, we will not know the effects of changes to primary education in 2002 on 5-year graduate earnings until 2023.

Related government policy

Since Roberts' Review in 2002, the government began by tackling the issue head-on in the traditional sciences and mathematics, especially in secondary education. One of the largest successes was the push to increase the availability and take-up of Triple/Separate Sciences at GCSE (NAO, 2010). This change helped to align career pathways for pupils at an earlier age. For example, Chemistry GCSE led to Chemistry A Level, which led to a Chemistry degree. The government has since continued to try fixing the issues of gender balance and teacher recruitment in STEM and, more recently, made drastic reforms to the UK's Computing education.

Over the past 15 years, the government seems to have consistently pushed the same message: the UK needs more specialist teachers in STEM because it is one of the barriers to a STEM skills shortage. In 2004, the target was "to eliminate as far as possible the undershooting of the national Initial Teacher Training (ITT) target by 2007/08" (HM Treasury, 2004, p.92). At this point, strategies for dealing with the shortage included increasing 'Golden Hellos' and ITT bursaries. By 2010, the situation had not changed much; although the shortage had reduced for biology and chemistry teachers, the targets for mathematics and physics were not going to be met (NAO, 2010). The government's response was to throw even more money at the problem: "We are allocating £67 million for new programmes to train up to 17,500 maths and physics teachers over the next Parliament" (BIS & HM Treasury, 2014, p.22). Recent statistics show that there is no longer a teacher recruitment shortage in Biology or Chemistry, but that significant shortages still exist in Mathematics, Physics and Computing, with Computing being the worst having only 68% of the ITT target being met. This is the "biggest margin of all English Baccalaureate (EBacc) subjects" (House of Commons Education Committee, 2017, p.5). STEM teachers were in shortage in 2004 and, overall and especially in Computing, they still are 15 years later. This raises concerns about the success of the government's strategies for boosting teacher recruitment.

The gender balance picture looks similarly static. In 2004, the government planned to invest £2.4m for encouraging more women to consider STEM as a career (HM Treasury, 2004). By 2014, very little had changed. "Only one in five A level physics students is female – a figure that has remained unchanged in the last 20 years" (BIS & HM Treasury, 2014, p.21). At this point the government acknowledged that whatever they had been trying to do to tackle this issue had consistently failed. The recent figures for Computing look even worse and show a desperate need for new strategies. 2016 data showed that only 9.7% of Computer Science A Level students were female and a shocking 66% of institutions providing the course had no females studying it (Kemp, 2017), which made it one of the most gender-unbalanced subjects to study in the country.

In 2004 the government noted that the drop in Maths and Physics A level passes was balanced with more people studying courses in D&T, Business, Psychology and Media/TV/Film Studies (HM Treasury, 2004). By aiming to "reverse this decline", they implied that they wanted fewer young people studying these subjects to take up STEM pathways instead. Looking at the choice of 'STEM or not STEM' could be seen as unhelpful because the reality of industry in STEM is not so monodisciplinary. For example, psychologists are necessary for understanding human use of technologies like social media. Nevertheless, overall student numbers are easily measurable and, by 2014, the government noted a significant increase in STEM take-up at university: 43% increase in Biology, 40% in Physical sciences and 55% in Mathematics (BIS & HM Treasury, 2014). This data was encouraging and, given a lifting of caps of HE student numbers, looked to continue improving.

At Level 3, the Computing picture was not so encouraging. The number of students taking Computing A Level dropped significantly by 33% from 5,610 in 2007 to 3,758 in 2013 (The Royal Society, 2017). In 2012, a scathing review by the Royal Society concluded that the education of Computing in schools and colleges was "highly unsatisfactory" and "there needs to be recognition that Computer Science is a rigorous academic discipline of great importance to the future careers of many pupils" (The Royal Society, 2012, p.5). As a result of this report, within two years, Information Communication Technology (ICT) in primary and secondary schools was replaced with new courses that were more computational in nature "rather than focusing on learning how to use word processing and presentation packages" (GOV.UK, 2014). This large shift brought computer programming into the National Curriculum and, along with the new GCSE in 'Computer Science', which was first taught in September 2016, brought 5-16 Computing education much more in line with the A Level and degree-level Computer Science pathway. Since these changes, student numbers in the new 'Computer Science' A Level have increased to 6,242 in 2016 and to 8,299 in 2017 (The Royal Society, 2017). This equates to a staggering 121% increase since 2013, showing how the reforms have significantly improved recognition and take-up of the subject at level 3.

However, the most recent report by the Royal Society, in 2017, found evidence to show that "computing education across the UK is patchy and fragile", citing teacher shortages, gender imbalance and inconsistent delivery as contributing factors (The Royal Society, 2017, p.3). This showed that the three main issues identified by Roberts in 2002 for general STEM education were just as relevant 15 years later in Computer Science. "Patchy and fragile" was certainly an improvement on "highly unsatisfactory", but there was still a long way to go. This review led to the government, in November 2017, committing £84m over four years to support the delivery of computing education in England (CAS, 2018). Such a large investment is incredibly encouraging and shows that the government is listening and responding to the needs of the subject.

Another recent development is the National Cyber Skills Strategy, which aims to close the government's cyber security skills gap as soon as possible. Since 2016, a set of initiatives including HE bursaries, GCHQ apprenticeships and school outreach hubs are trying to encourage many more young people to choose government cyber security as a career (GCHQ, 2018 & NCSC, 2018). The strategy also includes two very successful extra-curricular competitions: the Cyberfirst Girls' Competition and the CyberDiscovery programme. The Girls' competition is only open to young women and "the 2018 competition saw 4,500 young women from 400 schools participate" (DCMS, 2018, p.35). The strategy is proving to be very successful and is likely to encourage more students to pursue a Computer Science pathway through A Level. A qualitative study (Carter, 2006, p31) concluded that students', especially girls', largest barrier to choosing Computer Science occurs when they cannot see a link between it and other fields. These initiatives are directly linking computing skills to the specific field of cyber security, which could be a reason for their success so far.

Despite recent successes and promising investment, it seems that, for now, the STEM skills shortage remains. "The shortage is estimated to cost them [businesses] £1.5 billion a year" (STEM Learning, 2018). However, there does not appear to be a problem with the number of graduates from STEM degrees. It seems that the problem is more with existing STEM pathways not providing all the necessary content and work experience required by industries (UKCES, 2015). Perhaps this is an issue with the broad categorisation of 'STEM' degrees, within which there are some pathways that are 'doing it right', and others which are failing at preparing people for employment. Another possible explanation is that the changes *are* effective, and employers just need to wait for the fruit to grow. Especially with Computer Science, the most significant government reforms to its education are so recent that their effects on the skills shortage cannot be measured yet.

Impact

STEM education progress has always been measured by student numbers at levels 2 and 3, and teacher recruitment. The number of students taking A Level Computer Science is still increasing. At one large college in Hampshire, the number of students enrolled onto the course increased by 45%, from 99 in 2017 to 144 in 2018. This is good news for the economy, by indirectly reducing the skills shortage, and is a positive indicator for the increasing reputation of the course nationally. If more students take the course, it is more likely to become recognised by universities, employers, and FE institutions that currently do not offer it. However, the desperate shortage of teachers is not going away. For some institutions the teacher shortage leads to them not being able to offer the A Level course. In 2016, only 28% of schools and colleges did so (Kemp, 2017). The others miss out on potential funding by deterring students who want to study it. As student demand for the course increases, it could become even worse for institutions to not offer it. They may become more likely to ask non-specialists to teach the course if they fail to recruit those with relevant qualifications.

For the 28% that do deliver the A Level, increases in student numbers and the teacher shortage result in more students per class. For existing teachers, responsibility for more students adds to stress and workload. It influences the learning of students too: according to a study by Harfitt & Tsui (2015, p.863), "smaller classes might be more conducive to the formation and development of powerful CoPs". Here, they refer to Lave & Wenger's (1991) theory of 'communities of practice', which says that learning is, at its heart, a social process performed by groups of people working together.

The third main issue in STEM was gender balance, particularly in Computer Science. At one large college in Hampshire, the proportion of girls taking the course was static around 7% since 2013. However, since the new GCSEs were introduced, the percentage doubled to 13.9% in 2018. This promising increase indicates that the recent government reforms in schools are starting to have a positive effect at level 3. Nevertheless, with some classes still only having one girl, there is much progress to be made. The imbalance could deter female applicants from taking the course because of feeling like they would not fit into the male-dominated environment. In addition, institutions primarily selecting from boys means that there is a huge portion of the student population being missed. At this college, if an equal number of girls enrolled as did boys in 2018, the total course cohort would have been 72% larger.

The Computing reforms should form a visible pathway for students to Computer Science HE courses. The content and skills developed at school should lead well into the Computer Science GCSE. Similarly, the knowledge and skills required at GCSE should lead well into the Computer Science A Level domain. However, the transition from level 2 to level 3 may as yet not be so smooth for many students, due to the "patchy and fragile" (The Royal Society, 2017, p.3) implementation of the new courses. A substantial teacher shortage, combined with many existing teachers feeling underprepared for delivering the new curriculum, has led to inconsistent student experiences of the subject. TES reported that two in three 5-16 Computer Science teachers still did not feel sufficiently prepared to teach the subject properly (George, 2017). Some students will have been lucky enough to be taught by excellent, knowledgeable Computer Science teachers, while others will have been among the 30% who attended schools not offering the GCSE (The Royal Society, 2017). A result of this is a more polarised set of initial abilities within the A Level classroom. This has the effect of disadvantaging students without the GCSE or a poorly taught one. Furthermore, those who are more knowledgeable from well-taught GCSE content may drive up the grade boundaries at A Level by performing better, leaving other, less fortunate students behind. This also undoubtedly adds pressure on the teacher. Before the introduction of the new GCSE, A Level teachers could assume that very few students had proper prior experience of coding and computational thinking. However, now, with an increasing proportion of students taking the GCSE, teachers must deliver the course in an increasingly differentiated way. At one large college in Hampshire, the proportion of entrants to the Computer Science A Level course who held the GCSE increased from 62.0% in 2016 to 77.8% in 2018.

The government's recent drive for young people towards the cyber security profession could have played a part in this increase, with many of the new intake interested by a career in it. However, cyber security is just one relatively small part of the much wider technology sector. By advertising just this field to young people rather than a range of possibilities, there is a risk of giving an over-narrow message about what Computer Science is for. Not only might it lead to a decline in candidates for other specialist technology jobs, but it may also lead to students feeling more disengaged with aspects of the A Level syllabus that are not as relevant to cyber security. On the other hand, concretisation of the subject in the form of interesting competitions may be a solution to persuade more school pupils to continue studying it. Then, once studying the A Level, students will have time to learn about the wider range of available destinations.

If the provision of GCSE Computer Science remains inconsistent, FE institutions would face tough decisions about advertising entry requirements for their level 3 courses. In a nationally well-established curriculum like Mathematics, it is sensible for institutions to require applicants to achieve well in GCSE Maths. However, by applying a similar rule to Computer Science, colleges risk rejecting prospective students based on which school they attend. As a result of this risk, colleges do not require GCSE Computer Science as a prerequisite qualification, although some give preference to students who have it. This exacerbates the need for teachers to deliver the course in a more bespoke way, because they must also cover the GCSE content for some students at the same time as the A Level content for everyone.

There is a surprisingly similar second barrier on the pathway to a Computer Science degree at the next key transition point for many students: from FE to university. In addition to the fact that students are not required to study the GCSE in order to study the A Level, it seems that studying the A Level is far from a prerequisite for undergraduate study. The 2012 Royal Society review found that, although universities hypothetically wanted to have Computer Science A Level as an entry requirement, there were many reasons preventing this from becoming a reality. One of these was that “few HE departments appear to hold Computing A-level in high esteem” (Royal Society, 2012, p.12) and the other was low student numbers at A Level. This second reason is problematic: if universities do not ask for the qualification because not enough people take it, then fewer will take it. Six years on, the situation does seem to have improved. Student numbers have increased, and the A Level qualification has been rebranded to be more academically rigorous. The most up-to-date guidance is that the A Level might be essential for some HE courses. However, since A Level availability is still far from universal, Computer Science remains not to be a ‘facilitating’ subject (Russell Group, 2017). Progress has been slower at leading institutions, with some departments still discouraging students from taking the A Level. One reason for this is that much of the first year of undergraduate study repeats the content of a Computer Science A Level. If universities were to expect a level 3 Computer Science qualification, they could do away with much of the first year and produce higher-skilled graduates at the end, which is exactly the government's primary aim. They could also reduce the subject's relatively high undergraduate drop-out rates (Royal Society, 2012) by enabling prospective students to gain a proper taste of the subject before applying.

Overall, the state of HE Computer Science admissions is inconsistent and often contradicts the government's drive to increase uptake of the course at levels 2 and 3. It seems wrong to advise a student who wants to study Computer Science at university that they ought not to take it as an A Level. This leads to confusion for students when choosing which programme of study to follow in FE. They may need to decide at that point exactly which university they want to go to, since the entry requirements vary so much. This does not give the student any time to develop their interests and change their mind while at college. This inflexibility is made worse by the government's current rules for 16-19 funding, which mean that someone studying four A Levels receives no more funding than if they were to take just three (ESFA, 2018). This incentivises FE institutions to discourage applicants from studying four. It is relevant to Computer Science since the confusing HE advice might lead to students wanting to 'play it safe' by taking 3 facilitating A Levels. Those who are academically capable, and interested in a Computer Science degree, would still want to take Computer Science A Level, but perhaps as a fourth. The conflict here could add stress to incoming students when making their subject choices.

Potential future direction and conclusions

Current Computing education provision is inconsistent at every level, with national curriculum teachers not feeling equipped to teach coding, not all schools offering the GCSE, and numbers at A Level still being too low to give the subject the reputation it needs for HE departments to consider it as a prerequisite. Since 2002, the gender imbalance across STEM seems to have been at the bottom of most government STEM agendas. This is surprising because the female student population, which accounts for half, is currently barely tapped into for Computer Science admissions. Tackling gender imbalance should be the most effective strategy for increasing overall numbers. Another recommendation is that the government should try to enthuse more Computer Science students to become Computer Science teachers before aiming to push them onwards towards industry. With a smaller provision of the subject due to teacher shortages, there is a tight bottleneck on the stream of skilled, enthused young people. However, this may seem like too much of a long-term solution for industry, who need these graduates urgently, not in 15 years' time.

Despite all the current negative impacts felt by Computer Science A Level in FE, UK Computer Science education is undergoing a significant period of change for the better. This is evidenced by the fact that numbers are increasing at levels 2 and 3. The Royal Society's judgement of the system has improved from "highly unsatisfactory" in 2012 to "patchy and fragile" in 2017. Following this positive trend and given the significant recent £84m government investment in the subject, perhaps the judgement in 2022 will be something like 'stable, with continued work to be done'.

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