research note
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Science Fiction?
Uncovering the real level of science skills at school and university

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Executive Summary

Britain will need more science skills if it is to prosper. According to the CBI a staggering 92% of firms across all sectors require people with science, technology, engineering and maths (STEM) skills, but more than 59% are experiencing problems finding them. They estimate that there will be more than two million extra jobs needing people with STEM skills by 2014. The big question is - where are they going to come from? The Government has repeatedly claimed that the numbers of pupils studying STEM subjects is going up. However, this is misleading as the school population has also increased considerably since 1997, meaning that we cannot derive any accurate measure of how popular STEM subjects are from raw numbers. Instead, the percentage of pupils studying these subjects has to be analysed.

STEM at GCSE

The percentage of pupils studying three separate sciences barely improved from 1997 to 2007, with all three subjects attracting 6% of pupils in 1997 and 8% in 2007. Evidence from Ofsted and the Department for Children Schools and Families confirms that pupils who study Biology, Chemistry and Physics are more likely to go on to study science at A-Level and degree-level. In 2006 Gordon Brown pledged that all children achieving at least level 6 at Key Stage 3 would have an "entitlement" to study three separate science GCSEs. However, in practice this pledge has been seriously watered down. The 2006 Education and Inspections Act simply entitled a pupil to study *either* the three separate sciences *or* the new multiple-choice single science and additional science GCSEs – with the ultimate decision left up to the governing body. This fudge is disappointing. Only 46% of England's state schools entered at least one pupil last year for the traditional science GCSEs.

Instead the vast majority of pupils now take the new single GCSE Science qualification under the '21st Century Science' curriculum. This focuses on scientific literacy, tackling scientific issues that are in the public eye such as global warming and mobile phone technology, rather than the underlying grammar of the subject. One of the main concerns for many experts is that the GCSE examination only contains multiple-choice questions. One version of GCSE Science requires pupils to take six multiple-choice tests over two years, each lasting 20 minutes, but gives pupils the opportunity to re-sit each of these tests up to six times. The 45-minute written test set that also forms part of the assessment can be retaken up to 12 times. Moreover, it was recently revealed that the AQA exam board was forced, under protest, to lower their pass mark for a grade C in the new GCSE Science papers by

OFQUAL, the Government's new examination watchdog - a particularly ironic incident, given that OFQUAL was supposedly set up to ensure standards are maintained.

STEM at A-Level

Since 1997 the percentage of pupils studying A-levels in Biology, Chemistry and Physics has fallen, which raises serious doubts about the veracity of any success claimed by the Government in promoting these subjects. The percentages themselves are all extremely low – in 2008 6.5% of students were studying Biology (down from 7.2% in 1997), 4.9% were studying Chemistry (down from 5.5% in 1997) and 3.3% were studying Physics (down from 4.3% in 1997). The raw number of pupils studying these three A-levels has remained relatively constant in Biology and Chemistry since 1997, but Physics has seen a dramatic drop of 4,000 students over the same period. It is absolutely crucial that schools give better advice to pupils about the consequences of their A-Level subject choices. There is no doubt that people with traditional science skills are in demand yet this message does not seem to be filtering through to many pupils.

STEM at University

At first glance science subjects appear to be thriving at university level. Despite a slowdown in recent years, the number of students enrolled on STEM courses has grown from 379,000 to 515,000 in just over a decade. Even when converted to a percentage of all undergraduates, STEM subjects are still on the rise – from 38% in 1997 to 42% in 2008. Yet on closer examination of the traditional STEM subjects it is clear that only a handful have seen any substantial change in popularity. Medicine and dentistry have seen substantial rises, but the number enrolled in Biology, Chemistry and Physics has barely changed in this period. Biology had 18,081 students in 1997 and 18,405 in 2008, and Physics had 9,990 students in 1997 and 10,145 in 2008. The number studying Chemistry has in fact fallen during the same period– from 13,923 to 12,515. Meanwhile, Engineering and Technology subjects have dropped from 90,930 in 1997 to 80,425 in 2008.

Our analysis of the data over the last ten years reveals that the dramatic increase in science numbers has been driven partly by the growth of new subjects, and partly by a clever manipulation of what counts as science. The list of subjects classified as 'science' by the Government has become much broader, and now includes 'Nutrition and Complementary Medicine', 'Geography Studies', 'Physical Geographical Sciences', 'Sport Science' and 'Nursing' among others. Some of these courses, such as Nursing, do not require any science qualifications at GCSE or A-level. A significant number of subjects were reclassified as science in 2002-2003, which explains the notable jump in 'science' enrolment numbers at the time. Some of the key reclassifications, (with changes to the total number of students enrolled on 'science' courses) were:

- Psychology was previously split into two separate groups to reflect the fact that it could be offered as a BA or BSc. This was changed in 2003 so that all Psychology students were now counted as 'Biological Science' students, regardless of how their degree was classified (+13,105 students).
- 'Sport science' was added to 'Other Sciences' (+15,755 students).

- ‘Information Systems’, ‘Software Engineering’, ‘Artificial Intelligence’ and ‘Others in Computing’ were added to the ‘Computer Science’ category (+20,635 students).

Recommendations:

- The Government is deliberately trying to make the statistics on STEM subjects appear better than they really are. This must stop. We must have a sound picture, based on consistent and meaningful data, of what is really happening to STEM skills in our schools and universities.

- The Government should compel all schools to give pupils the option to study Biology, Chemistry and Physics at GCSE.

- The range of STEM qualifications available at GCSE level is highly confusing and should be simplified.

- A new ‘Standards Agency’ should replace OFQUAL and take control of GCSE and A-level examination standards. It should be run by school, business and university representatives, thus removing the incentive to lower grade boundaries in the name of increasing pass rates.

- The Standards Agency must move to restore the academic underpinnings of all STEM subjects. This requires a sharp reversal of recent trends that have seen an emphasis on ‘relevance’ and ’literacy‘ in STEM subjects, rather than a deep understanding of underlying methodologies.

- All secondary schools must appoint a lead teacher with responsibility for careers and education guidance.

- Universities should publish clear, unequivocal lists of less-preferred A-Level subjects. At the same time they should explicitly state the value of studying STEM subjects.

- To attract more science specialists into teaching we must shift away from the default model of university-based teacher training. Instead the Government should develop a suite of employment-based and school-based training routes for undergraduates and career-changers.

- The Government must compel universities to collect much more robust employability data to enable prospective students to make more informed choices about which degree to study. And rather than simply complaining about graduates having the wrong skills, leading employers must take more responsibility for speaking out about new scientific subjects that they regard as inadequate.

- The Government should endorse voluntary science degree kitemarking schemes for newer science degree subjects, run by learned societies. The course would be judged purely in terms of its scientific content This could be modelled on the Degree Recognition Programme run by the Institute of Biology.

Introduction

The case is clear. Britain will need more science skills if it is to prosper. According to the CBI a staggering 92% of firms across all sectors require people with science, technology, engineering maths (STEM) skills, but more than 59% are experiencing problems finding them. They estimate that there will be more than two million extra jobs needing people with STEM skills by 2014.[1] The big question is - where are they going to come from?

Science has been a personal priority of Gordon Brown's since his days in Number 11, and accordingly in recent years there has been a shower of initiatives attempting to address the low numbers of young people eager to don a white coat or grapple with subjects that are perceived to be tougher than others on offer. Mr Brown launched his ten-year Science and Innovation Investment Framework in 2004.[2] It set out the Government's ambition to achieve a "step change" in: the quality of science teachers, science GCSE results, the numbers of students choosing science at A-Level and beyond, and the proportion of better qualified students pursuing careers in research and development.

This open acknowledgement of the problems was welcome. Yet we have a very long way to go. If you only listen to Government pronouncements when the GCSE or A-Level results are published each year, you would be forgiven for thinking that we are on a fast upward trajectory when it comes to STEM skills. "More science students! Better results than ever before!" they say year after year. Sadly, the real picture is much more complicated and much less reassuring. This paper probes beneath the hyperbole, examining the most representative data on uptake and performance in STEM subjects at GCSE, A-Level and University. As well as revealing which subjects we ought to be most concerned about at each level, it suggests the way forward for the Government, schools, universities and employers.

Science skills at school

The Take-Up of STEM Subjects at GCSE

"We are delivering… Our performance in science GCSEs has been going up, not down."[3]

- Ed Balls, Secretary of State for Schools, July 2007

The Government has been quick to claim that the numbers of pupils studying science and other STEM subjects at GCSE is going up. However, this is misleading as the school population has increased by around 75,000 since 1997[4], meaning that any accurate measure of how popular STEM subjects cannot be derived from raw numbers. Instead, in this paper we will analyse the percentage of pupils studying these subjects.[5]

The days when most children who studied science took Biology, Chemistry and Physics separately are long gone**.** The percentage of pupils choosing to study the three core science subjects has remained worrying low since 1997. As can be seen in Figure 1[6] (page 6), despite the Government's ten-year plan, the percentage of pupils studying three separate sciences barely improved from 1997 to 2007, with all three subjects attracting 6% of pupils in 1997 and 8% in 2007 (hence the three lines on Figure 1 masking each other). There was an increase in 2008, which is cause for optimism, although the rise was only very small. It is too early to say whether this will be sustained or built upon in the long term, but this should be the Government's clear aim going forward.

Science experts are divided about efforts to broaden the type of science qualifications pupils can take. For some, anything that pulls children into science is worth considering. For others, straying away from the traditional subjects is nothing more than populist dumbing down that will leave students without the core science skills they need to progress. However, there is little disagreement that Biology, Chemistry and Physics remain the most solid grounding for pupils. Evidence from Ofsted and DCSF confirms that pupils who study these subjects are more likely to go on to study science at A-Level and degree-level, and for this reason the Government must continue to focus on ways to promote them[7].

Critically, there is a serious divide between independent and state schools when it comes to the traditional science subjects. Independent school pupils make up only 7% of pupils sitting GCSE exams, but they represent 21% of the total entries for Biology, 22% of the entries for Chemistry and 21% of the entries for Physics.[8] At the heart of this is the alarming reality that, contrary to Government rhetoric, the traditional sciences are not even offered in many state schools.

In the Government's flagship "Science and innovation investment framework 2004-2014: Next Steps" strategy report, a return to the issues approached in 2004's Ten Year Framework and published as part of the 2006 Budget, the then-chancellor Gordon Brown pledged that all children achieving at least level 6 at Key Stage 3 would have an "entitlement" to study three separate science GCSEs. The report made clear why this was crucial:

"The type of science GCSE taken has an impact upon the likelihood of pupils to progress to A-level study in science and their attainment. The odds of getting an A or B at A-level chemistry in the maintained sector are increased by 76 per cent for pupils who take three separate science GCSEs compared to those who took double science. Double science equips pupils with the necessary skills for A-level but the three separate sciences appear to be an important determinant of progression. It is also crucial to have mechanisms in place to stretch the most able pupils as much as possible. The policy priority is to increase provision of the three separate science GCSEs."[9]

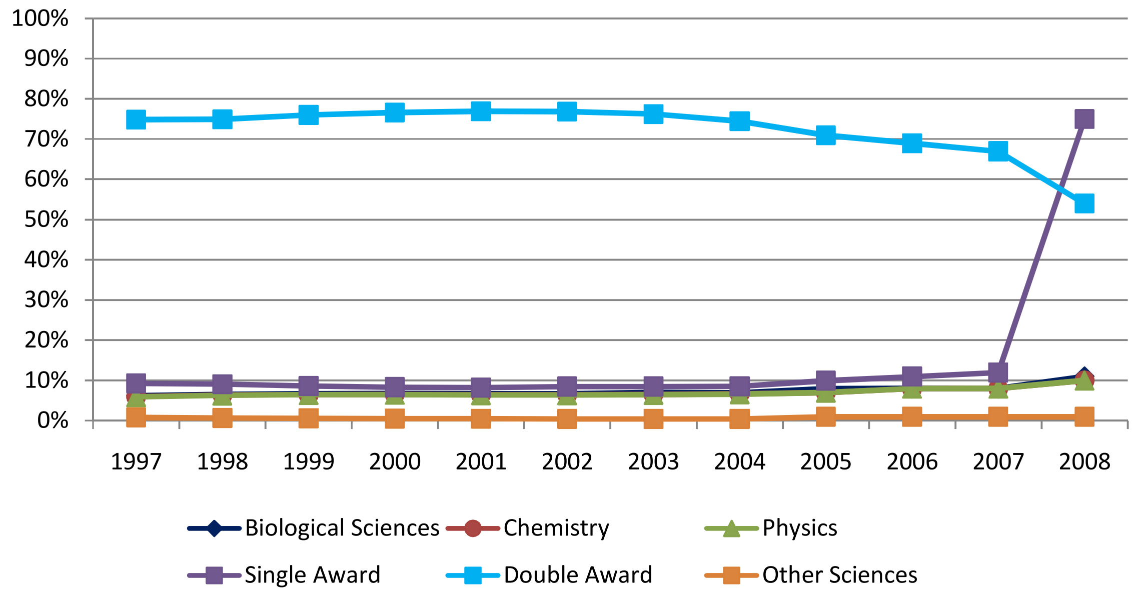
However, in practice this pledge has been seriously watered down. The 2006 Education and Inspections Act simply entitled a pupil to study *either* the three separate sciences *or* the new single science and additional science GCSEs (which we examine below) – with the ultimate decision left up to the school's governing body. This fudge is incredibly disappointing. Given the importance of league tables in today's world (putting pressure on weaker schools to move away from subjects that are known to be tough such as physics and chemistry,) and the difficulty of securing specialist science teachers, the Government should be sending a much stronger message that schools should not dodge the separate sciences. There is no doubt that this is what is happening in many cases. Data obtained by the Conservatives through Parliamentary questions shows that only 46% of England's state schools entered at least one pupil last year for the traditional science GCSEs. [10]

Encouraging more young people to choose the core science subjects at GCSE is crucial to increasing the number who go on to study science at A-Level and university. We recommend strongly that there should be a clear entitlement for every pupil to study Biology, Chemistry and Physics separately at GCSE, no matter where they go to school.

Single and Double GCSE Science

In the early 1990s, 'Double Award' science (worth two GCSEs instead of three) was created as an alternative to studying the three core science subjects separately. From its launch the 'Double Award' science was far more popular than the traditional science GCSEs, with over 70% of pupils electing to study it for most of the last decade. This combined qualification is by definition less challenging than studying three separate sciences, which may explain its popularity.

Figure 1: Percentage of all pupils studying science subjects at GCSE level



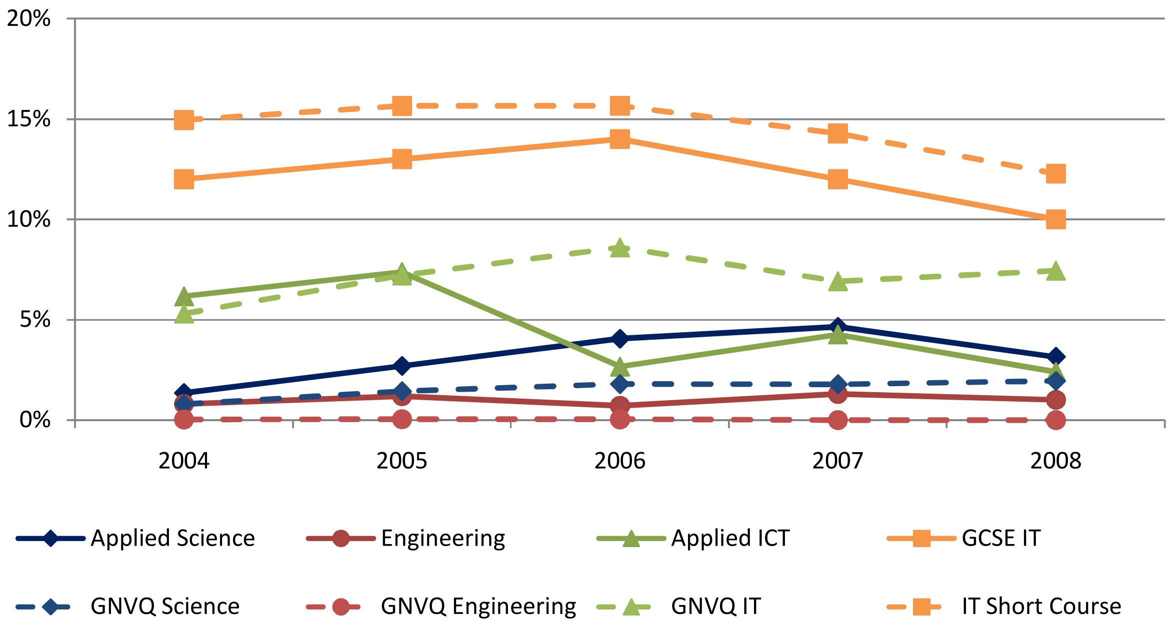
From 2003 we began to see a movement away from studying the Double Award (worth two GCSEs) towards choosing the Single Award (worth just one GCSE), leaving fewer pupils with a solid foundation of knowledge in the sciences. This was intensified in September 2006 when the old Double Award science was scrapped and pupils were shifted into a new single GCSE Science qualification under the new '21st Century Science' curriculum (hence the big leap for students studying the Single Award in Figure 1 above).

This new science curriculum focuses on scientific literacy, tackling scientific issues that are in the public eye such as global warming and mobile phone technology, rather than the underlying grammar of the subject. It gives pupils the option of either studying a single 'GCSE Science' course, containing a multiple-choice exam that tests basic elements of physics, chemistry and biology, or of combining it with GCSE Additional Science or GCSE Additional Applied Science. The additional science exam is an extension of GCSE science, whereas the applied science course has a more practical focus and is designed for those intending to take a vocational scientific course rather than A-levels.[11] In theory this does not reduce levels of knowledge, as pupils still have the option to take two science GCSEs. However, in practice what we see in the graph above is that 75% of pupils are now entered for the single GCSE Science but almost a fifth of these pupils do not take an extra science GCSE. This means that 14% of 16-year-olds are now taking nothing more than a basic multiple-choice science examination before leaving school. We will explore the worrying standards of these qualifications later in this section.

Pupils can also take several other more vocational options in science, technology and engineering at GCSE level. GNVQs were available between 1997 and 2007, although from 2004 these were replaced by Vocational GCSEs[12]. Regrettably, the percentage of pupils studying the new vocational STEM subjects is even lower than for the core sciences, with just 3.1% of pupils taking Applied Science, 2.4% taking Applied ICT and 1% taking Engineering in 2008. Furthermore, this represented a drop from the year before. These low percentages represent something of an improvement over GNVQ Science and GNVQ Engineering, which were even less popular, although GNVQ ICT bucks this trend.

It is striking that despite the huge emphasis placed on ICT in recent years, and the central role that technology plays in many children's lives, only 10% of pupils study it at GCSE level. An extra 12% of pupils study the ICT Short Course (equivalent to half a GCSE) but the percentage of pupils studying either GCSE IT, the IT Short Course or Applied ICT still accounts for fewer than 25% of all 16-year-olds. To compound the low take-up, poor levels of achievement are all too evident in these subjects. In 2008, only half of the pupils managed the equivalent of grade C in Applied ICT, while in both Applied Science and Engineering over 60% failed to reach this benchmark.[13]

Figure 2: Percentage of all pupils studying science-related subjects at GCSE level



The range of STEM qualifications available at GCSE level is highly confusing and should be simplified. For example, there are currently three different IT GCSE-equivalent qualifications. Moreover, GNVQs were replaced by Vocational GCSEs at the same time as the new Diplomas launched in 2008. Diplomas are now offered in

Information Technology and Engineering, even though Applied GCSEs are already available in both subjects, while a new Diploma in 'Science' is scheduled for release in 2011/12.

GCSE STEM Standards

An analysis of the data suggests that Ed Balls' optimism about GCSE science performance was misplaced. The relatively small proportion of children who choose to sit the core sciences tend to perform well. In 2008 more than 90% of pupils who sat GCSE Biology, Chemistry or Physics achieved a C-grade or higher. However, candidates of the new single GCSE Science examination – which as we have seen is vastly more popular - scored much lower. In 2008 just 59% of pupils entering this exam achieved a C-grade or above, meaning that four in ten pupils are leaving school without even a basic grasp of science. The picture fails to improve considerably for those who choose to add an extra science course, with 68% of those who also sit GCSE Additional Science and only 30% of those who sit GCSE Additional Applied Science achieving a C-grade or higher. The national results for Maths are particularly concerning, with 40% of all pupils leaving school at age 16 without achieving a grade C – generally seen as the standard required for being numerate. [14]

The academic rigour of the new GCSE Science qualification was immediately called into question by leading scientists and education experts on its release in 2006. Sir Richard Sykes, then Rector of Imperial College London, published a paper condemning the new 21st Century Science curriculum. He dubbed the new GCSE "sound-bite science" and warned that it would prevent many students getting into a good university.[15] He attacked the emphasis within the new curriculum on encouraging pupils to debate science issues in the news, arguing that science should inform the news and not the other way around. Respected educationalist Baroness Warnock agreed, saying: "Science is going to be relegated to the position of Latin and Greek and will only be taught in Independent schools."[16]

The shift towards 'literacy' and 'relevance' has seriously undermined the value of these new science qualifications. A report in 2009 by SCORE (Science Community Representing Education),[17] an association of six scientific bodies, found that some GCSE Science questions did not require any understanding of science or how science works, while other questions resembled nothing more than general knowledge.[18] One question from a recent GCSE Science paper read: "Why is wireless technology useful?" – the correct answer being "No wiring is needed."[19] A particularly alarming question from a 2006 GCSE Science paper read:[20]

> *"Our moon seems to disappear during an eclipse. Some people say this is because an old lady covers the moon with her cloak. She does this so that thieves cannot steal the shiny coins on the surface. Which of these would help scientists to prove or disprove this idea?*
>
> *A) Collect evidence from people who believe the lady sees the thieves*
> *B) Shout to the lady that the thieves are coming*
> *C) Send a probe to the moon to search for coins*
> *D) Look for fingerprints"*

More recently, the report from the Chief Examiner at EDEXCEL into their 2008 GCSE Science papers remarked that "Candidates seemed secure on some aspects of the solar system and space but over 20% of candidates thought the Sun orbited the Earth" and "only 58% realised that solar cells receive their energy from light energy."[21]

One of the main concerns for many experts is that the GCSE examination only contains multiple-choice questions. To compound this, one version of GCSE Science requires pupils to take six multiple-choice tests over two years, each lasting 20 minutes, but then gives pupils the opportunity to re-sit each of these tests up to six times – with only the best score on any of the re-sits counting towards the final grade. The 45-minute written test set that also forms part of the assessment can be retaken up to 12 times.[22] Moreover, it was recently revealed that the AQA exam board was forced, under protest, to lower their pass mark for a grade C in the new GCSE Science papers by OFQUAL, the Government's new examination watchdog[23] - a particularly ironic incident, given that OFQUAL was supposedly set up to ensure "standards are maintained."[24]

In fact even the traditional science subjects have not escaped controversy about dropping standards. A study published by the RSC last year found that 2000 students sitting a composite science exam made up of questions from five decades of O-Level/GCSE questions found more recent questions much easier than older ones. To ensure fairness the paper concentrated on topics that were still covered in the GCSE Chemistry curriculum in some form. The average mark for questions from the 1960s was 15% compared to 35% for questions from the current decade.[25]

GCSE Maths seems to be suffering a similar fate to science. A recent analysis showed that over time, the content covered in GCSE Maths has narrowed, the questions have become easier and the standards required to pass the examination have fallen dramatically (between 1990 and 2006, the pass mark for grade C fell from just over 50% to about 20%).[26] In December 2008, it was announced that secondary schools would pilot a 'twinned' Mathematics course that would be worth two GCSEs. As with the new structure of the science GCSEs, the signs are that a 'Double Maths' GCSE has been designed to encourage more students to take the subject by focusing on mathematical literacy rather than deeper understanding. The new course will examine "mathematics in everyday contexts including financial applications" and "problem solving". The DCSF press release announcing it stated that exam boards will be asked to develop a syllabus that "should help students develop confidence in maths"[27] rather than challenge and stretch the pupils in order to understand their true ability. After what happened with science, there is a serious risk that this new course could leave many pupils without a solid grounding in pure maths.

STEM GCSE Recommendations:

Encouraging more young people to choose the core science subjects at GCSE is crucial to increasing the number who go on to study science at A-Level and university. We recommend strongly that the Government should compel every school to offer Biology, Chemistry and Physics at GCSE for any child who wants to take them.

The range of STEM qualifications available at GCSE level is highly confusing and should be simplified. For example, there are currently three different IT GCSE-equivalent qualifications. Moreover, GNVQs were replaced by Vocational GCSEs at the same time as the new Diplomas launched in 2008. Diplomas are now offered in Information Technology and Engineering, even though Applied GCSEs are already available in both subjects, while a new Diploma in 'Science' is scheduled for release in 2011/12.

After years of debatable standards and the incremental creep of vocational courses into the space inhabited by GCSEs, a new approach is required to inject greater credibility and integrity back into the academic study of STEM subjects at the age of 14. We recommend that a new 'Standards Agency' should replace OFQUAL and take control of GCSE and A-level examination standards. The Standards Agency should be given responsibility for monitoring and maintaining exam standards, including full transparency of pass marks and grade boundaries. It should be run by school, business and university representatives, thereby removing the incentive to lower grade boundaries in the name of increasing pass rates.

This Standards Agency must move to restore the academic underpinnings of all STEM subjects. This requires a sharp reversal of recent trends that have seen an emphasis on 'relevance' and 'literacy' in STEM subjects, rather than a deep understanding of underlying methodologies. In the past few years, we have seen the introduction of new science GCSEs that have been widely criticised by university professors and employers for their lack of scientific content. The same now appears to be happening with mathematics at GCSE and A-level. We believe that an independent Standards Agency run by representatives from Higher Education and STEM employment sectors would be in a strong position to demand a tougher level of core knowledge content in qualifications. Having said that, the two pre-requisites of such changes are that fewer children start their GCSE courses without mastering basic skills and that strong Diploma and vocational routes are available for students for whom academic courses are not appropriate or desired.

STEM at A-level

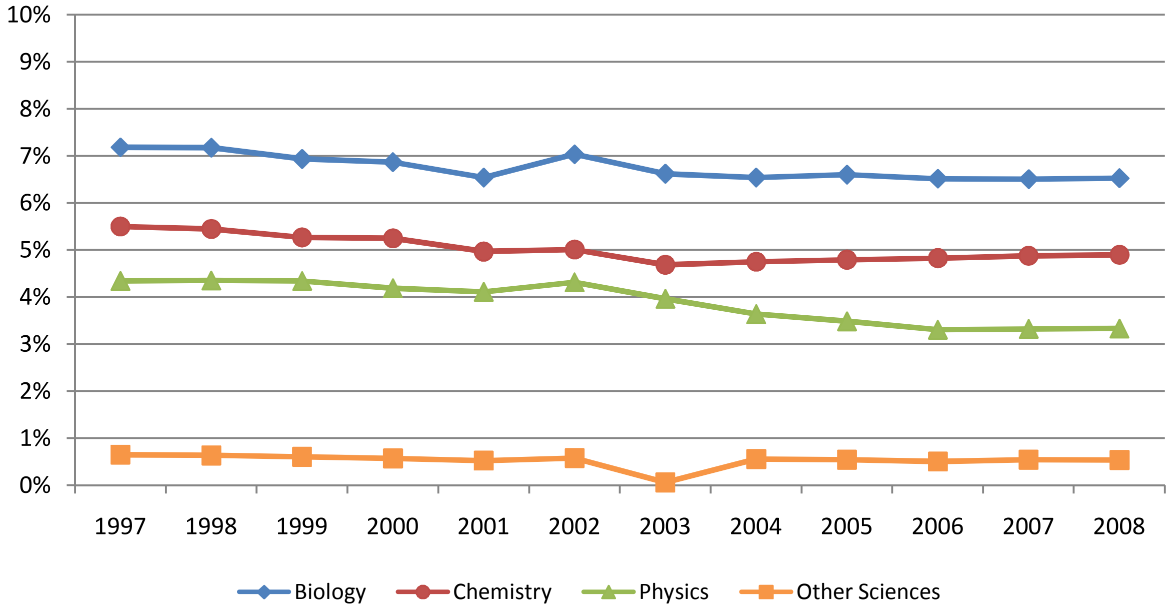
"The continued increase in those taking sciences [at A-level is] positive and testament to our drive to increase take-up of these subjects."[28]

- Jim Knight, Schools Minister, August 2008

As with GCSEs, it is more instructive to look at the percentage of 16 to 18-year-old pupils studying STEM subjects rather than raw numbers, to negate the issue of a rising student population. A-levels in STEM subjects have not seen the degree of upheaval that has characterised GCSEs in this field. Yet the popularity of the subjects is a serious concern.

Figure 3[29] demonstrates the problems facing science at A-level. Since 1997 the percentage of pupils studying A-levels in Biology, Chemistry and Physics has fallen, which raises serious doubts about the veracity of any success claimed by the Government in promoting these subjects. The percentages themselves are all extremely low – in 2008 6.5% of students were studying Biology (down from 7.2% in 1997), 4.9% were studying Chemistry (down from 5.5% in 1997) and 3.3% were studying Physics (down from 4.3% in 1997). This uptake is even lower than the equivalent at GCSE. The raw number of pupils studying these three A-levels has remained relatively constant in Biology and Chemistry since 1997, but Physics has seen a dramatic drop of 4,000 students over the same period. As with GCSEs, independent schools continue to produce a disproportionate number of entries for science A-levels. Although independent schools only educate 11% of all A-level students, they represent 18% of examination entries for Biology, 22% for Chemistry and 23% for Physics.[30]

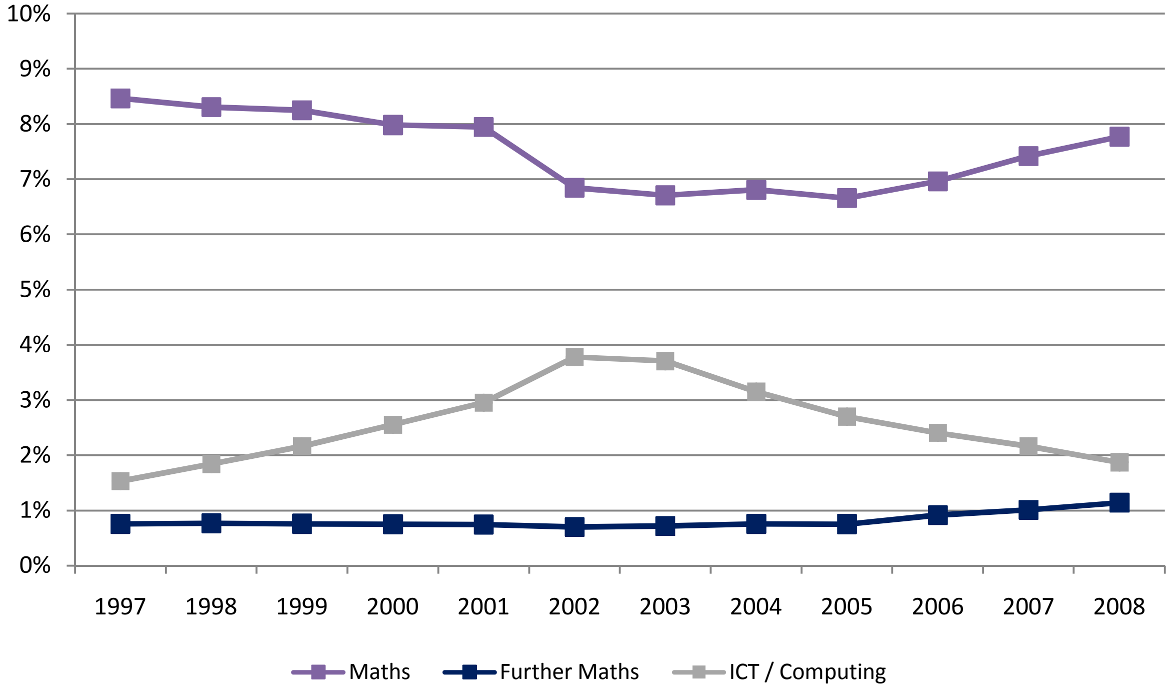
Figure 3: Percentage of students studying science subjects at A-Level



The performance of students in these subjects is also noteworthy. As we have seen, at GCSE level, over 90% of pupils who studied the three sciences as separate examinations achieved grade C or higher, but this pattern was not replicated at A-level in 2008. The percentage of pupils achieving at least grade C was 70% in Biology, 77% in Chemistry and 72% in Physics.[31]

ICT and Computing present a more complicated picture. If one combines entries for A-levels in Computer Studies and ICT, the situation has improved since 1997 to the tune of 3,744 students – equivalent to 0.4% of all students.[32] A closer inspection of the overall trend, however, reveals a much more concerning outlook. Computer Studies A-Level attracted 10,188 students in 1997 and rose to a peak of 10,913 students in 2001, but since then the subject has haemorrhaged students and in 2008 had only 4,192 entries. ICT was introduced in 1999 and rapidly grew to 16,309 entries in 2003, but this too has fallen dramatically to 9,760 entries in 2008. By combining these courses, the scale of the drop becomes even more evident: having peaked in 2003, the number of students studying ICT / Computing has plummeted by over 40% in just five years and the percentage of students studying these courses has dropped accordingly from 3.7% to 1.9% over the same period.

Figure 4: Percentage of students studying science-related subjects at A-Level



Maths at A-level appears to provide some cause for optimism, as shown in Figure 4.[33] Maths and Further Maths entries are currently rising, and the Government quite rightly drew attention to the impressive 14% rise in Maths entries between 2004 and 2007.[34] However, the overall picture since 1997 is more complicated than the Government wishes to admit. There was a sharp fall in A-Level Maths entries from 56,000 (8.5% of all students) in 1997 to 46,000 (6.7%) in 2005. Meanwhile, Further Maths only attracted an additional 192 students from 1997 to 2005, leaving it rooted at 0.8% of all A-level students. So what happened in 2005 to turn things around? In 2002 the Qualifications and Curriculum Authority (QCA) decided that Maths A-level was "too hard"[35] and as a result they changed the syllabus. As can be seen in Figure 4, the effect was impressive as both Maths and Further Maths entries began to slowly climb once the new syllabus was tested for the first time in 2005. Nonetheless the number of students choosing A-level Maths in 2008 has only now recovered to its 1997 level and the percentage of students taking the subject is still 0.7% behind the percentage in 1997. Achievement in these subjects overall is higher than for the traditional science subjects, with 82% of students reaching a C-grade or higher in maths and 90% reaching at least a C-grade in Further Maths in 2008.[36]

In 2009 another storm has hit regarding the new mathematics A-level course entitled 'Use of Mathematics'. This is currently taught at only AS-level (first year of Sixth Form) but the QCA intends to expand it into full two-year course. However, over 60 university academics have called for this course to be scrapped entirely because it does not prepare pupils for university.[37] They claim that the course is more concerned with practical activities than developing mathematical understanding, demonstrated by the compulsory algebra and calculus units being "considerably less demanding and covering less content than A-level". Professor Nick Shepherd-Barron from Cambridge University added that 'Use of Mathematics' described the course as "a mindless exercise in the execution of routines."[38] The response from the QCA to these criticisms was rather limp, merely stating that 'Use of Mathematics' is "designed to be accessible to a wide range of students." Opening up A-Level Maths to pupils who would otherwise not take it is a worthwhile goal, yet there is a very real risk that candidates for the straight Maths course might divert to the new option because they consider it to be easier. If the Use of Mathematics course is to continue it is essential that universities and employers give a clear message about the core skills they really value. This seems likely to become another ''soft' A-Level subject that top universities will prefer not to accept and employers will not value.[39]

This provides a stark reminder of why it is absolutely crucial that schools give better advice to pupils about the consequences of their A-Level subject choices. There is no doubt that people with traditional science skills are in demand yet this message does not seem to be filtering through to many pupils. Research from the Futuretrack survey,[40] found that there are serious gaps in the level and quality of advice in schools. Just half of young people who had applied for full-time courses through UCAS had received an adequate amount of individual careers guidance. Around three-quarters felt they had received either not enough or no information on the career implications of post-16 exam choices and 60% had received not enough or no information on the relationship between higher education courses and employment, or the range of higher education courses available. We fully endorse the Sutton Trust's recommendation that all secondary schools should appoint a lead teacher with responsibility for careers and education guidance, and that this teacher should be expected to undertake regular training to keep this knowledge up to date.

However, the problem does not lie with schools alone. Universities are quick to complain about the low levels of students with adequate science skills coming through the schools system, but they are not yet doing enough to steer pupils themselves. It is clear from our research that the vast majority of research-intensive universities like to recruit students who have studied STEM subjects at A-level. To give just one example, Biology, Chemistry, Further Mathematics, Mathematics and Physics comprise close to half of all accepted A-levels for Bristol University (49.8%) and University College London (46.9%).[41] Interestingly some admissions tutors told us that an ideal arts candidate would have studied Maths alongside more standard arts A-levels in order to demonstrate range and rigour. However, at present only one university, LSE, publishes a clear list of non-preferred subjects on its website. Disappointingly Cambridge University has recently withdrawn its list of non-preferred subjects and replaced it with general advice that is much more confusing. Admissions advice from the leading research universities is patchy at best and misleading at worst. As a result, in many cases (and particularly in state schools) pupils are continuing to select softer options that these institutions do not regard as proper preparation for higher education and that will seriously reduce their chances of winning a place. Universities should publish clear, unequivocal lists of less-preferred A-Level subjects. At the same time they should explicitly state the value of studying STEM subjects.

STEM A-Level Recommendations

Opening up A-Level Maths to pupils who would otherwise not take it is a worthwhile goal, yet there is a very real risk that candidates for the straight Maths course might divert to the new option because they consider it to be easier. If the Use of Mathematics course is to continue it is essential that universities and employers give a clear message about the core skills they really value. This seems likely to become another ''soft' A-Level subject that top universities will prefer not to accept and employers will not value.[42]

There is no doubt that people with traditional science skills are in demand yet this message does not seem to be filtering through to many pupils. We fully endorse the Sutton Trust's recommendation that the Government must fund all secondary schools to appoint a lead teacher with responsibility for careers and education guidance, and that this teacher should be expected to undertake regular training to keep this knowledge up to date.

Admissions advice from the leading research universities is patchy at best and misleading at worst. As a result, in many cases (and particularly in state schools) pupils are continuing to select softer options at A-Level that these institutions do not regard as proper preparation for higher education and that will seriously reduce their chances of winning a place. Universities should publish clear, unequivocal lists of less-preferred A-Level subjects. At the same time they should explicitly state the value of studying STEM subjects.

STEM Teachers

Finding enough specialists to teach STEM subjects at secondary school level has been a major policy headache for many years. The Government has consistently missed its targets for recruitment into initial teacher training courses in science and mathematics.[43] The number of science teachers has halved over the last 20 years. Now just one in five (22%) of school science teachers are specialists in physics and 22% are specialists in chemistry. For biology the figure is 32%. The figures also vary by school type, with many non-selective state schools really struggling to find STEM staff with the right qualifications. At present 75% of mathematics lessons at grammar schools are taught by teachers with a degree in mathematics, compared with just under half (47%) of maths lessons in comprehensives up to age 16 and 58% of comprehensives to age 18.[44] Such low numbers are obviously extremely worrying. If we are to enthuse students and encourage them to take the core STEM subjects the minimum requirement is that we must have teachers who are themselves skilled in and comfortable with these subjects.

One inevitable result of low application numbers for science and maths is that fewer candidates are turned away and standards of teachers coming through the system drop. At postgraduate level in 2005-06 (the last year for which figures are available) the standard of candidates for STEM subjects were significantly lower than other non-shortage subjects. For maths and science the proportions of entrants with a 2:1 or above were 46% and 50% respectively. In 2005-06 318 graduates started a Maths PGCE with only a third or pass in their first degree.[45]

The Government has tried a number of incentives to pull more STEM teachers into the system, such as the launch of "golden hellos' in 2000 (which caused an initial increase in teacher training applications, but numbers had started to dip significantly again by 2008).[46] It is now apparent that we need to take a new approach to attracting good teachers in these vital subjects. Teach First, a scheme run by an independent charity that parachutes top graduates into challenging schools to learn on the job, has provided a particularly striking example.[47] The programme, which allows star graduates to leave teaching after two years and go into a more corporate career, gives STEM teaching first priority. Of the 360 applicants that joined in 2008 over 100 are teaching maths and science. While this scheme has proved to be a real success the charity has told us that it does not envisage providing more than 5% of all teacher training places. However, we can learn from this example.

STEM Teaching Recommendations

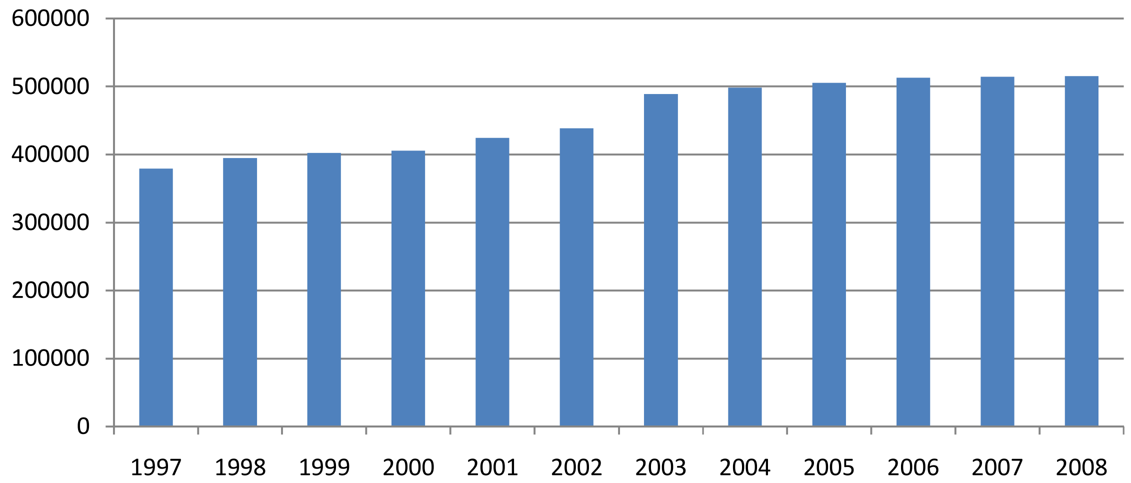
As we recommended in our earlier report, *More Good Teachers,* we must abandon the assumption that teaching must always be a job for life, rather than something talented people can opt in and out of at different stages in their career. This would attract new sorts of people into STEM teaching, allowing a strong chemistry graduate to teach for a few years before moving into a career that earns more money, or pulling in a talented older mathematician who has worked for a big company and wants to give something back to the community.

In addition we must shift away from the default model of training, in which trainees have to commit to returning to university for a year to study for a PGCE. Instead the Government should develop a suite of employment-based and school-based training routes for undergraduates and career-changers. STEM teacher numbers have been at crisis levels for many years. Only a real revolution in thinking will drive the serious change that is needed now.

Science skills at university

"We're seeing more young people studying maths, engineering and the pure sciences at undergraduate level".[48] - *Lord Drayson, Science and Innovation Minister, May 2009*

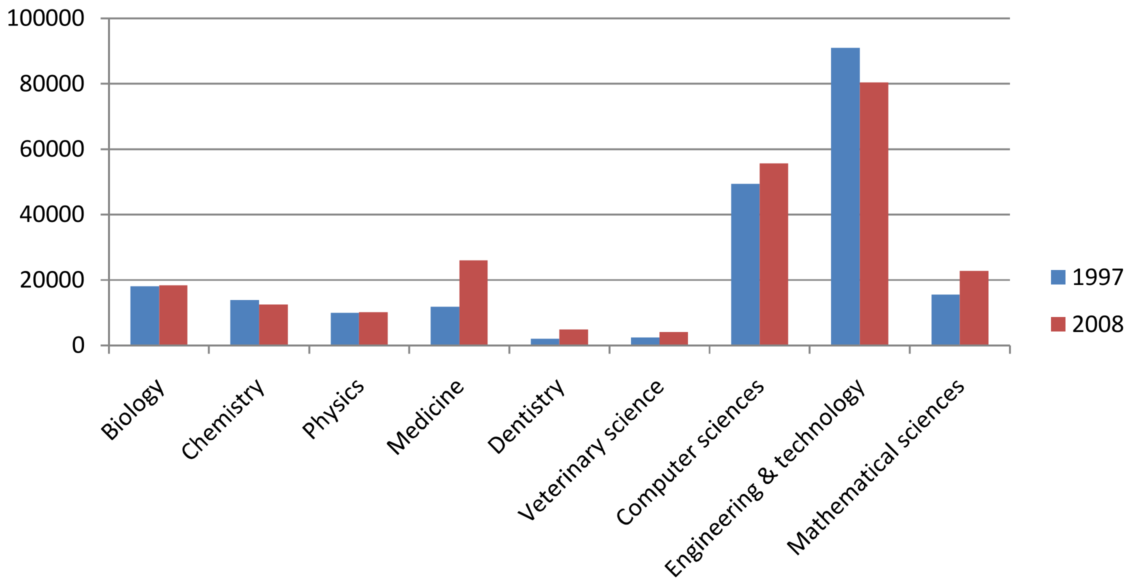
Figure 5: Number of undergraduate students enrolled on all 'science' courses



At first glance science subjects appear to be thriving at university level. Despite a slowdown in recent years, the number of students enrolled on STEM courses has grown from 379,000 to 515,000 in just over a decade (Figure 5).[49] Even when converted to a percentage of all undergraduates, STEM subjects are still on the rise – from 38% in 1997 to 42% in 2008.[50]

Yet when we examine the traditional STEM subjects it is clear that only a handful have seen any substantial change in popularity (see Figure 6 below).[51] Over the past decade the number of students studying Medicine has increased dramatically (+14,142) and Dentistry has also seen a notable rise (+2,741). Broad groupings of undergraduate courses such as Mathematical Sciences and Computer Sciences have also seen healthy gains. But the number enrolled in Biology, Chemistry and Physics has barely changed in this period. Biology had 18,081 students in 1997 and 18,405 in 2008, and Physics had 9,990 students in 1997 and 10,145 in 2008. The number studying Chemistry has in fact fallen – from 13,923 students in 1997 to 12,515 in 2008. Meanwhile, Engineering and Technology subjects have dropped from 90,930 in 1997 to 80,425 in 2008.

Figure 6: Number of undergraduates studying 'traditional' science subjects



Our analysis of the data over the last ten years reveals that the dramatic increase in science numbers has been driven partly by the growth of new subjects, and partly by a clever manipulation of what counts as science. There have been numerous changes to the way that subjects are categorised within the enrolment data. The list of subjects classified as 'science' by the Government has become much broader, and now includes 'Nutrition and Complementary Medicine', 'Geography Studies', 'Physical Geographical Sciences', 'Sport Science' and 'Nursing' among others. Some of these courses, such as Nursing, do not require any science qualifications at GCSE or A-level, which raises a question about whether it is misleading to classify them as science. A significant number of subjects were reclassified as science in 2002-2003, which explains the notable jump in 'science' enrolment numbers at the time in Figure 5 (page 15). Below we list some of the key reclassifications, with changes to the total number of students enrolled on 'science' courses in brackets.

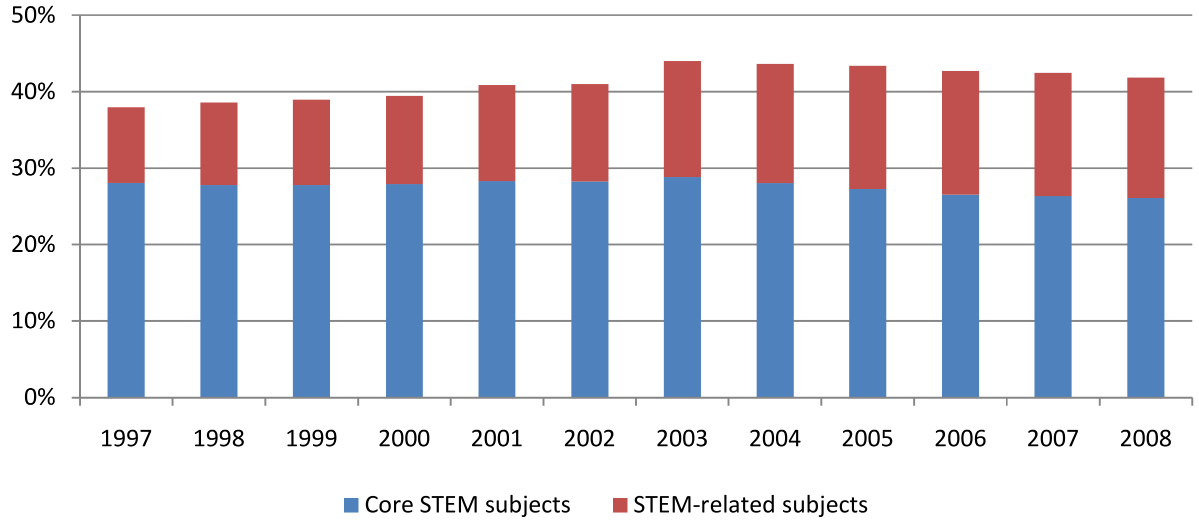
- Psychology was previously split into two separate groups to reflect the fact that it could be offered as a BA or BSc. This was changed in 2003 so that all Psychology students were now counted as 'Biological Science' students, regardless of how their degree was classified (+13,105 students)
- 'Sport science' was added to 'Other Sciences' (+15,755 students)

- ‘Forensic science’ was added to ‘Archaeological Science’ courses (+545 students)
- ‘Information Systems’, ‘Software Engineering’, ‘Artificial Intelligence’ and ‘Others in Computing’ were added to the ‘Computer Science’ category (+20,635 students)

Some of these changes seem sensible. For instance, new subjects have spun out of computer science and it makes sense to regard these new courses as STEM courses - although some technology experts we spoke to were disapproving of a move away from core technical knowledge at undergraduate level, However, the decision to include all psychology students appears to have been a more overtly political move to massage statistics. Such moves are deeply unhelpful. If the Government is serious about tackling the shortage of science skills the first step must be to maintain a clear picture of what skills we do have.

Because of the rapid expansion of the student population in recent years (there were 234,000 more full-time undergraduates in 2008 than in 1997) it is again more useful to talk about the percentage of students when assessing overall trends to gauge the popularity of STEM subjects. To investigate the impact that these subject reclassifications have had, in the graph below we have split the courses labelled as ‘STEM’ by the Government into two distinct categories – core STEM subjects and newer subjects related to STEM.

Figure 7: Percentage of all undergraduates studying core STEM subjects and STEM-related subjects



In this graph **Core STEM subjects** are: Medicine & Dentistry, Veterinary Science, Anatomy & Physiology, Pharmacology, Toxicology & Pharmacy, Opthalmics, Audiology, Medical Technology, Other subjects allied to Medicine, Biology, Botany, Zoology, Genetics, Microbiology, Molecular Biology, Biophysics & Biochemistry, Chemistry, Physics, Astronomy, Geology, ‘Mathematical Sciences’ (all subjects) and ‘Computer Sciences’ (all subjects).

STEM-related subjects are: Nutrition and Complementary Medicine, Science of aquatic & terrestrial environments, Physical geographical sciences, Others in physical sciences, Geography Studies, Archaeology, Forensic Science, Psychology, Nursing , Other biological sciences (including Sport Science).

It is clear from the graph above that non-traditional stem-related subjects have played a significant part in the increase of 'science' students. As stated earlier, the percentage of all undergraduates choosing 'science subjects', according to the Government's classification, has risen from 38% to 42% since 1997 and the raw number of science undergraduates has also increased. However, crucially the percentage of undergraduates studying the core STEM subjects listed above has fallen from 28% in 1997 to 26% in 2008.

One could argue that any new subjects that pull students into science must be a good thing – and that it is irrelevant what science subjects students study as long as they are learning basic science skills that will equip them for a possible scientific career. This latter point is of course the catch. A social psychology course can be useful in its own right, but will not provide a solid grounding in basic science skills. And there are growing concerns that some of the newer science subjects are not equipping students with the sort of skills that will be useful to employers, or even enough knowledge to make them scientifically literate.

Forensic Science is a case in point. The growth in Forensic Science undergraduate degrees has been phenomenal in recent years, rising from two in 1991 to 285 in 2009. Inspired by TV detective programmes including Crime Scene Investigation and Silent Witness, students have been flocking to what sounds like a focused vocational science degree with the likelihood of a good job at the end. As well as straight Forensic Science, undergraduates in the UK can study courses including Forensic Investigation with Tourism and Leisure, Counselling Skills with Forensic Biology or even Film Studies and Forensic Science. Yet there has been considerable scepticism about the usefulness of these degrees. Dr Angela Gallop, the founder of the Forensic Alliance, told the Commons Science and Technology Select Committee that in many cases universities were teaching "pseudo forensic science" where "all the basic, pure science that you need to operate as a really good forensic scientist is missing"[52]. The committee report 'Forensic Science on Trial', published in 2005, reported "extensive evidence that a large proportion of forensic science courses on offer provide poor preparation for a career in forensic science". Indeed, a minister from the Home Office warned that young people may be applying for courses that did not equip them in what they expect to be their future career.[53] Forensic science employers generally said that they wanted to hire scientists, and therefore preferred people with a first degree in a more traditional science such as Chemistry. Given this, there is a real case for arguing that some universities are misleading students by marketing these degrees.

If prospective students had access to robust employability data about particular courses one wonders whether Chemistry might overtake Forensic Science once more. We feel strongly that the Government must encourage or compel universities to collect much more robust employability data to enable prospective students to make more informed choices. This should include information on salaries (known to be higher for science graduates despite all the talk of a universal graduate premium). The Government should collate this data on a national, well-publicised website. As we have already noted, advice in schools must also be improved so that younger people have a better understanding of the implications of their choices. And rather than simply complaining about graduates having the wrong skills, leading employers must take more responsibility for speaking out about new scientific subjects that they regard as inadequate.

Of course, it is possible that newer scientific degree courses suffer from snobbery, or from recruiters who are stuck in the past and want degrees to remain exactly as they were when they went to university. For this reason it is not the course a student chooses but the skills he or she learns from that course that matter. The most worrying allegation against Forensic Science graduates is that often the most rudimentary science skills are missing. If a student comes away from a course without a basic understanding of scientific method then that course should not be classed as science. Academics we interviewed suggested that in some cases universities had rebadged Chemistry courses as Forensic Science, because it had become easier to sell that course to students. The question then becomes – has the chemistry content remained rigorous? At present there is no easy way for a prospective student, a parent or an employer to judge this.

We recommend that the Government should endorse voluntary science degree kitemarking schemes run by learned societies. So, for instance, universities keen to prove the rigour of their Forensic Science course to students and employers could apply to the Royal Society of Chemistry for a science kitemark. The course would be judged purely in terms of its scientific content (with the kitemark only up for renewal every three or five years to prevent unnecessary bureaucracy and expense). This could be modelled on the Degree Recognition Programme run by the Institute of Biology (but currently only used by universities in other countries)[54]. The Institute of Biology requires that a course must comprise at least 50% biology content, with a clear use of the application of biological principles including a balance of contemporary and traditional science. It must also include a project or dissertation in biology, and experience of experimental work or data handling in biology. Such criteria would need to be adapted to fit more general scientific courses, such as psychology.

STEM at University Recommendations

We feel strongly that the Government must encourage or compel universities to collect much more robust employability data to enable prospective students to make more informed choices. This should include information on salaries (known to be higher for science graduates despite all the talk of a universal graduate premium). The Government should collate this data on a national, well-publicised website. As we have already noted, advice in schools must also be improved so that younger people have a better understanding of the implications of their choices. And rather than simply complaining about graduates having the wrong skills, leading employers must take more responsibility for speaking out about new scientific subjects that they regard as inadequate.

The Government should endorse voluntary science degree kitemarking schemes for newer science subjects, run by learned societies. Thus universities keen to prove the rigour of their Forensic Science or medicinal chemistry course to students and employers could apply to the Royal Society of Chemistry for a science kitemark, and sports science or psychology courses would apply to the Institute of Biology. The course would be judged purely in terms of its scientific content (with the kitemark only up for renewal every three or five years to prevent unnecessary bureaucracy and expense). This could be modelled on the Degree Recognition Programme run by the Institute of Biology.

Conclusion

A closer examination of the statistics on numbers of young people studying STEM at GCSE, A-Level and university suggests that the Government is deliberately trying to make things appear better than they really are. This is of course completely understandable. First, there is the question of political capital – having flagged up a problem and set lots of targets for tackling it ministers must be seen to deliver. There is also probably a second, less cynical motivation, which is that endless pessimism about science skills would not be encouraging for young people (and may have the opposite effect of making these difficult subjects appear even less alluring) or for teachers who are trying their best to enthuse their students. However, this obfuscation must stop. It is incredibly important that we have a sound picture, based on consistent and meaningful data, of what is really happening to STEM skills in our schools and universities. If we do not have a clear idea of what the extent of the problem is how can we tackle it properly?

There is much that the Government can and must do, including focusing on new ways to pull in talented specialists to teach science, compelling schools to offer the core sciences and not just the more popular combined options, and backing a refocusing of STEM qualifications so that they are once more academically rigorous rather than just 'relevant' to students' lives. Yet this is not just a problem for Government. Schools must focus on giving much better advice to students about the implications of choosing different STEM subjects at GCSE and A-Level. And those who complain most vociferously about young people leaving schools without the right STEM skills - employers and universities – must work much harder to get the message across that they rate core STEM qualifications very highly when making decisions about who to recruit.

Some science experts and institutions have chosen to keep quiet about the scale of the problems facing us when it comes to STEM skills, for fear of annoying the Government or appearing ungrateful for the new pots of state money that have been handed out in this area in recent years. The Royal Society of Chemistry chose to speak out recently, publishing an e-petition on the Number 10 Downing Street website. This expresses a view supported by many:[55]

"Science examination standards at UK schools have eroded so severely that the testing of problem-solving, critical thinking and the application of mathematics has almost disappeared. Even bright students with enthusiastic teachers are being compelled to "learn to the test", answering undemanding questions to satisfy the needs of league tables and national targets. The RSC has powerful evidence of the decline in standards, adding to the revelation that students are able to receive a "good pass" with a mark of 20%. This system is failing an entire generation which will be unequipped to address key issues facing society, whether as specialist scientists or members of a wider scientific community. The record-breaking results in school examination passes are illusory, with these deficiencies having to be remedied at enormous expense by universities and employers. This is compounded by key sections of the education community being in denial. Unless addressed, we will see a continuing decline in our international competitiveness, reduced prosperity for ourselves, and limited career prospects for our children."

Perhaps the most crucial point, to be heeded by the Government, schools, universities and employers, came at the end of this petition. It warned: 'Urgent action is required before it is too late."

research note
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Policy Exchange

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Work on Education at Policy Exchange

Science fiction? is the second in a series of reports on innovation and industry. The first note in the series was on the role of government and future work will cover the role of higher education in fostering innovation and the future of manufacturing in the UK.

The Education Unit recently published **'Educating Rita?'**, the third report in a major new programme of work at Policy Exchange on universities. Over the course of this year we will be looking at a range of issues in higher education including how we should fund universities in the future, how we maintain fairness and promote wider access to universities, and whether the Government's current interventions on innovation within universities are working.

We have also published a number of reports on schools and recently launched a major new project on skills. **'A Guide to School Choice Reforms'** looks at the lessons learned from existing school reforms in England (the academies programme), Sweden (free schools) and the United States (charter schools). We assess the success of reforms in all these countries against seven criteria which we believe a schools market should meet in order to find the right balance between promoting innovation and choice while maintaining accountability and quality control.

For further information on the work of the Education Unit please contact Anna Fazackerley, Head of Education unit at anna.fazackerley@policyexchange.org.uk

About Policy Exchange

Policy Exchange, an independent educational charity, is Britain's largest centre-right think tank. Our mission is to develop and promote new policy ideas which will foster a free society based on strong communities, limited government, national self confidence and an enterprise culture. In contrast to many other think tanks Policy Exchange is committed to an evidence-based approach to policy development. Our impact speaks for itself: from housing to policing reform, education to the NHS, our proposals have been taken on board by the main political parties. Registered charity number 1096300.

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