Staying in the science stream: patterns of participation in A-level science subjects in the UK.


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**Abstract**

This paper describes patterns of participation and attainment in A-level physics, chemistry and biology from 1961 to 2009. The A-level has long been seen as an important gateway qualification for higher level study, particularly in the sciences. This long term overview examines how recruitment to these three subjects has changed in the context of numerous policies and initiatives that seek to retain more young people in the sciences. The results show that recruitment to the pure sciences has stagnated, general trends have hardly varied and the track record of government policy in influencing change is not strong. There is no evidence for increasing achievement gaps between the sexes at A-level and even national policy requiring that all young people study science up to the age of 16 appears to have had little impact on recruitment at this level.

**Introduction**

This paper describes patterns of participation in A-level science subjects from the early 1960s through to the present day. Long seen as the ‘gold standard’ qualification for entry to Higher Education in England and Wales; patterns of participation in the two year A-level provide a useful indicator of the relative health of subjects at school, college and at university. Of all the subjects on the school curriculum it is arguably the sciences, and the physical sciences in particular, which are subject to the greatest scrutiny with regard to what is taught, how it is taught, to whom and by who. The view of the current UK Government being that: ‘while not everyone is in the business of science, science is everybody’s business’ (Brown 2009). In the UK, the media is replete with stories of science in crisis: fewer young people are enrolling in the sciences at university (BBC 2007), there are insufficient well-qualified science teachers in schools (Guardian 2008) and the cost to the economy of the ‘swing’ from the sciences is estimated in billions of pounds (The Times 2008). The response to this ‘crisis account’
surrounding the supply and skills of future Science Technology Engineering and Mathematics (STEM) professionals by the Government has been an ambitious 10 year Science and Innovation framework (HMT 2004). The aim of which is:

“for the UK to be a key knowledge hub in the global economy, with a reputation not only for outstanding scientific and technological discovery, but also as a world leader in turning that knowledge into new products and services” (HMT 2004, p5).

The government’s commitment to make ‘Britain the best country in the world in which to be a scientist’ (Brown 2009) is underlined by recession proof increases in the Science and Research Budget to around £11.24 billion (or of about 17.5% between 2007/08 and 2010/11) (House of Commons 2008). The motivations behind such initiatives are largely economic and represent Industry’s concerns for a suitably skilled workforce (CBI 2008, Department for Business Innovation and Skills 2009), particularly in the face of competition from other established and emerging economies, such as India and China (Society of Chemical Industry 2006, Leitch Review of Skills 2006). Central to addressing this ‘skills shortage’ are strategies aimed at increasing recruitment to science subjects at school, at university and through vocational and work based provision (HMT 2004, Department for Business Innovation and Skills 2009).

Taken together the government’s response to the UK’s ‘science problem’, and its subsequent initiatives to develop the nations’ scientific skills base, largely lie through increasing the supply of young people into the science professions, either through attracting well qualified people into teaching, increasing the science content of the National Curriculum in schools or reforming the curriculum so as to encourage able young people to remain in the ‘science stream’ and subsequently study the subject at university. Many of these initiatives are well established and the aim of this paper is to consider the extent to which they are reflected in patterns of participation and attainment in A-level science courses over the history of the qualification.

Participation in post compulsory science programmes

‘A-levels are not what they were’ BBC news, 15th August 2005

‘Irresistible decline of physics’ Times Education Supplement, 11th August 2006, p5

‘Who’s killing science?’ Education Guardian 17th October 2006, p10

Concerns over the declining participation of young people in the physical sciences are not new, nor are they limited to the United Kingdom. In Europe we are told that young people are losing interest in scientific studies (Convert 2005, Haas 2005), in the United States that students are lagging behind their international peers in mathematics and science (Obama 2009) and internationally that only a minority of young people want to become professional
scientists (OECD 2007). The longevity of these concerns is also startling. The expansion of Higher Education in the UK during the 1960s while contributing to the social, educational and economic development of the country had, according to many commentators, an arguably less desirable impact on recruitment to the sciences (Council for Scientific Policy, 1968). Between 1962 and 1967 the proportion of candidates following the sciences at first year A-level fell from 42% of the cohort to 31%; at the same time, the proportion of candidates admitted to study science and technology at university fell from 46% of the cohort to 41%, leading to fears that if things continued as they were, university science faculties would find themselves ‘increasingly recruiting rather than selecting candidates’ (paragraph 6). Such concerns about an apparent ‘swing from science’ led the Government to commission a review of the sciences in Higher Education. The *Inquiry into the flow of candidates into Science and Technology in Higher Education* (also known as the Dainton report), recommended a broad range of sixth form studies as a means of encouraging more able young people to study the sciences at Higher Education so that ‘irreversible decisions for or against science, engineering and technology should be postponed as late as possible’ (paragraph 174).

The issue of early specialisation for those who wish to study the sciences in Higher Education has exercised many commentators in the intervening years (for example, Duckworth and Entwistle 1974, Bell et al. 2003). The organisation of the secondary school curriculum in England and Wales is such that students traditionally reduce the number of subjects they study first at age 14, in preparation for the GCSE (and its predecessors the GCE O-level or CSE), and then at age 16 in preparation for courses which lead to Higher Education, the workplace and so on. For students who take the A-level route into Higher Education, traditionally the most popular option, this would involve retaining three, or usually no more than four, of their secondary school subjects. Thus encouraging a degree of specialisation not required in many other countries and with the consequence that if one did not opt to study a subject such as Chemistry at 14, it would be very difficult to return to the subject at a later stage in one’s school career.

When science became a core component of the National Curriculum in England and Wales in 1989, the issue of specialisation in the sciences at 14 ought, arguably, to have been resolved: now all students were to spend a significant proportion of their time (for many around 20%) studying science through to the end of compulsory schooling. One consequence of this was the retention of large numbers of young people in the sciences up to the age of 16, so increasing the supply of potential A-level science candidates. Much more recently the Government has promised to increase this supply further by requiring that by 2014, 90% of state schools offer single subject science teaching (or triple science) and propose that the number studying for separate GCSEs in chemistry, physics and biology be doubled (Brown 2009, Fairbrother and Dillon 2009). The impact of these reforms on recruitment to post-compulsory science programmes does, of course, remain to be seen.

Reform of the A-level in 2000 resulted in the qualification being split into two stages - a one year Advanced Supplementary (AS) followed by a second year A2. AS is worth one half an A-level and students can either ‘cash in’ their AS qualification at the end of one year or continue to the full A-level. These Curriculum 2000 reforms, alongside the more recent
introduction of Applied A-levels and the Diploma qualification, have all contributed to a further broadening of the post 16 curriculum and with it the opportunity for more able young people to delay specialisation and remain in the ‘science stream’ for longer. The consequence of widening the choice of subjects studied at A-level on the uptake of science at university is interesting. According to Osborne et al. (2003), the percentage of students pursing science or science and mathematics post 16 has declined by more than one half - a trend which began in the 1980s and has been exacerbated by the greater choice presented by mixed A-level combinations. While AS qualifications appear to have been successful in broadening the curriculum experience for students, they have resulted in a decline in the percentage taking the three sciences at A level (Howson and Sprigade 2006). Although the ten most popular three A level combinations are still science based and between them account for 10% of the A level cohort (Bell 2003).

Despite science being a core National Curriculum subject which all young people must study until the age of 16, concerns remain over recruitment at post-compulsory levels. This has resulted in numerous initiatives which seek to address the content of the science curriculum as well as to broaden the choice of science and related courses that are offered at the post-compulsory phase and which aim to engage more young people in the sciences: or, in other words, which seek to make science more ‘attractive’. A situation which is neatly summed up by McPherson writing four decades ago:

‘If science were compulsory it must be attractive, if it is not attractive it will only suffer if made compulsory; and if it were attractive, it would not need to be compulsory’, (McPherson 1969).

Participation of Women in the Sciences

In addition to general concerns about falling participation in the sciences, there are more specific concerns about the recruitment of women into the STEM professions. Although by no means the only challenge facing STEM employees, concerns over the under-representation of women in STEM careers are well established: attrition occurs at each stage in the career pipeline from fewer girls opting to study science at school to fewer female scientists employed at the highest levels (for example, Blickenstaff 2005). In the UK during the early 1980s the ‘problem’ of ‘girls and science’ received widespread attention and led to initiatives such as the Girls into Science and Technology (GIST) (Smail et al. 1982) and the Women into Science Engineering (WISE) campaigns (WISE 2009). Both of which had the broad aim of increasing the numbers of women who follow careers in STEM subjects. These and other similar programmes were based on the premise that girls were not participating in science and that their subsequent lack of qualifications in this area would preclude them from most technical jobs, as well as leaving many women ‘technologically illiterate and at a distinct disadvantage in modern society’ (Smail et al. 1982, p.620). The last thirty years or so have seen an increase in the proportion of women who remain in education beyond the compulsory years and consequently in the supply of potential scientists. Nevertheless, twenty five years after the introduction of GIST and other initiatives, the recruitment and retention of
women in STEM subjects is still an area of both controversy and concern: for example, Harvard President Lawrence Summer’s comments about women in science in January 2005).

Despite concerns over the participation of women in the sciences, for much of the past two decades, the attention of many educational commentators, practitioners and researchers has been on the more general phenomenon of ‘underachieving’ boys. Arguably the predominant discourse in education in recent times, the apparent underachievement of boys in school has been attributed variously to the feminisation of the teacher workforce, assessment practices, the school curriculum, the conflicts of masculinity in today’s society and so on (Smith 2005). Evidence for the ‘underachievement’ of the nation’s boys comes largely from interpretations of examination results which suggest that girls now outperform boys on most measures and at most levels of qualification (Francis and Skelton 2005). Perhaps unsurprisingly, where this has happened in subjects which have traditionally been seen as the preserve of boys (namely the STEM subjects), such concerns have become more pronounced.

In order to examine how patterns of participation and attainment between the sexes have varied over the history of the A-level and to consider the extent to which the phenomenon of ‘underachieving’ boys is reflected in traditionally male dominated subjects at the highest levels, this paper will also consider changes in the relative attainment of male and female students at A-level grade C or above.

The A-level qualification

In this paper we focus on patterns of participation and attainment in A-level physics, chemistry and biology. Traditionally the most popular qualification route into Higher Education in England and Wales has been to study three or four subjects at A-level. However there are, of course, many other qualification routes that aspiring scientists may take such as the GNVQ. Arguably these routes may show different recruitment patterns to the A-level and issues which may appear relevant to the A-level may not apply to other qualifications. However, even though alternative routes into Higher Education have become more prevalent, even among traditional aged students (Table 1), for most people aiming for a university career, A-levels remain the most popular choice and will be the focus for this analysis.

Table 1: Qualification routes for Level 3 candidates aged 16-18, England

<table>
<thead>
<tr>
<th>Qualification route*</th>
<th>Percentage of candidates following qualification routes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
</tr>
<tr>
<td>GCE A-level</td>
<td>71.0</td>
</tr>
<tr>
<td>VCE/Applied A-level</td>
<td>4.2</td>
</tr>
<tr>
<td>International Baccalaureate</td>
<td>0.8</td>
</tr>
<tr>
<td>BTEC/OCR</td>
<td>21.4</td>
</tr>
<tr>
<td>NVQ/VRQ</td>
<td>2.7</td>
</tr>
<tr>
<td>All candidates (n)</td>
<td>154,944</td>
</tr>
</tbody>
</table>

*Qualification route is determined by the major qualification type

Source: DCSF 2009

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A-levels were first awarded in 1951 and are popularly perceived to be the ‘gold standard’ qualification for entry into Higher Education in England and Wales (for example THE 1995, SCORE 2008). The modern form of the A-level emerged in the early 1960s when passes were first awarded on a 5 point scale (from grade A to grade E). In 2008 a A* grade was introduced to distinguish performance at the highest level. The number of A-levels being taken each year has increased from 250,000 in 1961 (DES 1961) to over 800,000 in June 2009 (JCQ 2009). In 2007 the government established a series of seven year targets for increasing recruitment to the physical sciences. For A-level physics, entries are targeted to increase to 35,000 (from 24703 in 2008), for chemistry 37,000 (36,328 in 2008) and for mathematics 56,000 (57,618 in 2008). The aim is to meet these targets without adversely affecting recruitment to biology (48,397 in 2008) (DCSF 2009).

Since the early 1960s A-levels have been assessed using norm referencing techniques. This means that each year a given percentage of students would be awarded an A grade (10%) or a B grade (15%) and so on. This changed in 1987 to a system of criterion referenced marking whereby grade boundaries were set against pre-determined performance criteria and so the proportions gaining A or B grades, for example, were allowed to vary. This system remained until the introduction of Curriculum 2000 and the current system of ‘soft criterion referencing’ which combines features of both approaches (House of Commons 2003). As an indication of how grades have varied over the period, in 1965 one third of all A-level entries were awarded at C grade or higher (of which 8.6% were at grade A) (DES 1965). In 2009 74% of 18 year old candidates in England achieved a grade C or higher (of which 26% were at grade A), with 98% of candidates awarded grades A to E (DCSF 2009).

The A-level has long been a qualification of significant political, as well as educational, importance. For example, in September 2002 an article in the Observer newspaper threw the A-level system into crisis by suggesting that an adjustment to grade boundaries by the examination boards would mean that many able students would miss out on their university place. The implication was that this ‘adjustment’ had taken place after the exam boards had realised that the 2002 A-level pass rate would be 2-4 percentage points higher than in 2001 (the actual increase was 4.5 percentage points) and had moved to counter accusations that A-levels were becoming easier (Bright and McVeigh 2002, House of Commons 2003).

Variations in the systems for allocating grades over the history of the A-level mean that it is difficult to monitor performance over an extended period. However in this paper, we are interested in the relative performance of male and female candidates. As we have no reason to believe that candidates will differ in the grades they are allocated on the basis of their sex, such a comparison of relative performance over time is less problematic. We are also interested in entry patterns. These are likely to be affected by the number of candidates as well as the number of subjects, and curricula, on offer. However, changes in the administration and assessment of A-levels are unlikely to affect these patterns and so both the overall entry rate and the relative performance of male and female students can be examined in this way. The data presented here was obtained electronically and as hard copy from a variety of sources including the Department for Children, Schools and Families (and its predecessors the Department for Education and Skills and the Department for Education and
Science), the former Qualifications and Curriculum Authority, the Joint Council for Qualification, the Institute of Physics and the Assessment and Qualifications Alliance. Note however that achievement data in the grade range A-C was not available between 1961 and 1964 and 1986 and 1989.

**Participation in the pure sciences at A-level**

In physics there are now fewer male students studying the subject than in the early 1960s, with numbers in steady decline since the early 1990s (Graph 1). The stability in the female participation figures comes despite initiatives such as Girls into Science and Technology (GIST) and Women into Science and Engineering (WISE) that focus on encouraging girls to study physics after the age of 16. While there is no evidence to suggest that female candidates are being turned away from studying A-level physics in greater numbers than previously, there is nothing to suggest that these initiatives have had a notably positive effect on recruitment either.

Graph 1: Participation in A-level physics, male and female candidates 1961-2009

[Graph showing participation in A-level physics, male and female candidates 1961-2009]

Source: DES, DfES, DCSF, QCA, JCQ, AQA, Edexcel, IoP

Until relatively recently A-level chemistry was a male dominated subject (Graph 2). From the early 1990s there has been a gradual narrowing of the participation gap between the sexes. This has largely been due to a decline in the number of male candidates; indeed since 2000 the subject has attracted similar proportions of men and women. The introduction of compulsory science as part of the National Curriculum reforms at the end of the 1980s has had no noticeable impact on A-level recruitment to chemistry, for either sex. While we are currently seeing a slight increase in the number of men studying the subject, their numbers have declined steadily since the early 1990s. Among female candidates, numbers have varied little in the last decade.

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One feature of recruitment to biology over the last five decades has been its transition to a female dominated subject (Graph 3). In 1961, just over 7000 students were entered for A-level biology of whom, 60% were male. By 1977 there were roughly equal numbers of men and women studying the subject. Now 52,000 students were entered for the subject, almost 30,000 of whom were female. There appears to have been an increase in the number of female candidates studying A-level biology in the early 1990s, possibly coinciding with Science becoming a core component of the National Curriculum. Despite some slight increases in numbers during the mid 1990s, the participation figures for both sexes now appear to have plateaued.
Attainment at A-level

In order to examine how patterns of attainment between the sexes have varied over the history of the A-level and to consider the extent to which the phenomenon of ‘underachieving’ boys is reflected in traditionally male dominated subjects at the highest levels, we examined changes in the achievement gap between male and female students at A-level grade C or higher. The calculation of achievement gaps is a widely used technique for measuring relative attainment of two groups (for example, Arnot et al. 1996, 1999 and Gorard et al. 2001), and the equation on which it is based is presented in the Appendix.

What this historical analysis shows is that the achievement gap between the sexes in the ‘pure’ sciences has hardly varied over the last five decades, providing no evidence that male students have ever outperformed females at this level. In physics there has been some slight shifting of the achievement gap in favour of female candidates since the mid 1990s (Graph 4). However, any gender gap in the attainment of candidates is negligible and overall it can be said that attainment at the higher grade levels in physics is gender neutral.

Graph 4: Achievement gaps between male and female A-level physics candidates 1965-2009

Source: DES, DfES, DCSF, QCA, JCQ, AQA, Edexcel, IoP
A positive value indicates overall higher achievement among female candidates. Values of less than 4% are not considered to represent a noticeable gap (Gorard et al.2001).

The same is true for chemistry (Graph 5). Until the late 1990s there was no difference in the proportion of male and female candidates achieving a grade C or higher in A-level chemistry, more recently the achievement gap has moved to be slightly in favour of female candidates. As with physics, this appears to coincide with a decline in the number of men entered for the subject, which may suggest that chemistry is losing some of its higher attaining male entrants. However, the achievement gap between the two sexes is still relatively small suggesting that attainment in chemistry at the highest levels is also gender neutral.
Graph 5: Achievement gaps between male and female A-level chemistry candidates 1965-2009

Source: DES, DfES, DCSF, QCA, JCQ, AQA, Edexcel, IoP

One consequence of the increased participation in biology among female candidates that we have seen since the late 1990s has been a shift of the achievement gap in favour of women. This suggests that popularity of the subject among female candidates has encouraged more able students to study biology at A-level. However, although in favour of women the achievement gap between the sexes is nevertheless very small and attainment at grade C or higher in A-level biology is arguably also gender neutral.

Graph 6: Achievement gaps between male and female A-level biology candidates 1965-2009

Source: DES, DfES, DCSF, QCA, JCQ, AQA, Edexcel, IoP


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Discussion

Since the beginning of the modern A-level towards the start of the 1960s there have been numerous policies and initiatives that have aimed, either directly or indirectly, to encourage a greater number of able young people to remain in the ‘science stream’ and subsequently study the subject at university. In very different ways the expansion of comprehensive education, the raising of the school leaving age to 16, the National Curriculum, Curriculum 2000, increased diversity of vocational and academic pathways to Higher Education, not to mention associated initiatives such as GIST and WISE, have all sought some role in increasing the supply of potential recruits to post-compulsory science courses and eventually to undergraduate STEM programmes. Some of these initiatives have been implemented gradually and their impact on participation is hard to gauge. Others such as the introduction of compulsory science at age 14 in the late 1980s have had a very limited effect on post compulsory participation in the pure sciences.

What is apparent from this analysis of long term patterns of participation is that not one of the three science A-levels appears to be thriving: in physics fewer male students are studying the subject now than in the early 1960s, while female numbers have never really changed. In chemistry numbers have varied little in a decade and in biology, traditionally seen as the ‘healthiest’ of the pure sciences; numbers also appear to have reached a plateau. Achievement gaps between the sexes at the highest levels perhaps present more cause for optimism and no support for the ‘failing boys’ debate – attainment between the sexes is gender neutral and there is no evidence that boys have ever outperformed girls in subjects traditionally seen as the preserve of men.

But what is perhaps most interesting in this data is the limited impact of initiatives and policies whose aim is to increase or widen participation in the sciences. These initiatives are not peculiar to the UK. As mentioned at the start of this paper, many of our peer economies have their own version of the ‘science problem’ and have developed their own strategies for developing engagement and participation in the sciences. In the United States, the Obama administration has already launched a number of initiatives whose focus is on STEM education and specifically aimed at moving American children ‘from the middle to the top of the pack in science and math’ (Obama 2009). For example, the recently launched ‘Educate to Innovate’ programme encourages government, business and not-for-profit organisations to work with young people to raise attainment in maths and science programmes, similarly ‘National Lab Day’ aims to improve scientific literacy, increase academic attainment and recruit more people, especially those from underrepresented groups, into the STEM profession and even the venerable Sesame Street children’s television programme has begun a two year initiative to educate young children in maths and science (The White House 2009).

This historical overview of patterns of attainment and participation is important and one which is rarely considered in this context. Recruitment to the STEM subjects is a contemporary issue of high political status. Take for example this quotation from one of the most recent government reports on the issue: ‘STEM skills underwrite this country’s..."
competitive advantages’ (Department for Business Innovation and Skills 2009, p7). If we are to understand how we have arrived at this perceived recruitment crisis, then it is important to take the long view and consider the extent to which recruitment has been influenced by past social, political and educational events. For example, if we were to review the position of science education and training over the last 90 years, three themes would emerge: the nature and purpose of the school science curriculum, the recruitment of science undergraduates, and the teaching of science in schools (Author 2010). We would see that these are the very same themes which preoccupy us today, despite decades of reform, initiatives and government reports. This raises issues about the role of policy in influencing educational change more generally but also questions whether there ever was a ‘golden age’ for science education in the UK. These are questions which this review of participation and attainment data at A-level can start to help answer.

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Appendix

Calculation of Achievement gaps

\[
\text{Achievement gap} = \frac{\text{performance} - \text{entry}}{\text{gap}}
\]

\[
\text{Achievement gap} = \left(\frac{\text{GP} - \text{BP}}{\text{GP} + \text{BP}}\right) \times 100 - \left(\frac{\text{GE} - \text{BE}}{\text{GE} + \text{BE}}\right) \times 100
\]

GP = number of girls achieving that grade or better
BP = number of boys achieving that grade or better
GE = number of girls entered
BE = number of boys entered