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Women into science and engineering? Gendered participation in higher education STEM subjects

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This paper considers gendered patterns of participation in post-compulsory STEM education. It examines the trajectory of learning that takes students from A-level qualifications, through undergraduate work and into employment or further study. It also uses a long-term view to look at the best available evidence to monitor participation and attainment over an extended period of time. The findings suggest that almost three decades of initiatives to increase participation in STEM subjects have had little noticeable impact on the recruitment data and gendered patterns of participation persist in several subject areas. This is despite more women entering HE and little gender difference in the entry qualifications for STEM subjects. While more women are studying science, as broadly conceived, than ever before, recruitment to key areas, namely physics and engineering remains stagnant. However, for those women who do remain in the 'science stream' patterns of employment in graduate careers and further study appear relatively equitable.

Introduction

> The under-representation of women in science, engineering and technology threatens, above all, our global competitiveness. It is an issue for society, for organisations, for employers and for the individual. (Greenfield, 2002)

As the above quotation demonstrates, improving the recruitment, retention and training of the next generation of science, technology, engineering and mathematics (STEM) professionals remains an area of political priority and concern. Indeed, falling levels of engagement in STEM subjects at local and international levels is a problem that is well rehearsed and appears to persist. Its roots are considered to be in the poor quality of public education in the sciences, the high levels of dropout from science courses at university, poor pay and career prospects for STEM workers in

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comparison with other professions and a failure to respond to the changing demands of an increasingly globalised STEM market (for example Seymour & Hewitt, 1997; Prados, 1998; Butz *et al.*, 2006). Although by no means the only challenge facing STEM employers, 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, Greenfield *et al.*, 2002; Blickenstaff, 2005).

This paper examines gendered patterns of participation in STEM education in the UK. Although its focus is on one country, the inequalities and many of the solutions that are seen here are replicated internationally (for example, Gago *et al.*, 2004; National Academy of Sciences, 2007). While much of the research and policy focus around this issue tends to be on how science is taught in schools and, in particular, on the structure of the school science curriculum (Jenkins & Donnelly, 2006; Murphy & Whitelegg, 2006), much less attention has been devoted to the undergraduate student experience and the trajectory that learners take, which can lead to higher education and into careers as professional scientists and technicians (Institute of Physics, 2007). Here our interest is in that trajectory and in the gendered patterns of recruitment that underpin a sector that apparently struggles to recruit and retain the brightest and the best.

Widening participation in STEM subjects

Much of what is written about participation at university in general concerns itself with issues of equity and social justice and pays particular attention to what Brennan and Naidoo (2008) term the 'imports' to higher education (HE). This concern with 'imports' tends to involve research that looks at the social composition of institutions' faculty and student body and a consideration of who is or is not included (for example, Gorard *et al.*, 2007). In essence, such research focuses on the *private* benefits that HE confers on the life chances of the individuals who participate. Less often considered are the 'exports' from HE or, in other words, its wider *public* benefits, particularly for those who do not directly participate, and as a consequence the contribution the sector makes to 'achieving a fair and just society' (Brennan & Naidoo, 2008, p. 288). Arguably one reason why the need to increase participation in STEM subjects is so important is because it has the potential to constitute both the public and the private benefits of HE. Science, technology, engineering and mathematics courses are among the most prestigious, they attract the most highly qualified students and the return from STEM degrees in terms of future earnings is high (the *private* benefits of HE) (see, for example, Department for Education and Skills (DfES), 2006). On the other hand, STEM graduates have the potential to contribute to the advancement of science and the generation of jobs (and goods) in areas such as stem cell research, alternative energy technologies and so on, which will contribute to society's well-being as well as to its economic prosperity. In other words, there are clear *public* benefits as well. This society-wide function of science is evident in recent speeches by the two most recent British Labour Prime Ministers:

> This is Britain's path to the future, lit by the brilliant light of science. (Blair, 2006)

> …while not everyone is in the business of science, science is everybody's business. (Brown, 2009)

Thus the need to ensure equitable access and levels of participation in STEM subjects in the HE sector in general has implications for the individual as well as for society more widely. However, despite an increase in the number of people who study at this level in the UK, and current estimates place it at 43% of the 18–30 age group (Attwood, 2010), it is still the case that inequalities persist with regard to who participates and who does not. It is perhaps to state the obvious: as success in education is predicated on success at the previous educational stage (Gorard & Smith, 2007) and as young people from less elevated social groups achieve at lower levels throughout schooling, then it is perhaps unsurprising that entry to HE is stratified by examination outcome and also by social characteristics. Indeed, previous research in this area suggests that in most contexts the limiting factor regarding participation in HE is attainment (Raffe *et al.*, 2006). However, this argument is less clear when we consider gender inequalities in participation. The relatively lower attainment of young men in certain school subjects is a well-established part of the wider national discourse on 'boys' underachievement' in school (Francis & Skelton, 2005). If it is the case that women now achieve at higher, or at least comparable, academic levels to men then arguably these 'traditional' barriers to participation no longer apply and should be reflected in increased levels of participation in STEM subjects among female undergraduates. This is an important issue to bear in mind when examining gendered participation in subjects traditionally seen as the preserve of men (such as physical science and engineering) and is a key focus of this paper.

The recent expansion of the UK HE system has meant that we are training more scientists than ever before. In 2009, almost 200,000 people began studying for full-time undergraduate degrees in science and science-related subjects: a number that has trebled since 1986 (Smith, 2010). In an economy and a society with increasing demands for scientific- and technological-based goods and skills, a shortage of appropriately skilled workers will, according to many commentators, 'threaten our productivity, competitive position and level of innovation' (Greenfield *et al.*, 2002, p. 27; see also Zalevski & Kirkup, 2009). These shortages are exacerbated by high levels of leakage among science and engineering graduates. Such attrition is a particular issue for women and those from other under-represented groups, whose levels of participation are already relatively low (Broecke & Hamed, 2008).

In the UK during the early-1980s the 'problem' of girls and science received widespread attention and contributed to initiatives such as the Girls into Science and Technology (GIST) (Smail *et al.*, 1982) and the Women into Science Engineering (WISE) campaigns (WISE, 2007), 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). This aspect of the STEM agenda has been largely focused on increasing the numbers of female participants in the field; rather less attention has been paid to what happens to them once they enter employment (Acker, 1992). Research that has been undertaken in this area suggests that female science graduates tend to make less direct use of their qualifications (for example by becoming teachers) and are more likely to be over-qualified for their job: analysis of first destination data suggests that there are over three times as many women science graduates in non-professional employment in science than there are men (Glover & Fielding, 1999). An associated issue is the disproportionate number of women on short-term contracts or at the lowest grades within academia (Institute of Physics, 2005).

While there is some evidence to suggest that biological factors may have a role in developing the mathematical ability needed to gain access to many of these maths-intensive fields, Ceci *et al.* (2009) argue that the 'data are not consistent enough to claim that the dearth of women in STEM careers…are primarily a result of direct consequence of biological sex differences' (p. 249). Rather, any differences in ability are likely to be influenced by interests and motivations that are environmentally driven: for example women with high-mathematical ability choose non-STEM fields more often than men of similar ability.

The influence of the socio-cultural environment on women's participation is an area with its own, occasionally contradictory, literature (Ceci *et al.*, 2009). For example, one account of these socio-cultural barriers argues that while science is inherently gender-blind, structural barriers have emerged that prevent gender equality and so force women to be treated as 'strangers' in science (for example, Massachusetts Institute of Technology, 1999; Sonnert *et al.*, 2007). These barriers mean that women have been, and indeed often still are, treated differently to men and may face legal, political and social obstacles to their advancement. Such barriers might be institutional, perhaps linked to promotion and tenure, or they may be more informal, for example through the organisation of research groups, which may result in women being less likely to be included in collaborative partnerships (Fox, 2001). Once these formal and informal barriers have been removed, as in the case with equal opportunities legislation, the argument is that the path will be laid clear for equality. Proponents of this deficit model of barriers to advancement argue that once the number of women reaches a 'critical mass' they will no longer be 'strangers'—something they argue that is already happening in the increasingly feminised biological sciences where women scientists are better integrated and more likely to receive tenure. However, Glover and Fielding (1999) offer limited support for the 'critical mass' model. Using British data they argue that even in biology, hierarchical segregation means that women occupy more junior roles which are of lower status with less pay. Similarly Ceci *et al.* (2009) suggest that 'institutional barriers and stereotypes, both of which are real, do not appear likely to account for most of the sex differences…there is no compelling evidence that removal of these barriers would result in equalisation of sex ratios' (p. 247).

An alternative view of female under-representation in the sciences offers a model that emphasises the difference between men and women and that focuses on how it is women's *actions* that mark them out as strangers in science. From this perspective, supporters argue that the reason why women scientists are less successful than men is because of how science is socialised: science is viewed as a masculine pursuit that is practised in ways that are incompatible with being female (for example Harding, 1991; Kenway & Gough, 1998; Phipps, 2002). For example, science pedagogy succeeds in reinforcing girls' negative attitudes to the subject, the expectation that young people will fulfil gender roles reinforces science as a masculine pursuit in which female scientists are seen as being unattractive and where being a scientist would compromise one's femininity (Kelly, 1985; Acker, 1992; Terzian, 2006). Perhaps unsurprisingly this perspective of women's role in science has been much criticised by female scientists from within the field who reject the notion of women as passive within a male-dominated discipline (Sonnert, 1995).

Despite limited consensus over why women remain under-represented in many parts of the STEM field, this is an area that continues to attract a great deal of investment and attention. Here we look at the impact that many decades of initiatives and programmes to increase the participation of female scientists in STEM education have had on recruitment to the field at the highest levels.

Research approach

One key aim of this study was to examine long-term trends in the participation of men and women in post-compulsory science programmes. This has required the retrieval and analysis of archive data on gendered patterns of participation and attainment at A-level and in HE. The datasets used for this analysis are of the highest quality available and they represent many hundreds of thousands of individuals. They enable us to take a long-term view on how the participation of male and female students in post-compulsory STEM subjects has been shaped by an expanding HE sector and allow us to evaluate the long-term impact of policies and initiatives that have aimed to encourage more young women, in particular, to study the sciences. The results presented here span three phases of post-compulsory STEM training: attainment at A-level (a key gateway qualification for entry to HE), uptake of STEM subjects at undergraduate level and the immediate career destinations of recent STEM graduates.

This analysis of A-level data starts from 1961, the first year in which A-level grades were awarded on the A–E scale. Data were obtained electronically and as hard copy from a number of government departments and other official organisations, including the Department for Children, Schools and Families (and its predecessors the Department for Education and Skills and 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. In addition, data retrieved from the Universities Central Admissions Service (UCAS) were used to investigate patterns of participation in STEM first degree and Higher National

Diploma[1] programmes at UK universities. Since 1993 candidates wishing to apply to study at university have had to make their application through UCAS. Prior to this date, applications to universities and the former polytechnics[2] were made through the Universities Central Council on Admissions (UCCA) and the Polytechnics Central Admissions Service (PCAS). Both organisations merged in 1993 to form UCAS. Data prior to 1996 are not available electronically and so were entered manually from the UCAS/PCAS/UCCA Annual Reports, which were retrieved as hard copies from the UCAS archives. Patterns of participation from 1986—the first year in which applications were administered through the UCCA/PCAS schemes—were examined. This historical overview is important and one that is not often considered in this context. As outlined above, recruitment to the STEM subjects is a contemporary issue of high status. 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. There are significant difficulties in tracking participation and attainment over such an extended period. As a consequence, the datasets used here required a substantial amount of preparation before they were ready for analysis, for example to ensure that the data covered the same population in each year and, in the case of A-levels, that it included different versions of the syllabus. For the HE data, changes in the recording of different subjects and areas of study had to be accounted for, as well as the increasing diversity in the number of institutions and the choice of courses that are offered (see Smith, 2008 for further details).

The final part of this study involved an examination of the destinations of STEM undergraduates. Data on participation in further study and employment destinations were retrieved from the Higher Education Statistics Agency (HESA). Analysis of the UCAS data shows that the majority of STEM graduates are UK-domiciled, full-time students, so the focus here was limited to this group. The HESA first destination survey gathers information on the activities of graduates six months after they leave university. Response rates tend to be relatively high: for the physical sciences they are over 80%. It is recognised that this dataset only considers destinations six months after the student has left university and that career trajectories may be very different in the subsequent period. However, it tells us a great deal about the sorts of jobs that are available to science graduates.

In the present study, the analysis is confined to first degree and HND students who access HE through the UCAS scheme as well as A-level students studying the pure sciences (biology, chemistry and physics). One consequence of this is that certain types of learners are excluded from the analysis, namely those who study with the Open University (whose applications are not processed by UCAS) as well as the minority of students who study different types of qualifications. One additional consideration comes in the definition of science subjects. Numerous definitions exist: for example, there is the categorisation into the four STEM subject areas (namely science, technology, engineering and mathematics), there is also the frequently drawn, and often contested, distinction between 'hard' science (physics and mathematics) and 'soft' science (evolutionary biology, psychology, social science) (Pigliuicci, 2008). However, this study adopted an inclusive definition as used by the International Standard Classification of Education (UNESCO 1997) and the Department for Innovation, Universities and Skills (DIUS) (2009a) to include the life, health, physical, mathematical and engineering sciences, as well as agriculture and architecture. Although where possible, the focus is upon the main STEM shortage subjects: chemistry, physics, mathematics and engineering (Higher Education Funding Council for England [HEFCE], 2008).

Findings

The findings presented here explore gendered patterns in post-compulsory education in STEM subject areas in three phases. They begin with an examination of participation and attainment in A-level subjects, before considering the types of subjects studied by male and female undergraduates and finally the destinations of STEM graduates six months after completing their course.

Participation in the pure sciences at A-level

Since the creation of the modern A-level 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. Some of these initiatives, such as increases in the number of university places, 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 noticeable, although apparently short-lived, effect on post-compulsory participation in the pure sciences (Smith, 2010b).

A consideration of long-term trends in participation in A-level pure science courses (biology, chemistry and physics) suggests that not one of these subjects appears to be thriving. In physics there are now fewer male students studying the subject than in the early-1960s, with numbers in decline since the early-1990s (Figure 1). The stability in the female participation figures comes despite initiatives (such as GIST and 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.

Until relatively recently A-level chemistry was a male-dominated subject (Figure 2). From the early-1990s there has been a gradual narrowing of the participation gap. 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 in the late-1980s appears in itself to have had no noticeable impact on A-level recruitment to chemistry, for either men or women. Rather we have seen a steady feminisation of the subject to the extent to which, at present, participation in A-level chemistry is not necessarily increasing but is gender neutral.

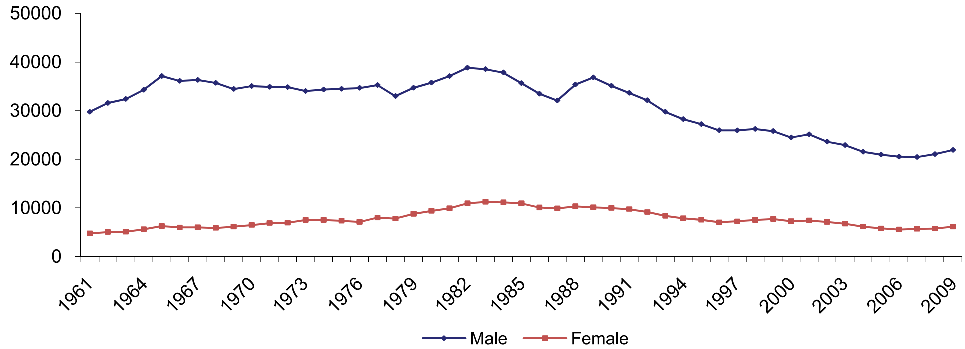

Figure 1. Participation in A-level physics, male and female candidates 1961–2009
Source: DES, DfES, DCSF, QCA, JCQ, AQA, Edexcel, IoP.

Similarly over the last five decades, biology has also become increasingly feminised. There was a slight increase in the numbers of female biology candidates in the early-1990s, when science became a core component of the National Curriculum enabling more students to consider studying the subject post-16. However, more recent reforms appear to have accompanied a slight decline in the numbers of candidates entered for A-level biology, although, as with chemistry, these numbers have plateaued recently (see Smith, 2010a for a fuller discussion).

Attainment in the pure sciences at A-level

For much of the past two decades, the attention of many educational commentators, practitioners and researchers has been on the phenomenon of 'underachieving'

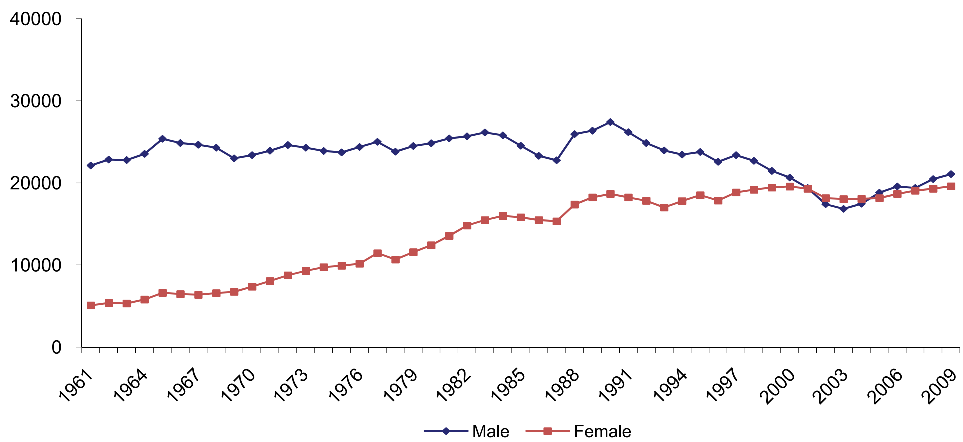

Figure 2. Participation in A-level chemistry, male and female candidates 1961–2009
Source: DES, DfES, DCSF, QCA, JCQ, AQA, Edexcel, IoP.

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. 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 (Smith, 2005; Francis & Skelton, 2005). Perhaps unsurprisingly, where this has happened in subjects that have traditionally been seen as the preserve of boys (namely the STEM subjects), such concerns have become more pronounced.

In order to examine how gendered patterns of attainment 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 relative attainment of male and female students at A-level grade C or higher.[3] What this historical overview shows is that the gender achievement gap 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 (Figure 3).

For example, in physics there has been some shifting of the achievement gap in favour of female candidates since the mid-1990s. However, the gap is negligible and overall it can be said that attainment at the higher grade levels is gender neutral. The same is true for chemistry. 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 men and women is still relatively small suggesting that attainment in chemistry at the highest levels is gender neutral.

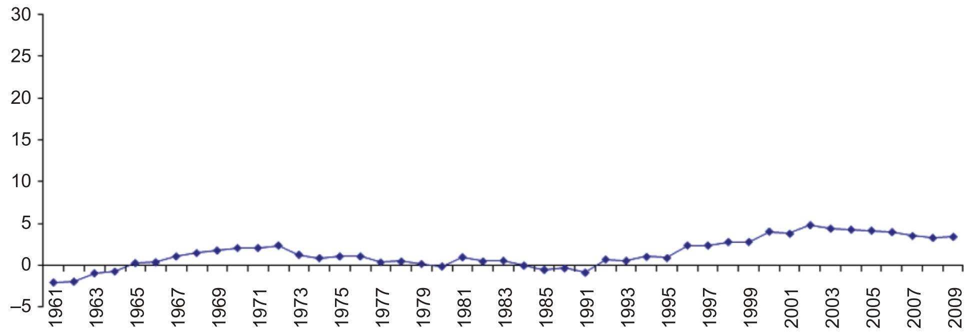

Figure 3. Achievement gaps between male and female A-level physics candidates 1961–2009
Note: A positive value indicates overall higher achievement among female candidates. Values of less than 4% are not considered to represent a noticeable gap (Gorard *et al.*, 2001).

In short, the findings presented here do not suggest that initiatives at the school level to increase participation in the pure sciences have had a significant long-term impact on recruitment at A-level: 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 men and women at the highest levels perhaps present more cause for optimism and no support for the 'failing boys' debate—attainment between these groups is largely gender neutral and there is no evidence that boys have ever outperformed girls in subjects traditionally seen as the preserve of men. That male and female students achieve at similar levels in the pure sciences at A-level, and have done so for some time, has implications for the literature on barriers to HE that suggests that for most under-represented groups, the barriers to participation are largely academic (for example Gorard *et al.*, 2007) but for gendered participation in science subjects, that appears not to be the case.

Recruitment to higher education STEM subjects

The expansion of the UK HE system over the last 20 years or so is reflected in a quadrupling of the number of candidates offered places to study at undergraduate level. This increase is particularly apparent among previously under-represented groups: in 1986, 47,696 women accepted places on UCCA and PCAS-administered HND and first degree programmes; by 2009 this had risen to well over 200,000. The early-1990s saw the end of long established trends of HE courses recruiting more male candidates. Now more female candidates apply and are accepted, a rate of increase since 1994 that has been faster than that for men (Figure 4).

Since 1986, the different STEM subject groups[4] have tended to recruit a steady share of female candidates with rates only varying by around 1–2 percentage points.

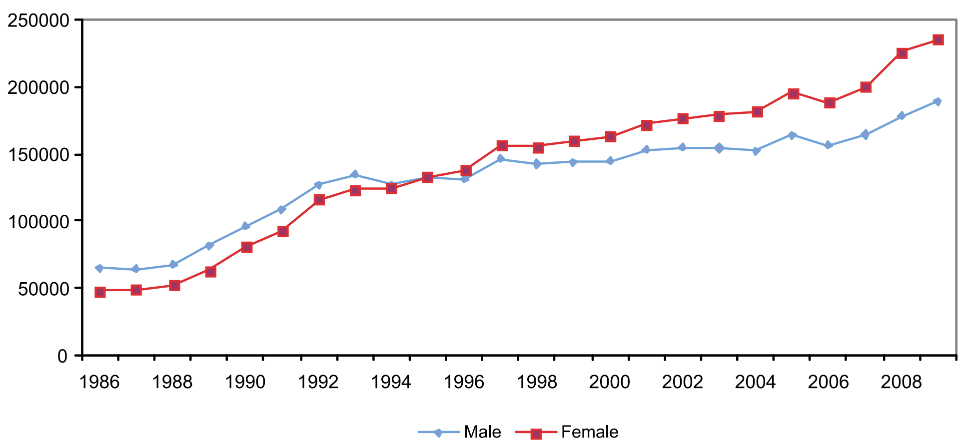

Figure 4. Male and female home acceptances to all first degree and HND programmes, 1986–2009

For example, in 1986 5% of all places accepted by female candidates were in the physical sciences, this has varied only slightly in the intervening years, although currently the trend is towards a slightly lower share (3%) of female candidates who are accepted to study this group of subjects. When all science subject groups are considered together, around one third of all HE places that are accepted by female candidates are in science or science-related subject areas, a trend that has varied little over the last two decades. While this suggests that a relatively large and stable proportion of women do wish to study science (as broadly conceived), gender stereotyped patterns of subject choice still persist—over 50% of candidates studying the biological and medical sciences are female, while the proportion of female students studying the engineering sciences has hardly varied over the period considered (Figure 5). On the other hand, almost half of all places on science and related courses are now taken by women, a proportion that as Figure 5 shows has steadily increased since 1986 and is in line with the increasing numbers of women studying at university.

The extent to which certain science subjects continue to divide students according to their gender can be seen in Table 1. While trends have varied for certain subjects, indeed higher proportions of women now study chemistry and mathematics, gender stereotyped patterns of participation do still persist in subjects such as physics, engineering and psychology.

The stability of many of these participation figures is quite remarkable. Physics, for example, despite many initiatives to increase the numbers who study the subject, continues to recruit around 3000 undergraduate students (male and female) each year. The robustness of the participation figures for female physics and engineering candidates is illustrated in Figure 6. Note also the gradual increase in the proportion of women who study mathematics.

Table 2 compares the relative success of male and female candidates in being offered places to study science subjects in HE. This is simply expressed as the

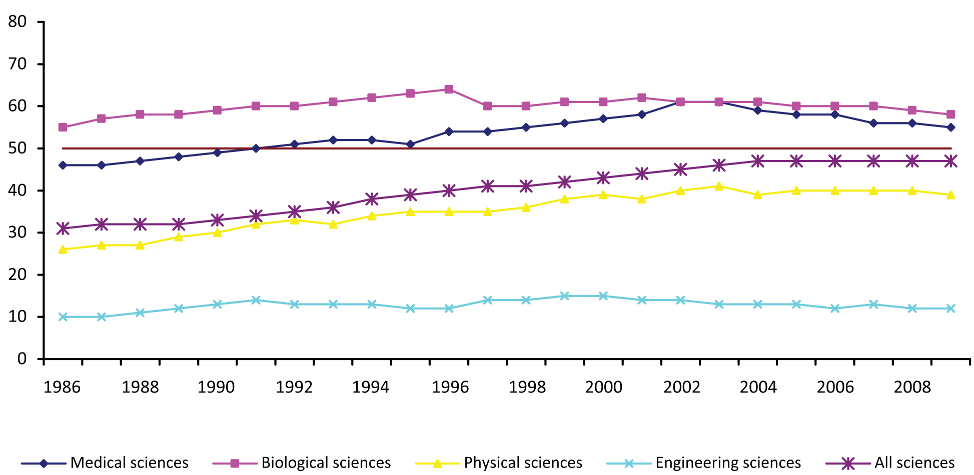

Figure 5. Proportion of candidates accepted to main STEM subject groups who are female, 1986–2009

Table 1. Percentage of female candidates accepted to the largest-recruiting science subjects, selected years 1986–2009

	1986	1990	1994	1998	2002	2007	2009
Medicine	46	49	52	56	61	56	55
Pharmacy	58	61	57	60	64	59	58
Biology	51	54	56	57	61	58	56
Psychology	72	74	74	80	80	81	80
Sports science	–	–	–	36	34	34	31
Chemistry	31	35	35	39	42	41	40
Physics	17	16	16	19	19	18	20
Mathematics	32	35	37	37	39	39	40
Computer science	12	20	18	18	15	13	13
Civil engineering	10	13	12	12	12	13	13
All subjects	42	46	49	52	53	55	55

percentage of male and female applicants who were offered places. One noticeable difference between the acceptance rate of all candidates in 1994 and 2009 is that they are much more likely to be offered places in HE now than previously. With the exception of all science subjects taken together, male and female candidates have similar rates of acceptance, largely because for most subjects acceptance rates are close to or above 100%.

It is worth emphasising that most of these STEM subjects are recruiting rather than selecting subjects, in other words, they recruit more students than originally apply. This is particularly striking given the enhanced position of these 'strategically important and vulnerable' (HEFCE, 2008) subjects in contemporary UK government HE policy. In the context of recent wide-ranging and unprecedented funding cuts to the

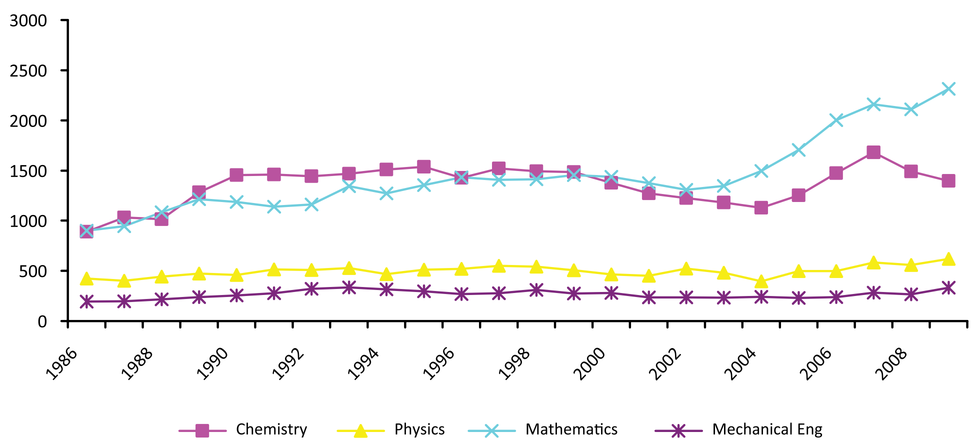

Figure 6. Variation in the number of female candidates accepted to study selected STEM subjects, 1986–2009

Table 2. Percentage of applicants who were accepted to selected STEM degree programmes, 1994 and 2009

	1994		2009	
	Male	Female	Male	Female
Biological sciences	76	76	91	94
Psychology	57	63	86	89
Biology	90	100	98	*
Physical sciences	91	97	*	*
Chemistry	99	*	*	*
Physics	91	88	95	94
Mathematical sciences	90	*	*	*
Mathematics	*	*	93	93
Computing	87	*	99	*
Engineering sciences	91	*	99	*
All sciences	84	80	97	95
All subjects	71	67	80	77

Note: * denotes subjects where more students were accepted to courses than originally applied; this is likely to be a consequence of them being offered places through the UCAS Clearing[6] system.

HE sector in England, STEM subjects are one area that has been identified by the government for 'enhanced support' (DIUS, 2009b, p. 45). This means that whereas other subject areas are likely to see a reduction in the number of funded places for students, money will be diverted to STEM courses 'which meet strategic skill needs' (DIUS, 2009b, p. 45). This is exemplified by the Chancellor's undertaking in the March 2010 Budget to allocate £270million to a University Modernisation Fund in order to fund 20,000 more university places 'largely' in STEM subject areas (HM Treasury, 2010). So we have an interesting paradox of a subject area that is seen as being an important contributor to the nation's economic prosperity being offered additional student places and yet struggling to recruit.

The destinations of recent STEM graduates

According to a recent survey by the Confederation of British Industry (CBI) (2008), one third of employers reported shortages of graduates and 42% claimed that graduates lack the appropriate skills. Similar surveys by the Sector Skills Council and other organisations also point to skills shortages among graduates across STEM areas (DIUS, 2009a). These shortages are particularly evident among female STEM employees who experience higher levels of attrition at different stages along the STEM pipeline (Harding, 2009). Using data derived from the annual HESA graduate destination survey, it is possible to gain an understanding of the sorts of careers that are open to STEM graduates six months after they have left university. Of particular interest here is the extent to which female graduates are fairly represented in traditional STEM careers and training opportunities. We begin by considering graduates who undertake further study and then move on to those who enter employment.

The data that are presented in the following five tables are for home, first degree graduates who completed a period of full-time study in the academic year 2007–2008. The focus is on the main science subject areas of the biological, physical, engineering and mathematical sciences, as well as on a smaller number of individual subjects. Tables 3a and 3b show the main destinations of male and female graduates. There are interesting subject-related differences, in particular the relatively lower proportion of engineering science students entering further study, especially when compared with chemists and physicists. Unemployment levels are similar for all subject areas, but tend to be lower for female graduates. Across all subject areas the proportion of male and female graduates who remain in education is similar.

Tables 4–6 compare the percentage of male and female physical science graduates who are employed in the largest recruiting science-related careers. The figures in parenthesis are the Standard Occupational Class groupings.[5] Comparisons focus on male/female participation in science careers only—a wider discussion of the variety of careers embarked upon by STEM graduates appears in Smith (2009).

As Table 4 shows, around 40% of male and female physical science graduates who enter employment work in an area that is related to their degree, with little difference in the proportions of male and female graduates who entered STEM

Table 3a. First destinations of UK domiciled graduates, selected subjects 2007–2008 (%)

	Physical science			Chemistry			Physics		
	All	Male	Female	All	Male	Female	All	Male	Female
Full-time work	42	40	44	37	34	41	33	32	38
Further study	28	28	27	37	39	34	37	37	36
Unemployed	9	11	7	9	10	7	9	10	4
Total (*n*)	9215	5215	4000	1910	1065	845	1600	1255	345

Table 3b. First destinations of UK domiciled graduates, selected subjects 2007–2008 (%)

	Biology			Engineering sciences			Mathematics		
	All	Male	Female	All	Male	Female	All	Male	Female
Full-time work	40	39	40	60	60	60	41	41	41
Further study	26	24	27	11	12	11	24	24	23
Unemployed	10	12	8	10	11	9	9	10	6
Total (*n*)	3205	1250	1955	9530	7915	1610	3345	1985	1360

Table 4. First destinations of physical science graduates who enter employment (%)

Occupation	Physical Sciences		Physics		Chemistry	
	Male	Female	Male	Female	Male	Female
ICT professionals (213)	3	1	10	3	2	1
Research professionals (232)	4	4	5	6	9	7
Science professionals (211)	9	10	5	8	14	19
Science/engineering technicians (311)	5	7	3	3	11	11
Engineering professionals (212)	5	2	8	6	4	3
Conservation assistant professionals (355)	3	3	–	–	–	–
Teaching professionals (231)	3	5	5	11	4	8
Business and statistical professionals (242)	4	3	10	11	5	4
Business and finance assistant professionals (353)	4	4	7	8	6	4
Subtotal (%)	40	39	53	56	55	57
Total (*n*)	2790	2390	575	180	485	455

occupations. Physics and chemistry graduates were more likely to be working in a field related to their degree subject. Occupations in the business and statistical professional group (namely accountancy and economist jobs) were particularly appealing to recent physics graduates, while relatively high proportions of chemists were employed as science professionals or technicians. There are some differences in the types of employment sought by physics graduates, namely teaching for

Table 5. First destinations of engineering, mathematics and computer science graduates who enter employment (%)

Occupation	Engineering sci.		Mathematics		Computer sci.	
	Male	Female	Male	Female	Male	Female
ICT professionals (213)	6	3	7	2	35	21
Research professionals (232)	1	1	2	2	–	–
Science/engineering technicians (311)	2	1	–	–	1	1
Engineering professionals (212)	48	32	2	–	2	1
IT service delivery occupations (313)	2	1	–	–	10	9
Design assistant professionals (342)	2	5	–	–	–	–
Media assistant professionals (343)	2	3	–	–	–	–
Teaching professionals (231)	1	1	9	9	2	6
Business and statistical professionals (242)	2	1	25	26	2	3
Business and finance assistant professionals (353)	2	2	14	13	2	4
Sales and related assistant professionals (354)	1	7	3	2	2	4
Subtotal (%)	69	57	62	54	56	49
Total (*n*)	5710	1200	1255	945	4950	1000

Table 6. First destinations of biological science graduates who enter employment

	Biological sci.		Biology		Psychology	
Occupation	Male	Female	Male	Female	Male	Female
Research professionals (232)	3	3	5	5	3	3
Science professionals (211)	3	3	6	10	–	–
Science/engineering technicians (311)	3	3	8	10	1	–
Health professionals (221)	1	2	–	–	2	3
Teaching professionals (231)	7	6	4	5	4	4
Business and statistical professionals (242)	2	1	3	1	2	1
Public service professionals (244)	1	2	–	–	2	3
Business and finance assistant professionals (353)	3	2	3	3	4	2
Health assistant professionals (321)	1	1	2	2	1	1
Therapists (322)	1	1	–	–	1	1
Sales and related assistant professionals (354)	4	3	5	3	5	3
Social welfare assistant professionals (323)	3	6	1	2	5	9
Sports and fitness occupations (344)	13	4	–	–	2	–
Public service and other assistant professionals (356)	2	3	2	2	3	5
Subtotal (%)	47	40	39	43	35	35
Total (*n*)	4695	8865	720	1140	1005	5045

women and ICT roles for men, but otherwise the types of jobs taken by both groups are fairly similar. Among chemistry graduates a higher proportion of women take jobs as science professionals and as teachers, but otherwise, patterns again are relatively similar for men and women.

Well over half of engineering science students who enter employment remain in the field, indeed by far the largest recruiter of engineering graduates are the engineering professional occupations (civil engineers, production engineers and so on). As we have seen, this is an area where gender stereotypes patterns of participation persist and to some extent they remain when female engineers leave education and enter the workforce. However, despite the area remaining one where men continue to be over-represented, it is still the case that well over half of female engineering graduates who enter employment do so in an area related to their degree. With the exception of recruitment to the ICT professions, gendered recruitment patterns among mathematical science graduates are relatively slight. A large proportion of these graduates who enter employment work in the business and finance professions and associate professions, which recruit similar proportions of men and women.

In comparison with the other science subject areas described above, biological science graduates are less likely to gain employment in a science-related field. In psychology, in particular, only around one third of male and female graduates who enter employment work in an area related to their degree. Indeed the occupation that recruits the highest proportion of psychology graduates are sales and customer service jobs (SOC group 7, not shown in table). Gendered patterns of participation are minimal in these subjects, the most pronounced difference coming in the 13% of male biological science graduates who seek employment in sport and fitness occupations.

Discussion

This paper has considered gendered patterns of participation in STEM-related post-compulsory education in the UK. It has examined the trajectory of learning that takes students from A-level qualifications, through undergraduate work and into employment or further study. As well as looking at how levels of engagement between men and women vary at each stage, the research reported here has also taken a long-term view and considered the best available evidence to monitor participation and attainment over an extended period of time. Although this is an area with a long and distinguished research history, the more recent context for academic and policy interest in the differing levels of engagement with STEM subjects between men and women coincided with the introduction of compulsory school science for students aged 14 and older as part of the National Curriculum reforms in England and Wales in 1988. These reforms meant that all students were to spend a significant proportion (for many around 20%) of their time studying science through to the end of compulsory schooling. More recent government proposals to enhance the science content of the National Curriculum mean that by 2014, 90% of state-funded schools will offer single subject science teaching (or *triple* science) and the number studying for separate GCSEs in chemistry, physics and biology will be doubled (Fairbrother & Dillon, 2009). This further broadening of the science curriculum is, in part, in the hope that more young people will be encouraged to study the subject beyond the age of 16.

Since the mid-1980s there have been a number of initiatives, programmes and projects aimed at improving levels of recruitment and retention among women in STEM subjects. Some of these projects like the GIST research programme and the WISE campaign have sought to encourage girls in school to consider careers in areas such as the physical sciences and engineering (for example WISE, 2007). Others such as the UK Resource Centre for Women in Science Engineering and Technology have a broader aim to support the career development of professional female scientists. In fact, the SET Fair report (Greenfield *et al.*, 2002), commissioned in 2002 and chaired by Baroness Susan Greenfield, identified around 70 organisations, projects or initiatives aimed specifically at increasing the participation of women in science, engineering and technology subjects but concluded that many of these initiatives were fragmented and their contribution 'unclear' (p. 10). Indeed, despite efforts to develop and coordinate these many initiatives over subsequent years, women still remain under-represented in the field and as the results presented here show, levels of unequal participation in key STEM subjects have varied little over the last 25 years. This is despite more women entering HE and little gender difference in the entry qualifications for STEM subjects. So if qualification is not a barrier to participation, then why have the increased number of women studying in HE not been reflected in subjects such as physics and engineering?

The answer, according to much of the literature in this area, would lie in the various socio-cultural barriers to STEM education that women experience (for example Ceci *et al.*, 2009). However, the data presented here shows that women are engaged with science and wish to study the subject at the highest levels. Rather, the types of science subjects they study, and psychology is a notable example here, are not necessarily those that policy makers and employers consider to be the 'strategic, important and vulnerable' science subjects. Women are also studying many science subjects in higher numbers than previously and yet recruitment to physics and engineering remains stagnant. This may be a reflection of the critical mass model, which suggests that female recruitment to these subjects is still too low to be self-sustaining and generate future growth. However, it is important to remember that numbers of male participants in physics and engineering subjects are also stable. In addition, for women who do remain in the 'science stream', patterns of employment in graduate careers and further study appear relatively equitable: over half of all chemistry and physics graduates (male and female) who enter employment remain in the field and similar proportions engage in further study.

It is very difficult to provide policy recommendations that will easily remedy inequalities in the numbers of women who participate in physics and engineering in HE. Decades of well-funded and well-targeted initiatives have had limited impact and even making all young people study the sciences up to the age of 16 had little long-term effect on recruitment at the next educational levels. As male and female students achieve at similar levels in gateway qualifications, there is limited evidence that attainment is a barrier to participation and for women who do study these shortage subjects evidence suggests that many are likely to remain in the field upon graduation. Whatever socio-cultural barriers are preventing the recent expansion of the HE system being reflected in female participation in physics and engineering, they appear to also apply to men and remain largely unaffected by gender-related participation-widening initiatives.

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Notes

1. Higher National Diploma: this is a HE qualification that is equivalent to the first two years of an undergraduate degree.
2. Polytechnics were tertiary level institutions that differed from universities in that their focus was traditionally on vocational programmes. The 1992 Further and Higher Education Act abolished the distinction between polytechnics and universities.
3. See Appendix 1 for a description of the method used to measure relative achievement.
4. The organisation of UCAS STEM subject groups is provided in Appendix 1.

5. SOC groupings represent the official UK government's classifications for employment. Those beginning with 2 represent 'Professional Occupations' and those beginning with 3 represent 'Associate Professional and Technical Occupations'.
6. Clearing is a service which is offered by UCAS to help people without a university place to find a suitable vacancy. It runs annually from July to September after the usual period of recruitment has ended.

References

Acker, S. (1992) New perspectives on an old problem: the position of women academics in British higher education, *Higher Education*, 24, 54–75.

Attwood, R. (2010, February 26) Mind the gap, *Times Higher Education Supplement.* Available online at: www.timeshighereducation.co.uk./story.asp?sectioncode=26&storycode=410531&c=2 (accessed February 2010).

Blair, T. (2006) *Our nation's future—science,* speech given to the Royal Society, Oxford, UK, 3 November 2006. Available online at: www.number10.gov.uk/Page10342 (accessed October 2008).

Blickenstaff, J.C. (2005) Women and science careers: leaky pipeline or gender filter, *Gender and Education,* 17(4), 369–386.

Brennan, J. & Naidoo, R. (2008) Higher education and the achievement (and/or prevention) of equity and social justice, *Higher Education*, 56, 287–302.

Broecke, S. & Hamed, J. (2008) *Gender gaps in higher education participation: an analysis of the relationship between prior attainment and young participation by gender, socio-economic class and ethnicity,* DIUS Research Report 08 14. Available online at: http://www.dius.gov.uk/research_and_analysis/~/media/publications/D/DIUS_RR_08_14 (accessed February 2010)

Brown, G. (2009) *The Romanes Lecture,* given at the Sheldonian Theatre Oxford, 27 February. Available online at: www.number10.gov/Page18472 (accessed May 2009).

Butz, W. P., Bloom, G. A., Gross, M. E., Kelly, T. K., Kofner, A. & Rippen, H. E. (2006) *Is there a shortage of scientists and engineers?* Issue Paper: Science and Technology (Santa Monica, CA, The RAND Corporation).

Ceci, S. J., Williams, W. M. & Barnett, S. M. (2009) Women's under-representation in science: sociocultural and biological considerations, *Psychological Bulletin*, 135(2), 218–261.

Confederation of British Industry (2008) *Taking stock: CBI education and skills survey 2008* (London, CBI). Available online at: http://www.cbi.org.uk/pdf/skills_report0408.pdf (accessed June 2009).

Department for Education and Skills (2006) *The supply and demand for science, technology, engineering and mathematics skills in the UK economy,* DfES Research Report No. 775. Available online at: http://www.dcsf.gov.uk/research/data/uploadfiles/RR775.pdf (accessed January 2010).

Department for Innovation, Universities and Skills (DIUS) (2009a) *The demand for science, technology, engineering and mathematics (STEM) skills.* Available online at: http://www.bis.gov.uk/assets/biscore/corporate/migratedd/publications/d/demand_for_stem_skills.pdf (accessed March 2010).

DIUS (2009b) *Higher ambitions: the future of universities in a knowledge economy,* Department for Business, Innovation and Skills. Available online at: www.bis.gov.uk/assets/biscore/corporate/docs/h/09-1447-higher-ambitions.pdf (accessed February 2010).

Fairbrother, R. & Dillon, J. (2009) Triple science back on the agenda, *School Science Review,* 91(334), 65–69.

Fox, M. F. (2001) Women, science and academia: graduate education and careers, *Gender and Society,* 15(5), 654–666.

Francis, B. & Skelton, C. (2005) *Reassessing gender and achievement: questioning contemporary key debates* (Abingdon, UK, Routledge).

Gago, J. M., Ziman, J., Caro, P., Constantinou, C., Davies, G., Parchmann, I. *et al.* (2004) *Increasing human resources for science and technology in Europe,* Report of the High Level Group on Human Resources for Science and Technology in Europe (Luxembourg, European Communities).

Glover, J. & Fielding, J. (1999) Women and science in Britain: getting in? *Journal of Education and Work*, 12(1), 57–73.

Gorard, S., Adnett, N., May, H., Slack, K., Smith, E. & Thomas, L. (2007) *Overcoming the barriers to higher education* (Stoke-on-Trent, UK, Trentham Books).

Gorard, S., Rees, G. & Salisbury, J. (2001) Investigating the patterns of differential attainment of boys and girls in school, *British Educational Research Journal,* 27(2), 125–139.

Gorard, S. & Smith, E. (2007) Do barriers get in the way? A review of the determinants of post-16 participation, *Research in Post-Compulsory Education*, 12(2), 141–158.

Greenfield, S., Peters, J., Lane, N., Rees, T. & Samuels, G. (2002) *A report on women in science, engineering and technology for the Secretary of State for Trade and Industry.* Available online at: http://extra.shu.ac.uk/nrc/section_2/publications/reports/R1182_SET_Fair_Report.pdf (accessed March 2010).

Harding, R. (2009) *Women's enterprise and SET* (London, NPCWE).

Harding, S. (1991) *Whose science? Whose knowledge? Thinking from women's lives* (Ithaca, NY, Cornell University Press).

Higher Education Funding Council for England (HEFCE) (2008) *Strategically important and vulnerable subjects,* Final report of the 2008 advisory group. Available online at: www.stemnet.org.uk/_db/_documents/strategic_subjects_final_report_08_20090323042053.pdf (accessed April 2010).

HM Treasury (2010) *Chancellor of the Exchequer's budget statement, 24 March 2010.* Available online at: www.hm-treasury.gov.uk/budget2010_speech.htm (accessed April 2010).

Institute of Physics (2005) *Survey of academic appointments in physics 1999–2004, United Kingdom and Ireland* (London, Institute of Physics).

Institute of Physics (2007) *Tracking the careers of UK physics students,* Project No. 1242, September 2007 (London, Institute of Physics).

Jenkins, E. W. & Donnelly, J. F. (2006) Educational reform and the take-up of science post-16, paper presented at the *Royal Society Conference 'Increasing the take-up of science post-16',* March 16, London.

Kelly, A. (1985) The construction of masculine science, *British Journal of Sociology of Education*, 6(2), 131–154.

Kenway, J. & Gough A. (1998) Gender and science education in schools: a review 'with attitude', *Studies in Science Education,* 31(1), 1–29.

Massachusetts Institute of Technology (1999, March 1999) A study on the status of women faculty in science at MIT, *The MIT Faculty Newsletter.* Available online at: web.mit.edu/fnl/women/women.html (accessed May 2010).

Murphy, P. & Whitelegg, E. (2006) *Girls in the physics classroom: a review of the research on the participation of girls in physics* (London, Institute of Physics).

National Academy of Sciences (2007) *Rising above the gathering storm: energizing and employing America for a brighter economic future.* Available online at: http://books.nap.edu/openbook.php?record_id=11463&page=86 (accessed November 2009).

Phipps, A. (2002) Engineering women: the 'gendering' of professional identities, *International Journal of Engineering Education*, 18(4), 409–414

Pigliucci, M. (2008) *Soft v. hard science: part one.* Available online at: www.scientificblogging.com/rationally_speaking/soft_vs_hard_science_part_i (accessed February 2010).

Prados, J. W. (1998) *Engineering education in the United States: past, present and future.* Available online at: www.ineer.org/Events/ICEE1998/Icee/papers/255.pdf (accessed December 2009).

Raffe, D., Croxford, L., Iannelli, C., Shapira, M. & Howieson, C. (2006) *Social-class inequalities in education in England and Scotland,* Special CES Briefing No. 40 May 2006, Centre for

Educational Sociology. Available online at: http://www.ces.ed.ac.uk/PDF%20Files/Brief040.pdf (accessed February 2010).
Seymour, E. & Hewitt, N. M. (1997) *Talking about leaving: why undergraduates leave the sciences* (Boulder, CO, Westview Press).
Smail, B., Whyte, J. & Kelly, A. (1982) Girls into science and technology: the first two years, *School Science Review*, June, 620–629.
Smith, E. (2005) *Analysing underachievement in school* (London, Continuum).
Smith, E. (2008) *Patterns of participation in UK undergraduate STEM subjects 1986-2007*, ESRC interim report, University of Birmingham, UK.
Smith, E. (2009) *Who is studying science? An analysis of patterns in the recruitment, training and employment of scientists*, End of Award Report, ESRC RES 22002005.
Smith, E. (2010a, forthcoming) Staying in the science stream: patterns of participation in A-level science subjects in the UK, *Educational Studies*, 36.
Smith, E. (2010b, forthcoming) Do we need more scientists? A long term view of patterns of participation in UK undergraduate science programmes, *Cambridge Journal of Education*, 40(4).
Sonnert, G. with Holton, G. (1995) *Gender differences in science careers: the project access study* (Piscataway, NJ, Rutgers University Press).
Sonnert, G., Fox, M. F. & Adkins, M. (2007) Undergraduate women in science and engineering: effects of faculty, fields and institutions over time, *Social Science Quarterly*, 88(5), 1334–1356.
Terzian, S. G. (2006) Science world: high school girls and the prospect of scientific careers 1957–1963, *History of Education Quarterly*, 46(1), 73–99.
UNESCO (1997) *International standard classification of education*. Available online at: http://www.unesco.org/education/information/nfsunesco/doc/isced_1997.htm (accessed November 2009).
WISE (2007) *Women into science, engineering and construction*. Available online at: http://www.wisecampaign.org.uk/ (accessed December 2009).
Zalevski, A. & Kirkup, G. (2009) *The case for increasing gender diversity of company boards in SET, Policy Briefing No. 12* (Bradford: UK, Resource Centre for Women in SET).

Appendix 1. UCAS main subject group categories for science and science-related subjects

- Medicine and dentistry (medical sciences)
- Subjects allied to medicine (allied medical sciences): including nursing and pharmacy
- Biological sciences (biological sciences): including biology, microbiology, biochemistry, psychology, sports science and combinations thereof.
- Veterinary sciences, agriculture and related (agricultural sciences)
- Physical sciences (physical sciences): including chemistry, physics, physical geography and environmental and forensic science and combinations thereof
- Mathematical and computational sciences (mathematical sciences)
- Engineering and group J technologies (engineering sciences)
- Architecture, building and planning (architectural sciences)
- Sciences combined with social sciences or arts (combined sciences and other)
- Combined sciences (combined sciences)