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Measuring determinants of post-compulsory participation in science: a comparative study using national data

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Abstract

Increasing post-compulsory participation in science and science-related subjects is seen as a key education policy priority in England and more widely. This paper uses descriptive analysis of national data to investigate the effects of science attainment at 16, gender, socio-economic status, and school science pathway on progression into post-16 traditional and vocational science courses in state funded schools in England. Comparisons are also made with progression into non-science subjects (history, mathematics and psychology). Multi-level statistical modelling is employed to provide independent estimates for all these effects, whilst also taking into account mathematics attainment at 16, and whether or not the 14-16 school also teaches to 18.

The key findings of the descriptive analysis are that progression rates vary widely across post-16 sciences in terms of both gender and socio-economic status, but that other subjects too vary in these regards. Once prior attainment is accounted for, the gender differences across science and some other subjects largely remain but those due to socio-economic status are to some extent ameliorated. In terms of school science pathways, those students doing 'more' science at 14-16 are found to be more likely to progress to traditional science post-16. The statistical modelling further

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quantifies the relative importance of each of these effects in determining progression and shows how, in comparison to other courses, there is more variation at the school level in progression to vocational sciences. Further, the determinants of participation in these vocational sciences courses are of a different character to the non-vocational sciences.

Key words

post-compulsory science participation, national data, multi-level modelling

Introduction

Policy background

Since the introduction of the national curriculum in schools in England from 1989, the study of elements of the three separate sciences has been compulsory for all students in state maintained schools. However, once students reach age 16 this is no longer the case and students remaining in education post-16 can choose whether or not they include any science subjects as part of the mix of courses they might study. In England there has been an ongoing concern for many years with the number of students studying sciences post-16, and this is particularly true of the physical sciences (Gill & Bell, 2011; Gorard & See, 2009; The Royal Society, 2011). The concern centres on the view that a strong science base and the adequate supply of scientist are key determinants of a successful modern economy, one that is able to successfully compete on the global stage (HM Treasury et al., 2009). [2]

[2] Concerns about participation in post-compulsory science are far from new (Smith, 2010).

In part as a response to these long-term concerns, a major reform of the 14-16 science curriculum in England in 2006 stated as one of its key longer term aims to increase the participation in post-compulsory sciences, thereby ensuring the adequate supply of scientists and engineers (DfES, 2005; Ryder & Banner, 2010) . Whilst this reform has a diversity of aims, a key aspect at 14-16 is to engage more students in doing more science through the inclusion of elements of scientific literacy, the study of the nature of science, and the discussion in science lessons of socio-scientific issues (Banner et al., 2010; Millar, 2006). In the classroom, these changes promote a move towards more discussion and consideration of ethical issues, together with a greater understanding of 'how science works', and were intended to make school science more appealing and therefore increase students' disposition towards science. This in turn might encourage more students to continue studying science post-16, particularly those from traditionally under-represented sub-groups (Ryder & Banner, 2010).

In 2008, shortly after the 2006 curriculum reform, a policy of an entitlement to study the separate sciences (GCSEs[3] in biology, chemistry and physics – collectively known as Triple award) at 14-16 was also introduced for highly achieving students (HM Treasury et al., 2009; Fairbrother & Dillon, 2009).[4] Again, the aim was to

[3] Students take a number of GCSEs (*General Certificates of Secondary Education*) typically at age 14-16. Progression to post-16 courses is often dependent on sufficiently high attainment in particular GCSEs.

[4] In the final years of secondary education, studying science in England is compulsory but students can 'choose' one of several different science pathways. For the purposes of this study, students have been grouped into three categories (Triple science – separate qualifications in biology, chemistry and physics; Dual award science – a combined course of all sciences worth two GCSEs; and Other – all other science qualifications at 16, including Dual award applied science, Single award science and

encourage more students to do more science at 14-16, with the expectation that this could lead to higher participation rates in post-16 sciences. As Fairbrother & Dillon (2009) point out, there is, however, evidence that for some students doing more science at 14-16 could have the opposite effect to that intended.

In light of these policy developments, and the relatively high profile that science education continues to play in the national and political discourse, it is natural to ask what, according to national data, are the key determinants of whether or not students continue their science studies post-16. With the first post-2006 cohort having now completed their two-year post-16 courses, this paper provides a quantitative snapshot of these determinants. In time, comparisons with later cohorts will provide insight into if and how these determinants are changing as the system evolves. A brief survey follows of what is known about these issues from the literature; the full aims and scope of the paper are then detailed.

Key determinants of post-compulsory science participation

Some important influences on continuing the study of science post-16 are well-known. Research review articles in this area include those of Tripney et al. (2010), Wynarczyk & Hale (2011) and Boe et al. (2011). In addition, a recent European research collaboration[5] (IRIS) has demonstrated how these issues extend across

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some other non-GCSE qualifications). Homer et al. (2011b) has more details of the nature of these science options at 14-16, and of their take-up over a five year period to 2010.

[5] Interests and Recruitment in Science (IRIS) is a network of six European partners conducting research to understand how young people (and women in particular) choose education and careers in science, technology and mathematics: http://www.iris.v-izdelavi.si/about-iris/

different countries within Europe and beyond (Henriksen, Dillon, & Ryder, forthcoming). This body of work shows that students with more positive experiences of, and dispositions towards, school science are more likely to continue studying science post-16 (Osborne, Simon, & Collins, 2003, Hazari et al). However, it is also clear that such positive experiences do not necessarily lead to post-16 participation; liking science is not of itself sufficient. Awareness of the extrinsic benefits of post-16 science courses, such as its contribution in progression into secure and well-paid employment, is also important (Mujtaba & Reiss, 2012). The role of 'significant adults', such as a family member or teacher, in encouraging consideration of a post-16 science pathway is also often critical (Archer et al., 2010). Within this, the role of the teacher, and associated teaching approaches, are central to the development of positive dispositions. The interplay of personal student dispositions and broader socio-cultural factors highlights the significance of 'student identity' in relation to subject choice, with many students seeing science as 'important, but not for me' (Archer et al., 2012; Jenkins & Nelson, 2005). More recent research has demonstrated the extent to which subject choice is a process that takes place over time, rather than being a decision made at a particular point, and that dispositions not to pursue science future science can be set early within compulsory schooling (Maltese & Tai, 2010). Furthermore, such choice processes continue beyond key decision points, leading many students to choose to leave, or consider leaving, post-16 science courses before they have been completed (Henriksen et al., forthcoming).

Whilst recognising this broad set of interacting factors, and their interplay over time, the focus of this paper is on determinants of participation that are available in existing national data for England. The crucial role that prior attainment has on post-compulsory choices is clear (Rodeiro, 2007). Beyond attainment, there is the varying role of gender, where girls are more likely to take up biology A-level[6] compared to boys, whereas they are very much less likely to take-up A-level physics (Mujtaba & Reiss, 2012; Smith, 2011b). Studies have also shown that students from lower socio-economic backgrounds tend not to choose science post-16 (Gorard & See, 2009) although, this is to some extent driven by the lower average attainment of students from poorer backgrounds. In addition, the impact of the nature of the science course studied at 14-16 is also likely to affect post-16 science study. Following the 'push' for Triple award in England, there has been a large increase in the proportion of students taking this pathway, and a consequent decline in the proportion taking Dual award (Homer et al., 2011a). Whilst it is probable that students are more likely to continue studying science post-16 having done Triple award, there has only been only limited recent work (Broeke, 2010; Gill & Bell, 2011) quantifying some of these effects, and little investigation of vocational science and other non-science courses with regard to influences on progression.

[6] A-levels (more formally the *Advanced Level General Certificate of Education*) are usually studied for two years, and admission to university is often dependent upon obtaining sufficiently highly in three or four A-levels.

This study

This paper uses national data to first investigate descriptively how progression to post-16 science courses varies by a range of student characteristics: prior science attainment at 16, gender, measures of socio-economic status and 14-16 science pathway. In a second analysis, using statistical modelling, these effects are investigated together, alongside two additional measures: (i) prior attainment in mathematics, as it is recognised that success in mathematics is commonly seen as an important precursor to continuation of study in science beyond 16, especially for physics (Gill & Bell, 2011); and, (ii) if the 14-16 school also teaches up to age 18; this might, in part, be an important influence on student progression for some courses (Bennett et al., 2011). This quantitative analysis is part of a larger project, the Enactment and Impact of Science Education Reform (EISER), a three-year longitudinal study involving database analysis alongside more in-depth school-based case studies using qualitative methodologies[7].

As well as including the three most popular separate sciences A-levelsin this progression study (biology, chemistry and physics), attention is also given to two post-compulsory vocational science courses that are rarely included in academic studies; Applied science A-level and BTEC National Award Applied Sciences. The former of these has a focus on how science is applied across a mixture of industries and professions but, in common with other A-levels, is assessed largely through formal examinations. The latter is designed as training towards particular scientific

[7] http://www.education.leeds.ac.uk/research/projects/enactment-and-impact-of-science-education-reform-eiser. In turn, the EISER project is part of a larger research program comprising five major national projects: the Targeted Initiative on Science and Mathematics Education (TISME), http://tisme-scienceandmaths.org/.

careers, and is assessed through a mixture of criterion referenced tasks including projects, case studies, performance observations and time-constrained assessments.

To assess the extent to which influences on progression are unique to science, this study also analyses progression to three other popular non-science subjects – A-levels in history, mathematics and psychology. These subjects were chosen partly on the basis of popularity in terms of national uptake in England[8], but also because they vary in terms of when studying them as separate subjects usually begins. At 14-16 in England, students do not generally study psychology at all, whereas history is optional at this age but mathematics is compulsory up to 16. Of course, within the sciences, mathematics as a discipline plays a special role since post-16 students studying physics, and to a lesser extent chemistry, might also be encouraged or expected to study some mathematics.

[8] Broadly, the total number of entries to mathematics and psychology A-levels each year are similar to that of chemistry and physics combined.

The key research questions this paper addresses are:

- What is the degree of differential participation (i.e. stratification) by gender, socio-economic status and 14-16 science pathway in post-16 science courses, and how do the non-science courses compare in this regard?
- To what extent is any stratification due to differential prior attainment in science across sub-groups (e.g. girls, students from lower socio-economic backgrounds)?
- What are the independent effects of students and school characteristics on participation in science, and in comparator subjects?
- What are the strengths and weaknesses of this kind of analysis based on national data?

The paper quantifies the independent influences on post-compulsory participation across a wide range of science courses, both academic and vocational, and across select non-science comparators. It complements other more focussed and/or qualitative research, and aims to give policy makers and other stakeholders a better understanding of the current national picture, in order to provide new insights into how policy changes at 14-16 might impact on post-16 participation in science.

Whilst this study investigates *progression*, it is hoped that a follow-up study will use similar data to investigate the influences on *attainment* in science post-16, and in comparator subjects.

Methods

National data for England

This study follows a single national cohort of students who completed their compulsory education in 2008 at age 16. It investigates whether or not they were then awarded, up to two years later (by 2010), any of the post-compulsory qualifications listed in Table 1.

<table>
<tr><th>Name of qualification</th><th>Type of qualification</th><th>More details of qualification types</th></tr>
<tr><td colspan="2">Science courses</td><td rowspan="11">A-levels (formally Advanced Level General Certificate of Education) are usually studied over a two-year period, and entrance to university is normally predicated on sufficiently high achievement in these qualifications.

Applied A-levels are A-levels with a vocational emphasis.

BTEC National Awards are equivalent to A-levels in terms of academic value, but have a vocational focus.</td></tr>
<tr><td>Biology</td><td>A-level</td></tr>
<tr><td>Chemistry</td><td>A-level</td></tr>
<tr><td>Physics</td><td>A-level</td></tr>
<tr><td>Applied Science</td><td>Applied A-level –a vocationally orientated qualification</td></tr>
<tr><td>BTEC National Award Applied Sciences</td><td>Also vocationally orientated</td></tr>
<tr><td colspan="2">Comparator courses</td></tr>
<tr><td>Mathematics</td><td>A-level</td></tr>
<tr><td>Psychology</td><td>A-level</td></tr>
<tr><td>History</td><td>A-level</td></tr>
</table>

Table 1: The set of post-compulsory qualifications investigated in this study

The data for the study is from the National Pupil Database (NPD)[9], which contains student and school level assessment data from all maintained schools and colleges in England. Data from the NPD has been widely used in academic studies investigating aspects of participation and attainment in science, and other subjects (Homer et al., 2011a; Homer et al., 2011b; Noyes, 2009; Gill & Bell, 2011).

The NPD only contains information on qualifications actually awarded rather than courses started but never completed. Hence, the terms ‘participation’ and ‘completion’ are used synonymously throughout this paper, as are ‘course’ and ‘qualification’. The NPD also contains student personal characteristics (e.g. gender and free school meal eligibility, an indicator of socio-economic status), and school-level measures such as the age-range the school/college caters for.

Descriptive analysis

Descriptive statistics detail the percentage participation within each post-16 course (Table 1) by particular student-level characteristics: gender, free-school meal eligibility and 14-16 science pathway. This initial analysis reveals the extent to which these student characteristics impact on national participation rates in the post-compulsory courses.

Progression to post-16 courses is to an extent predicated upon sufficiently high attainment at age 16 in relevant 14-16 courses. In an attempt to control for this

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[9] See http://www.adls.ac.uk/department-for-education/dcsf-npd/ or http://nationalpupildatabase.wikispaces.com/

confounding factor, a descriptive analysis parallel to that above is carried out for the sub-set of students who attained relatively highly in science at 16.

Modelling participation

It is recognised that calculating frequencies and proportions will only take one so far in terms of understanding the key influences on progression to post-16 courses. For each of the separate post-16 subjects listed in Table 1, a multi-level modelling approach (Goldstein, 1995) is used to estimate the *independent* effect on participation of each of a set of likely predictors, based on existing research discussed in the Introduction. These include student-level measures of 14-16 attainment in science, 14-16 science pathway, gender and socio-economic status. The full set of explanatory variables is listed in Table 2, which also gives further details of their nature.

Predictor	Type of variable	Further details
Mean prior attainment in science at 16	Continuous	Since students can do 1, 2 or 3 science qualifications (GCSEs) at 14-16 it is rational to use a mean value across these to 'score' them on the same scale - see Homer (2011b) for more details on this issue. This scale is 0 (below GCSE) to 58 (mean grade A*) with 6 points between grades so that mean grade A=52, B=46 and so on.
Prior attainment in maths at 16	Continuous	This is the GCSE points score the student achieved in mathematics. It is on the same scale as the prior attainment in science score (0 to 58)
Gender	Dichotomous	The reference group (coded 0) is female so the effect in the model is for male (1).
Free school meal eligibility (FSM)	Dichotomous	This is a measure of socio-economic status based on whether the student is eligible and in receipt of free school meals (coded 1, eligible) or not (0).
Income deprivation affecting children index (IDACI)	Continuous	This is a second, distinct, measure of socio-economic status on a scale from 0.0 to 1.0 indicating the proportion of children under age 16 in the local area living in low income households. Lower values of this index relate to wealthier areas, and higher values to poorer areas.
14-16 science pathway: Triple award (TA)	Dichotomous	This indicates whether the student studied the three separate sciences at 14-16 (coded 1) or not (0). The reference group is those students who studied Dual award (DA).
14-16 science pathway: Other	Dichotomous	This indicates whether the student studied something other than TA or DA at 14-16 (coded 1) or not (0). Again, the reference group is those students who studied DA.
14-16 school also teaches up to age 18	Dichotomous	This indicates whether the 14-16 school also provides post-compulsory education up to age 18 (coded 1 for yes, and 0 for no).

Table 2: Predictors used in the multi-level logistic regression modelling

The multi-level model employed is a two-level random intercepts logistic regression model with participation (Yes/No) as the outcome. This approach takes account of the natural structure in the data with students (the lowest, level 1, units) nested in schools (level 2 units). It results in a more accurate and insightful model compared to the simpler approach of ignoring this hierarchy (Hutchison & Schagen, 2008). MLwiN software (J Rasbash, Charlton, et al., 2009) is used for the estimation, with full model details given in Appendix 1.

Odds ratios

For each predictor, the modelling produces an odds ratio estimate (Bland & Altman, 2000), from which the importance of the predictor in influencing participation can be deduced. An odds ratio of exactly 1 implies that the predictor has no effect on the outcome (doing or not doing the particular qualification), whereas an odds ratio greater than 1 implies that cases with higher values of the predictor are more likely to do the qualification, and an odds ratio less than 1 implies that this is less likely. See Appendix 2 for more on interpreting odds ratios.

Variation at the school level

The multi-level modelling approach is used to account for the lack of independence between students in the same school, but, importantly, also provides an estimate of the proportion of the variance in the outcome (i.e. progression or not for each course) that is at the school level, once all the predictors have been accounted for. For each course (i.e. model), this gives an indication of the variation in progression rates across schools nationally (i.e. the extent to which individual schools vary in this regard). Hence, one can compare across courses the national ‘school effect’ on progression.

Formally, this statistic is called the variance partition coefficient (VPC), and is calculated as:

$$\frac{Level\ 2\ variance}{Level\ 2\ variance + 3.29}$$

based on an underlying latent variable approach (Goldstein, 1995, p110). Two values of the VPC are given, one for a simple (null) model that includes no predictors, and secondly for the full model when all predictors (Table 2) have been included. These coefficients give an indication of the importance that schools are making to the likelihood of participation in each course above and beyond any predictors included in the modelling.

Limitations of the study

As already alluded to in the introduction, no attitudinal measures are available national data, and this is an important but unavoidable limitation of this type of analysis. Further, data from schools independent of state funding are not available, and hence the analysis only includes maintained schools within England.

It is known that ethnicity play a complex role in educational attainment, and in attitudes towards and decisions related to subject choices post-16 (Jones & Elias, 2005; Gorard & See, 2009; Strand, 2011; OECD 2007). However, for this study it was decided not to include this student characteristic, partly for reasons of parsimony, since variations in attainment by ethnicity are to a degree, but certainly not completely, related to measures of socio-economic status which are included. The influence of ethnicity on progression to post-16 science is worthy of a separate study of national data on its own.

Finally, it is recognised that subject choices post-16 are not independent of one another. In effect, students generally choose subject *combinations*, not individual subjects on their own. However, the number of possible combinations of subjects quickly becomes large when considering national data. To keep the analysis manageable, this study considers only progression to separate subjects rather than to combinations, but it is recognised that this is an additional limitation of the study.

Results

Descriptive analysis

Table 3 shows the number of students completing a selection of post-16 qualifications in England. These include the three main A-level sciences, two vocational science courses and three popular non-science A-level comparators (see Table 1). For each course listed, the table also shows the percentage of females and the percentage eligible for FSM completing each course, as well as a breakdown by 14-16 science pathway. The final two rows of the table give the overall percentages for two base populations – (i) the combined group of students (n=127,819) who completed at least one of the post-16 qualifications listed in Table 1, and (ii) the complete cohort at age 16, the end of compulsory schooling in England (n=606,618). For each course, this allows for direct comparisons with the make-up of these two populations.

Cohort or qualification	Total number of students	Percentage within row				
		Female	FSM-eligible	14-16 science pathway		
				TA	DA	Other
Full cohort at 16	**606,618**	**48.9**	**14.0**	**8.4**	**54.9**	**36.7**
Post-16 science qualification						
Biology	37,717	56.7	4.9	38.4	59.4	2.3
Chemistry	27,370	47.3	5.6	45.8	52.5	1.7
Physics	18,691	19.1	3.6	46.8	51.5	1.7
Applied Science	1,554	55.9	7.5	5.0	53.6	41.4
BTEC National Award Applied Sciences	1,570	54.0	14.4	7.6	56.5	35.9
Post 16 comparator qualification						
Mathematics	45,571	40.5	4.7	36.9	59.4	3.8
Psychology	42,974	73.9	6.2	16.2	73.3	10.5
History	33,238	51.8	3.8	21.1	70.1	8.8
Post 16 total						
Group of students taking at least one of the eight courses above	**127,819**	**53.7**	**5.2**	**26.3**	**66.1**	**7.6**

Table 3: Percentage female, FSM-eligible, from 14-16 science pathway

In terms of gender, Table 3 shows that female students are over-represented in the majority of courses both in comparison with the 14-16 figure (48.9% female in the final year of compulsory education) and also within the post-16 group of students doing at least one of the courses listed (53.7% female in this group). This is particularly true of biology (56.7%) and psychology (73.9%). In contrast, females are strongly under-represented in physics (19.1%), and to a lesser extent in mathematics (40.5%).

Turning to socio-economic status, FSM-eligible students are strongly under-represented across the board in comparison with their overall presence at 14-16 (14.0%). Their weakest representation is in physics (3.6%), but they have a stronger presence in the vocational courses, especially BTEC national award in applied sciences (14.4%).

Finally, comparing 14-16 science pathways, Triple Award students are strongly represented across all the traditional (i.e. non-vocational) A-level subjects in comparison to at 16 (8.4% TA), and as one might expect this is particularly true in the three sciences (38.4 to 46.8%). Conversely, TA students are relatively weakly represented in the post-16 vocational courses (5.0 to 7.6%).

Controlling for prior attainment in science

Table 4 presents a similar analysis as in Table 3, but only includes the sub-sample of students who were 'highly' achieving in science at age 16. The criteria for inclusion in this second analysis is to have obtained at least a (mean) grade of 'B' in science - this is often the minimum requirement for acceptance on to A-level courses. [10] It is acknowledged that the subsequent descriptive findings are partly conditioned by this definition of 'highly' achieving in science – choosing a different threshold would impact on the exact figures.

[10] So for Triple award students this would include a student who achieved BBB but not BBC, whilst for Dual award student would only be included if they had at least BB on average.

Cohort or qualification	Total number of students	Percentage within qualification				
		Female	FSM-eligible	14-16 science pathway		
				TA	DA	Other
Full cohort at 16	**157,009**	**51.2**	**5.2**	**23.6**	**68.0**	**8.5**
Post-16 science qualification						
Biology	34,626	57.0	4.6	39.2	59.7	1.1
Chemistry	26,035	47.5	5.2	46.6	52.7	0.6
Physics	17,752	19.5	3.5	47.7	51.8	0.5
Applied Science	502	55.2	6.0	4.4	60.2	35.5
BTEC National Award Applied Sciences	487	54.8	9.0	9.0	52.0	39.0
Post 16 comparator qualification						
Mathematics	41,311	40.8	4.2	38.8	59.3	1.9
Psychology	26,714	73.4	5.0	19.4	74.2	3.0
History	22,900	53.5	3.0	25.2	70.0	4.8
Post 16 total						
Group of students taking at least one of the above courses	**95,786**	**51.9**	**4.2**	**30.8**	**65.4**	**3.8**

Table 4: Percentage female, FSM-eligible, from 14-16 pathway (amongst those achieving mean grade B in science at 16)

To provide additional insight into the impact of taking prior attainment into account, the figures from Tables 1 and 2 are represented together graphically in Figures 1, 2 and 3 showing the effect for gender, FSM-status, and 14-16 science pathway respectively.

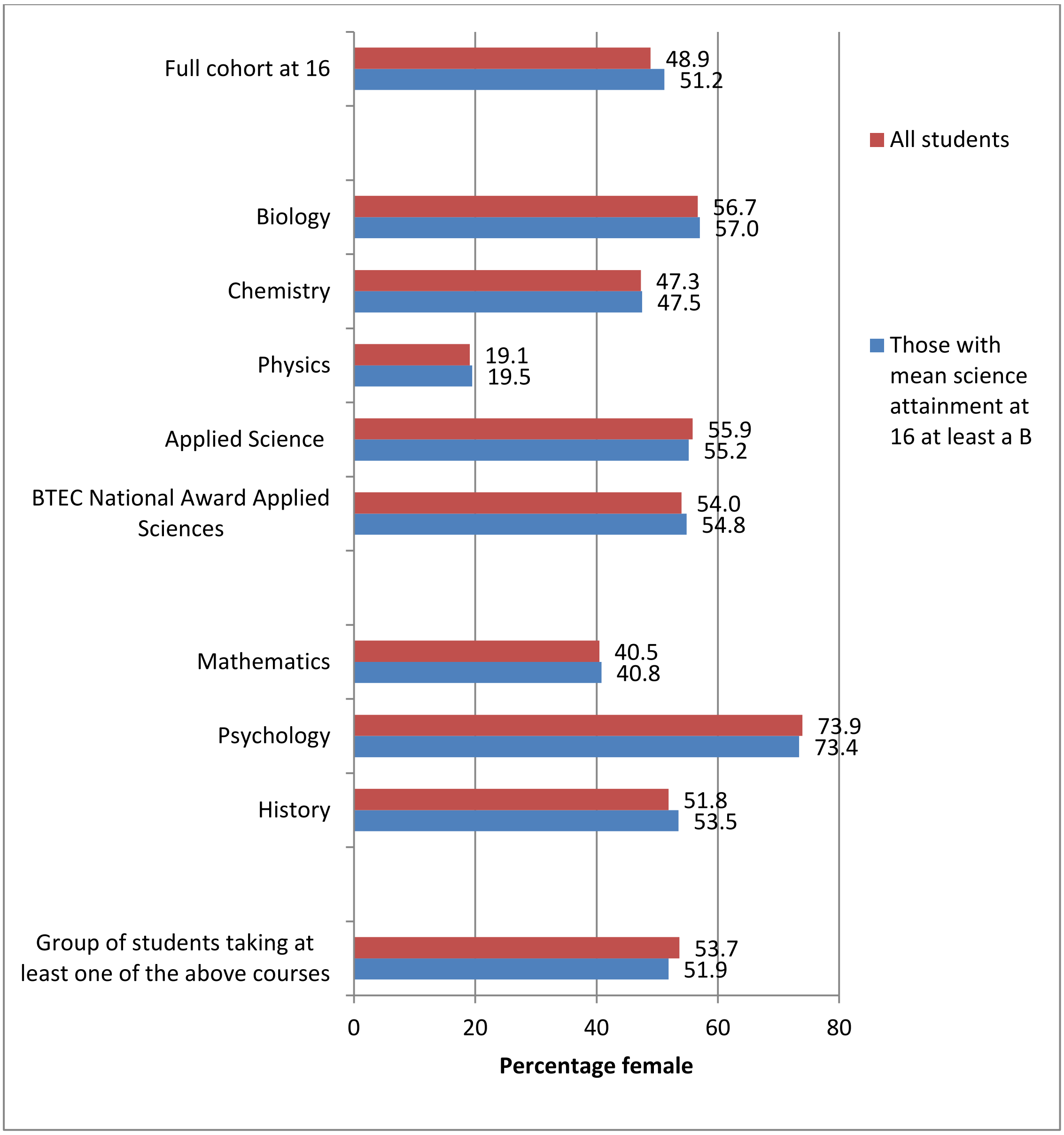

Figure 1: Percentage female within course/cohort

At 16 (the end of compulsory schooling), females make up 48.9% of the overall cohort, but 51.2% of the higher achievers in science at this age. Females are 53.7% of the group of students who took at least one of the courses listed in Table 1, but form 51.9% of those who achieved highly in science. These figures imply that girls are a little more likely than boys to participate in this set of post-16 courses, and that taking into account prior attainment in science has little overall effect on any gender effect in terms of progression. Across the individual post-16 courses, it is striking that controlling for prior attainment in science consistently makes little difference to the original variation in female participation rates. Hence, the strong under-representation in physics and mathematics, and the over-representation in psychology, remain having accounted for any differential prior attainment in science by gender.

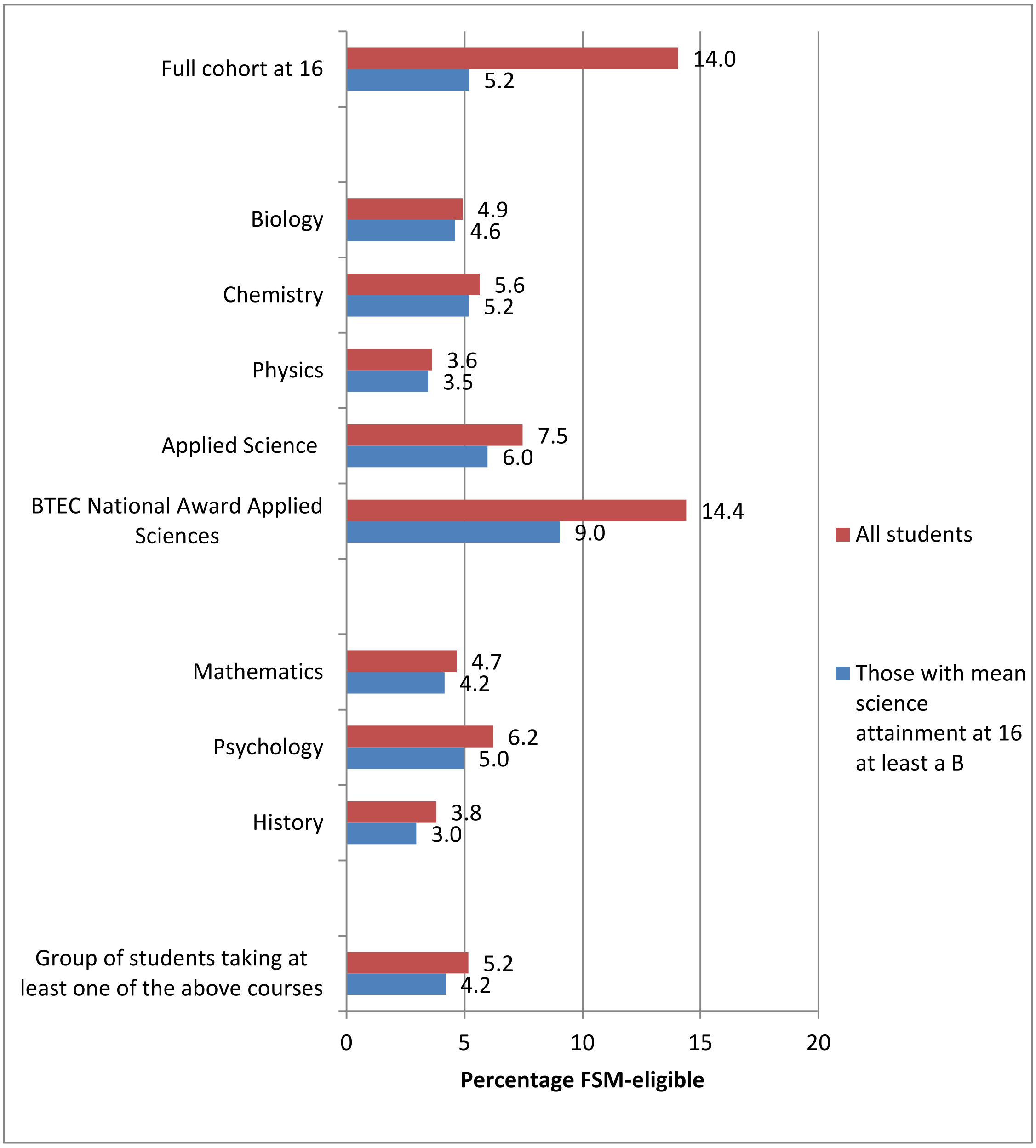

Figure 2: Percentage FSM-eligible within course/cohort

In the 14-16 cohort as a whole, 14.0% are FSM-eligible, but this drops to only 5.2% for the high-science-achieving sub-group at this age. In terms of those going on to study post-16 courses listed in Table 1, 5.2% are FSM-eligible, thus almost exactly reflecting the proportion of high-science-achieving students at age 16. Further, only 4.2% of the higher-science-achieving students post-16 are FSM-eligible. Hence, whilst FSM-eligible students tend to achieve relatively poorly at age 16, they do progress to the set of post-16 courses at a rate similar to their representation in the population having taken this into account.

At the subject level, a more nuanced picture emerges and whilst under-representation remains, the strength of the effect is certainly weakened having controlled for prior attainment. In physics (3.5% FSM-eligible) and history (3.0%) there remains poor relative representation of FSM-eligible students once prior attainment is accounted for, but in chemistry (5.2%), and especially the vocational science courses (6.0 to 9.1%), they are perhaps over-represented. In biology (4.6%) representation becomes broadly equitable having controlled for science attainment at age 16, and the same is true of mathematics (4.1%).

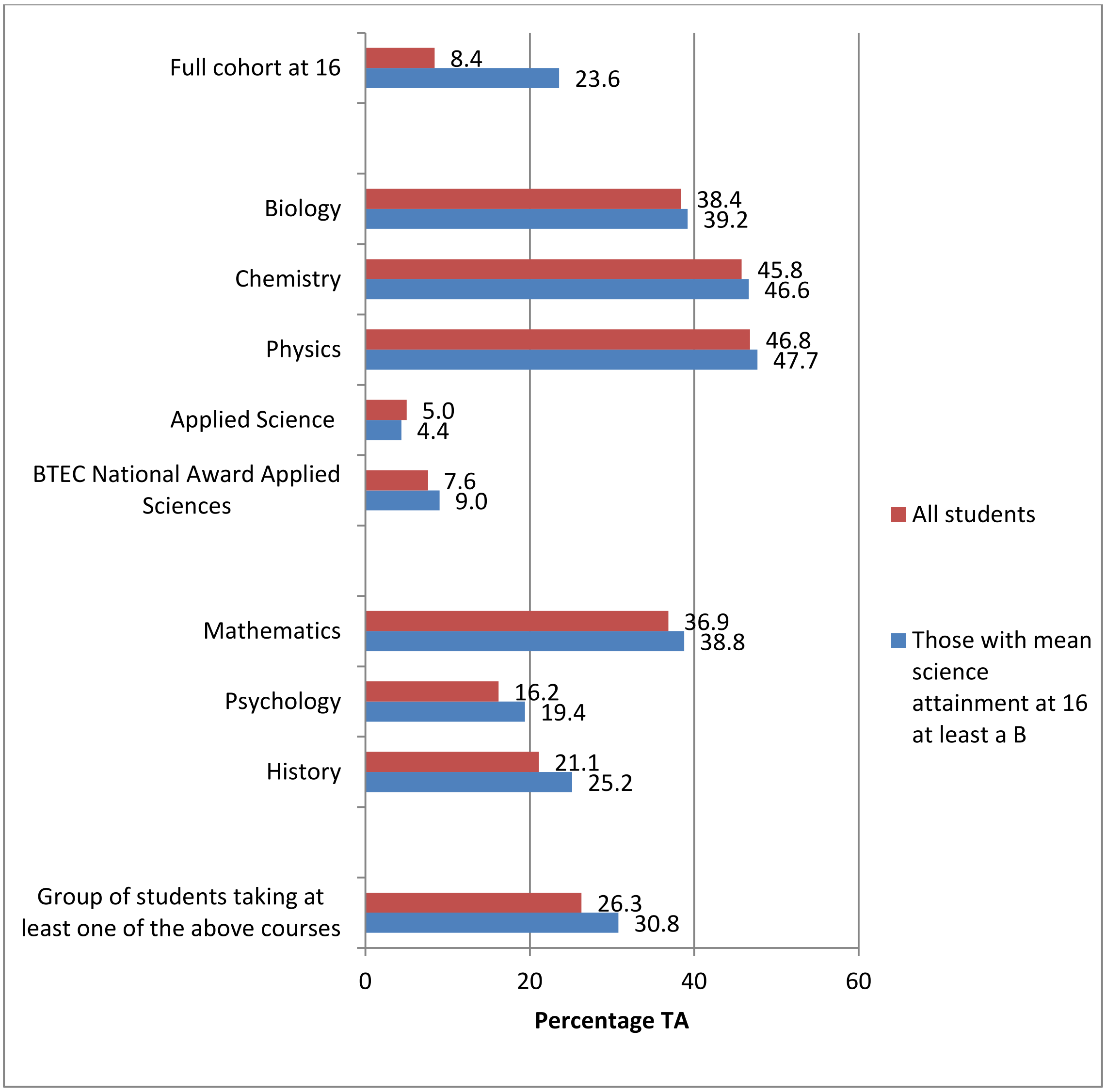

Figure 3: Percentage TA within course/cohort

Triple award (TA) students tend to be high achieving in both science and non – science subjects (Homer et al., 2011b), and this is made clear when comparing the TA proportion at age 16 (8.4%) with the TA proportion amongst those who achieved highly in science at this age (23.6%). Within the post-16 population, 26.3% of students had followed TA and 30.8% of the high-science achieving sub-group had also. Hence TA students progress strongly into post-16 courses, and tend to be amongst the highest (science) achievers at 16.

At the subject level, as might be expected, representation of TA in the three science A-levels is strong, particularly for physics (46.8% TA) and chemistry (45.8%), and accounting for prior attainment makes very little difference to these figures. TA students are poorly represented in vocational science courses (5.0 to 7.6%), and again controlling for prior attainment makes little difference. In terms of comparator subjects, TA students are over-represented in mathematics (36.9%), but are under-represented in history (21.1%) and psychology (16.2%). Again, accounting for prior attainment in science makes little difference here.

Modelling participation

Table 5 presents the results (odds ratios) for eight separate multi-level logistic regression models, predicting participation in each of the qualifications listed in Table 1 and using the set of predictors describe in Table 2. [11] As with all regression modelling, the effect of any variable is estimated *independently* of any other. Understanding this fact is crucial in accurately interpreting the findings from the models.

The sample used in each model is 549,834 students in 3,402 schools. There is missing data for approximately 55,000 students in comparison to the descriptive analysis reported earlier (n=606,618), largely due to students who had either no science or mathematics results in the NPD for the relevant year. These are most likely students who were not entered for any examination in these subjects, and are hence those towards the bottom of the attainment range. Whilst the issue of this

[11] The log(odds ratios) estimates and associated standard errors are given in Appendix 3.

missing data cannot be ignored, the impact on the veracity of the findings is limited since these students are very unlikley to progress to any of the courses listed in Table 1 – in a sense they are outliers who are best considered as a distinct sub-group.

Post-16 course	Odds ratios estimates for participation[12]								Percentage residual variance at school level	
	Mean prior attainment in science at 16	Prior attainment in maths at 16	Gender: Male	Measures of socio-economic status		14-16 science pathway		14-16 school teaches to 18	Null (no predictors)	Full (all predictors)
				FSM-eligible	IDACI	TA	Other			
Biology	1.237	1.008	0.652	1.052	1.281	2.550	0.132	1.077	23.8	6.6
Chemistry	1.260	1.068	1.177	1.313	2.702	3.435	0.138	0.963	30.3	11.3
Physics	1.188	1.133	7.683	0.971	1.076	2.275	0.168	1.239	31.7	9.9
Applied Science	1.074	1.007	0.849	0.846	0.824	0.298	2.106	2.020	75.2	69.3
BTEC National Award Applied Sciences	1.068	0.998	0.838	1.107	2.044	0.708	1.094	1.381	78.2	74.1
Mathematics	1.061	1.402	2.368	1.049	1.600	1.370	0.660	1.075	28.4	10.2
Psychology	1.076	1.034	0.292	0.856	0.780	0.715	0.453	0.967	13.9	8.4
History	1.115	1.010	0.924	0.653	0.391	0.778	0.501	1.680	20.5	9.2

Table 5: Odds ratios and residual variance for two-level logistic regression models predicting participation in each post-16 course

[12] Odds ratio estimates are significantly different from 1 at 5% level except for those shaded.

For example, the results for biology are interpreted in detail in Table 6:

Predictor for participation in biology A-level		Odds ratio for predictor	Effect size[13]	Interpretation in terms of participation in biology A-level *(all other variables held equal)*
Mean prior attainment in science at 16		1.237	(0.118)	One additional mean point in science attainment at 16 increases the odds ratio by 23.7% - hence, as might be expected, higher attainment at 14-16 in science implies a greater likelihood of participating.
Prior attainment in maths at 16		1.008	(0.004)	One additional point in mathematics attainment at 16 increases the odds ratio by 0.8%. This means that higher attainment in mathematics tends to increase participation, although the effect is small.
Gender: Male		0.652	-0.236	The odds ratio is 34.6% lower for males – so males are less likely to participate.
Measures of socio-economic status	**FSM-eligible**	1.052	0.028	The odds ratio is 5.2% higher for FSM-eligible students (but is not statistically significant at the 5% level). In other words, there is a greater likelihood of FSM-eligible students participating, but this is not statistically significant.
	IDACI	1.281	(0.137)	A change in IDACI from 0% (no children in poor households in the area) to 100% (all children are in poor households in the area) increases odds ratio by 28% - this means that students in more deprived neighbourhoods are more likely to participate.
14-16 science pathway	**TA**	2.550	0.517	Odds ratio is 155.0% higher for TA compared to DA – so students who did TA are more likely to participate than those who did DA after having accounted for (mean) prior attainment in science at 16.
	Other	0.132	-1.119	Odds ratio is 87.8% lower for Other compared to DA – this means that students who did Other courses are less likely to participate compared to DA.
14-16 school teaches to 18		1.077	0.041	If the school teaches 16-18 as well as 14-16 then the odds ratio for participation is 7.7% higher. So students in such schools are more likely to participate.

Table 6: Interpreting the odds ratios from modelling biology A-level participation

A comparison across courses of the effect of each predictor is as follows:

[13] For continuous predictors, the brackets indicate interpretation of effect size is dependent on the underlying scale of measurement and requires caution.

- **Prior attainment in science** – the odds ratios are of the same order of magnitude for the three science A-levels and history, but for the other courses (vocational sciences, psychology and mathematics) are not so large, indicating that for these latter courses prior attainment in science is not as important a predictor of participation. [14]

- **Prior attainment in mathematics:** Unsurprisingly, mathematics attainment at 16 has its strongest effect in predicting mathematics participation post-16. This is followed by physics, chemistry and biology. Attainment in mathematics at 16 has no predictive power in determining participation in either of the post-16 vocational science courses. For physics, the odds ratios for prior attainment in science and maths are very similar.

- **Gender** – the gender 'bias' in favour of boys' participation is strongest in physics, and then mathematics and chemistry, whereas the 'bias' in favour of girls is strongest in psychology and then biology. In the vocational science courses, there is a smaller 'bias' in favour of girls.

- **Socio-economic status** – FSM-eligible students are more likely than their non-eligible peers to participate in chemistry, but are less likely to participate in psychology or history. There is an interesting difference between the two vocational courses, with FSM-eligible students more likely to participate in BTEC national award science, but less likely to participate in applied science A-level, although both of these effects are non-significant at the 5% level. Broadly speaking, the odds

[14] Note that mathematics attainment at 16 is separately included in the modelling, and this has the effect of weakening the independent 'science attainment' effect on participation, particularly for physics, since the correlation with maths attainment at 16 is very high – if mathematics were not included as an explanatory variable, then prior attainment in science would show a bigger effect, especially for physics.

ratios for IDACI tell a similar story to that of FSM, with students from poorer areas less likely to participate in psychology and history.

- **14-16 science pathway** – Compared to Dual award students, Triple award students are more likely to participate in the three separate sciences and mathematics, with the strongest effect for chemistry and the weakest for physics amongst the three traditional sciences. The Triple award 'effect' is in the opposite direction for history and psychology, but is strongest in this regard for applied science A-level. Correspondingly, the only post-16 courses for which following the 'Other' 14-16 science pathway increases the likelihood of participation are for the vocational science courses.
- **14-16 school teaches to 18 –** This predictor has its strongest effect in the two vocational science courses and for history, followed by physics. In all these cases being in a school at 14-16 that taught up to 18 increases the likelihood of participation.

A further comparison within each course indicates that strongest independent predictors of participation vary as follows:

- **biology and chemistry**: following Triple award science at age 14-16
- **physics, mathematics and psychology**: gender – with boys much more likely to participate in the first two of these, but girls much more likely in the latter.
- **applied science** – not doing Triple award science at age 14-16, and the school teaches up to 18
- **BTEC national award applied sciences** – lower levels of socio-economic status as measured by the IDACI, and the school teaching up to 18

- **history** – higher levels of socio-economic status, and the school teaches up to 18

Finally, Table 5 also includes two values for the percentage of residual variance at the school level. These figures for the three main sciences courses, mathematics and history are of the order of 20-30% in the null model, but this decreases to 7 to 11% once all the predictors are included. [15] So, for these five courses, approximately a quarter of the overall variance in likelihood to participate can be attributed to schools, but when other factors (predictors) are accounted for this drops significantly. For psychology, the residual school variance is relatively small (14% in the null model), which decreases to 8% in the full model.

Arguably, the most interesting of these figures are those for the vocational courses where the residual school variance is much higher than for other courses, and does not decrease significantly once predictors are included. This indicates that there is much more variation by school in the likelihood to participate in post-16 vocational science courses compared to the other post-16 courses. In other words, there are schools that tend to encourage participation to these courses whilst others do not. This is likely to be an 'availability' issue in that a minority of schools offer these courses, whilst the majority do not.

[15] One would automatically expect a decrease in the percentage of variance attributable to schools on the inclusion of additional predictors since, on the inclusion of predictors, a proportion of the difference across schools is now accounted for at the student level.

Discussion

Issues of equity

Previous studies have demonstrated the importance of prior science attainment as an influential factor in student participation (Gorard & See, 2009; Rodeiro, 2007). The present study adds to this work by revealing the patterning of this prior attainment factor across the different sciences, and how these patterns relate to other factors such as gender and socio-economic status. This reveals several issues of equity as explored below. We have also included selected non-science subjects within our analysis, as comparators. For example, our analysis of physics post-16 participation shows that mathematics attainment at age 16 is as important an influence on progression as is science attainment.

In the 'traditional' sciences our modelling analysis indicates that, provided students from poorer backgrounds attain sufficiently highly at 16, they do go on to study science in the broadly the same proportions as their peers from higher up the socio-economic scale [16]. Thus, the heavy under-representation of lower socio-economic status students within post-16 science courses reflects largely the strong correlation between attainment at 16 and socio-economic status (Gorard & See, 2009). Thus, addressing concerns about social equity within post-16 science participation involves reducing attainment gaps between social groups wherever they appear in compulsory schooling. This is arguably the most significant message for policy makers from our research.

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[16] Emerging unpublished analysis shows that, in terms of value-added attainment within science A-level, students from lower socio-economic status backgrounds tend to *outperform* their peers from higher socio-economic backgrounds. An earlier study showed the opposite trend for value-added within science at KS4 (Homer et al., 2011b).

Furthermore, our more fine-grained 'between sciences' modelling shows that chemistry is a distinctive science subject in that lower socio-economic status appears as a *positive* influence on post-16 participation, in comparison with biology and physics, once prior attainment and other factors have been taken into account. Interestingly, a different study of participation within England and Wales using descriptive statistics shows an over-representation of ethnic minority students within chemistry post-16 (Elias, Jones, & McWhinnie, 2006). Elias et al. suggest that this over-representation arises from specific career aspirations prevalent amongst particular ethnic minority groups, for example, pharmacy. A-level chemistry is typically the only pre-requisite science for entry to university pharmacy courses in England. Should these ethnic groups be over-represented within lower socio-economic groups (Gorard and See, 2009; Strand, 2011) then this could account for the distinctiveness of chemistry within our modelling analysis. The significance of careers education as an important influence on post-16 choices has been identified in several other studies (Mujtaba & Reiss, 2012). In policy terms, this points to a need for additional focus on education about the potential career opportunities arising from biology and physics in particular, targeted at students from lower socio-economic groups.

In contrast to socio-economic status, differential participation within the sciences by gender is not significantly reduced by controlling for prior science attainment. Gender patterns are also strongly conditioned by the specific science discipline. Thus, it is inaccurate and unhelpful to talk of girls being under-represented in post-16 science courses. Rather, our analysis shows that girls are heavily over-represented in biology, slightly under-represented in chemistry courses, and heavily under-represented in physics courses. Significantly, girls are slightly over-represented within applied science courses, and heavily over-represented within psychology (further discussed below). These strong and distinctive patterns point to the significance, for gendered participation, of factors not represented in our quantitative analysis. A recent quantitative analysis in England (conducted as part of the TISME research initiative cited earlier) identifies the differential influence on intention to participate in physics for 15-year old boys and girls of a range of factors such as emotional response towards physics lessons, competitiveness and home support for achievement in physics (Mujtaba and Reiss, 2012). Another TISME study demonstrates how girls inclined towards physical sciences course choices are often involved in significant ‘identity work’ in order to reconcile their own identities with subjects that tend to be associated with ‘cleverness’ and masculinity (Archer et al., 2010).

Findings from international studies such as PISA in 2006 (OECD, 2007) and the Relevance of Science Education (ROSE) project, a comparative study across approximately 40 countries of students’ views of science and science education (Jenkins et al, 2006), indicate that in the UK, attitudes towards science show a large variation by gender in comparison with many other countries. Overall, all these studies point to the need for both qualitative and quantitative methodologies in the exploration of gender equity issues with regard to progression to post-16 science.

Subject pathways

Triple/Dual Award

The findings in this paper indicate that students who follow Triple award at 14-16 are much more likely to study sciences post-16, even after accounting for their higher average attainment at 16. Arguably, this is not surprising since those students age 13-14 years with a disposition towards pursuing a post-16 science pathway are more likely to choose (or be guided towards) the Triple award science pathway than other pathways, in schools where such multiple pathways are available. However, Broeke (2010) has gone further to suggest a causal connection between the Triple award pathway and post-16 science participation. Their analysis of the national dataset in England identified those schools that either stopped, or began offering, Triple award over the academic years 2001/02 to 2002/03. They then analysed the post-16 participation of these 'adjacent' student cohorts to identify any trend associated with schools stopping offering, or starting to offer, Triple award. They found significant positive effects on post-16 science participation related to Triple award, particularly amongst boys and pupils from lower socio-economic groups. This might suggest, for policymakers, that a shift to more students following a Triple award pathway would certainly enhance post-16 science participation. We would urge some caution here. Our evidence relates to student cohorts at the beginning of a policy of enhanced Triple award entitlement, whilst the Broeke study involves GCSE cohorts examined in 2002/2003, at a time when the numbers studying Triple award were approximately half the number they are today. It is not necessarily the case that a positive impact on science participation would be sustained as larger numbers of students follow a Triple award pathway. The mix of students studying Triple award in England is changing over time with more students as a whole, and especially more girls, studying the separate sciences at 14-16 (Homer et al., 2011a). Additional study is needed to see whether or not the 'Triple award effect' indicated above is sustained as the Triple award student population increases and broadens. Furthermore, it is important to consider other potential consequences of a shift to Triple award science. The problem of fitting three separate sciences into an already crowded 14-16 curriculum remains a major challenge in many schools (Millar, 2011; Fairbrother & Dillon, 2009). There is already much anecdotal evidence that many schools are completing Triple award courses in the same curriculum time as that for Dual award, with potentially damaging effects on the student and teacher experience. The existence of multiple routes into post-16 science also results in an additional problem for schools, with students in the same post-16 class potentially starting their studies with very different levels of content familiarity and understanding, Millar (2011).

Vocational pathways

Participation within vocational science pathways has rarely been the focus of academic research (Donnelly, 2009). For the cohort in our study, 14.9% of students completed vocational science qualifications within 14-16 education (Homer, Ryder & Donnelly, 2011). However, only 2.4% of students completing one or more of our focus post-16 qualifications completed a post-16 vocational science qualification (Table 3). Thus, this science pathway within 14-19 education in England is currently a small but significant one at 14-16, that shrinks substantially post-16.

Our analysis indicates that influences on post-16 participation in the two vocational science courses are of a different character to those in the traditional sciences (Table 5). Attainment in science and mathematics at 16 is not so important, the 14-16 pathway is generally different (e.g. is not Triple award), and schools have a greater variation in influencing participation. In addition, according to the descriptive analysis, students eligible for free school meals are overrepresented in both vocational courses, particularly the BTEC National award, even after accounting for differences in prior attainment in science (Figure 2). However, it is notable that the more sophisticated modelling analysis (Table 5) indicates that socio-economic factors are less important once a range of additional explanatory variables are included (Table 2).

These findings underline some of the tensions and ambiguities in current policy. The goal of encouraging more students to participate in science post-16 tends to be operationalised in terms of participation in the ‘traditional’ science courses. The role of enhanced participation on vocational science courses 14-19 in achieving this policy goal is often not articulated (Donnelly, 2009). Currently, vocational science courses tend to have a lower academic status and policy visibility, as compared to traditional science courses. This may be related to the extent to which these provide meaningful routes into either employment or further and higher education (Donnelly, 2009; Woolf, 2011). Our research suggests that vocational science routes (14-19 and beyond) appear to attract students with distinctive characteristics into post-16 science education, and therefore promise to contribute to the policy goal of broadening post-16 science participation. However, the provision of 14-16, and particularly 16-19, vocational science courses within schools in England is far from universal. Arguably, an initial policy goal would be to enhance uptake of such courses across a broader range of schools. However, given concerns over the potential for social stratification across academic/vocational courses (van Langen et al, 2008), it is important that the socio-economic status of students following these courses is monitored. The approaches followed in this paper provide one mechanism for such monitoring.

Subject comparisons

A distinctive feature of the analysis in this paper is the use of non-science comparator subjects. This has highlighted that the gender imbalance is not confined to participation in traditional science subjects. For example, boys are strongly over-represented in post-16 mathematics courses, even after other factors such as prior attainment are accounted for (Table 5). Given the discussion earlier of the need for more attention on vocational science 14-19 pathways, it is striking that girls are slightly over-represented within post-16 vocational science courses, although the absolute student number on these courses is small. These findings suggest that this 'science-related' pathway may be one way of broadening girls participation in post-16 science (on a related issue, the particularly strong over-representation of girls within psychology is discussed below).

In terms of socio-economic status, Table 5 suggests that participation in A-level psychology and history appears particularly inequitable: both showing under-representation of students from lower socio-economic backgrounds. However, some caution is required here. The socio-economic inequity within A-level history may reflect differential attainment within 14-16 history, and the humanities more broadly, across different social groups, factors not included in the modelling here. Further research, accounting for broader subject attainment, is needed to investigate these issues in detail.

Although not categorised in our analysis as a science, school psychology has arguably more the character of a science than a humanities course. Furthermore, there are large numbers of students completing A-level psychology courses in England; for every A-level physics student there are 2.3 A-level psychology students (Table 3). The large number of students following this 'science-related' A-level makes it an important comparator for determinants of post-16 science participation. Psychology is the only science-related A-level to show, across both available measures, a statistically significant under-representation of lower socio-economic status students within the modelling analysis (Table 5). In terms of gender, using descriptive statistics (Table 3), psychology is second only to physics in the extent of the gender imbalance, with girls comprising 73.9% of A-level psychology students. Thus, for every female A-level physics student in England there are around nine female A-level psychology students, and a large gender imbalance remains within the modelling analysis (Table 5). Psychology, then, is by far the most popular science-related A-level for girls, but has a curriculum that includes not only science content from the biological sciences, but also content from mathematics (statistical analysis) and often the physical sciences (e.g. forensics). We argue that further research to investigate the choice rationales, and experiences, of girls following A-level psychology would inform the development of broader policy reforms to increase female participation in the sciences. It is possible that 'new' science-related school science courses would provide more open and flexible opportunities for girls' 'identity work' (Archer et al., 2012). Studies within the higher education sector also suggest that new, multi-disciplinary courses that include aspects of several of the traditional sciences, such as forensic science, are also preferentially attractive to girls (Henriksen et al., forthcoming).

School effects

One advantage of the multi-level modelling approach is that it provides a national measure of the variation between schools in influencing progression to post-16 courses. The figures for the non-applied A-level subjects are all of the order of 10% in this regard (Table 5, final column). The source of this variation is likely to be across multiple unmeasured factors including, for example, teacher effects and school policies with regard to course options and progression. From school effectiveness research it is known that around 5-20% of the variation in student *progress* (i.e. value-added attainment) can be attributed to schools (Rasbash et al., 2010). The findings in this paper, concerning influences on post-compulsory *participation*, are mostly of a similar magnitude (the exception being the vocational courses, where this effect is much larger). It is important, therefore, to note that whilst some schools clearly make a difference in terms of encouraging students to participate in science post-16 (Bennett et al., 2011), the analysis presented here indicates that the overall difference schools make nationally is limited once a range of student and school factors (as listed in Table 2) are taken into account.

Methodological considerations

The modelling approach taken here is different to that of some other studies such as that of Gill & Bell (2011). Gill & Bell model post-16 participation in A-level physics using as a population those students studying at least one A-level in any subject. By way of contrast, the current study is interested in the *a priori* influences on progression amongst the whole national population at 16, arguably a more parsimonious approach in the sense of being less restrictive. The issue of which 'population' to choose as the basis for modelling progression, and the consequences of such a choice on model estimates, could prove an interesting area for future work. A second methodological point relates to the inclusion of two measures of socio-economic status in the modelling. Whilst there are clear benefits to their both being included, as they do capture different information (Table 2), the interpretation of the subsequent model estimates needs to be done carefully. These are independent effects so that the estimate for each is based on holding the other constant.

A natural follow-up to this study would look at influences on *attainment* (rather than progression) in post-16 sciences, using value-added techniques applied to the same or similar data to that presented here. Methodologically, such a study would be likely to employ similar methods to that of Homer *et al.* (2011b) to assess, for example, the impact of socio-economic status on post-16 science progress. Alongside the current study this work would help complete the picture as to what types of students tend to do the post-16 sciences (and comparators), and, importantly, how they achieve once on these courses.

Internationally, it would be useful to compare the findings of this study with those from other countries or jurisdictions where similar such national (or equivalent) data is available (e.g. in Denmark; Henriksen et al., forthcoming). However, there is very little current evidence in the literature of such work, although this might change in the future with the growth in the availability of large-scale administrative datasets.

Conclusions

Smith (2011a) argues that UK government educational policy over the last 40 or so years, including making science participation compulsory at ages 14-16, has had little overall impact on A-level participation in the science. Nevertheless, at the time of writing (January 2013), school science policy in England is in flux, with the ongoing national curriculum review, and recent changes to accountability measures working their way through the system (DFE, 2010). It is likely that 'applied' science routes, already with lower status, will be squeezed out of 14-16 provision and that the 'push' for Triple award will continue. These changes at 14-16 science are likely to have important impacts on participation in post-16 sciences and influences thereon. For a particular cohort and prior to these policy changes, this paper has quantified the key determinants of post-16 science participation using national data. This study is not in a position to refute Smith's argument about the ineffectiveness of policy, but future studies, looking for changes in patterns of participation using similar methods, and comparing their findings to the basline results presented here, might be able to.

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Appendix

1. The two-level random intercepts logistic regression model

For each post-16 course, the binary response is yij which takes the value 1 if student *i* in school *j* participates in the course, or 0 if not. The probability that $y_{ij} = 1$ is denoted by is π_{ij} .

With a single explanatory variable, the random intercept model is given, for each course, by:

$$\mathrm{Logit}(\pi_{\mathrm{ij}}) = \log \frac{\pi_{\mathrm{ij}}}{1-\pi_{\mathrm{ij}}} = \beta_{0\,\mathrm{j}} + \beta_1 \mathrm{x}_{\mathrm{ij}}$$

$$\beta_{0\,\mathrm{j}} = \beta_0 + \mathrm{u}_{0\,\mathrm{j}}$$

In this equation, the intercept $\beta_{0\,\mathrm{j}}$ consists of two parts: a constant β_0 and a school-level random effect $\mathrm{u}_{0\,\mathrm{j}}$ which it assumed follows a normal distribution with mean zero and variance σ_{u0}^2 . β_1 is the usual regression coefficient corresponding to explanatory variable x_{ij}. Additional explanatory variables are added in the usual way.

2. Interpreting odds ratios

Odds ratios are difficult to interpret but for dichotomous variables can be converted to effect sizes by dividing the log(odds ratio) by 1.81 (Chinn, 2000).[17] To aid interpretation of odds ratios, and following Cohen's (1988) guidance, Figure 4 allows conversion between the two:

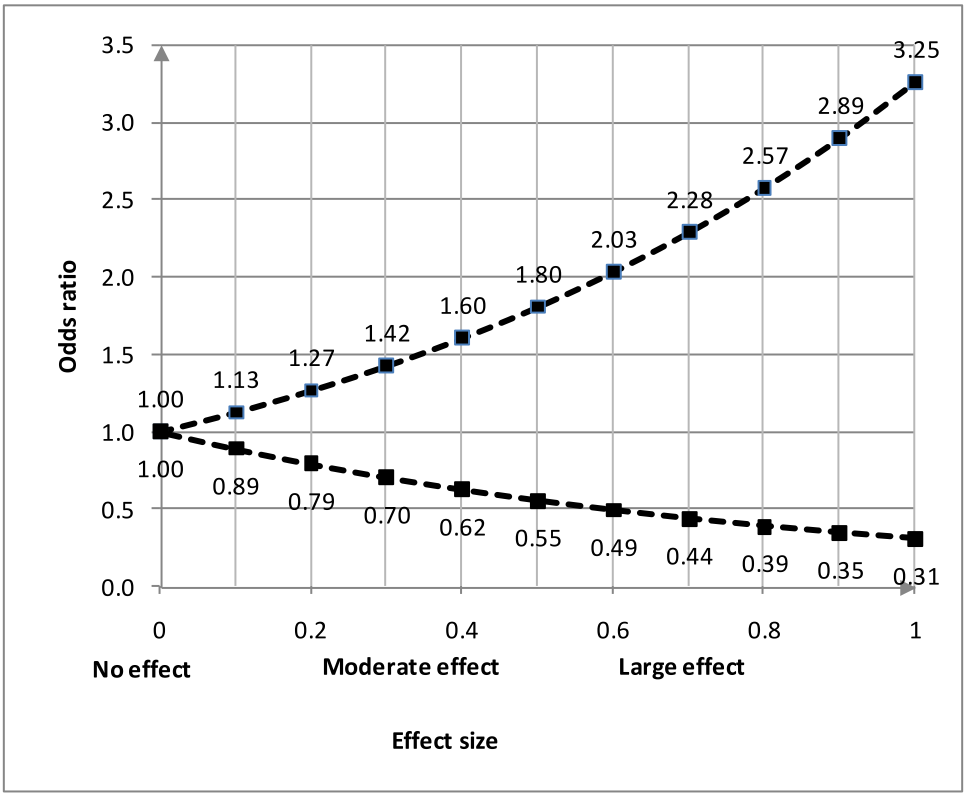

Figure 4: Conversion of effect size into odds ratio (for dichotomous predictors)

For example, a 'moderate' effect size of 0.3 corresponds to odds ratios of 0.70 or 1.42.

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[17] For continuous variables, this conversion is more problematic as the scale of the measurement affects the size of the odds ratio and hence the apparent effect size.

3. Parameter estimates for the multi-level models

Post-16 course	Fixed parameter estimate (standard error)									Level 2 variance estimate (standard error)	
	Constant	Mean prior attainment in science at 16	Prior attainment in maths at 16	Gender : Male	Measures of socio-economic status		14-16 science pathway		14-16 school teaches to 18	Null	Full
					FSM-eligible	IDACI	TA	Other			
Biology	-12.683 (0.066)	0.213 (0.002)	0.008 (0.001)	-0.427 (0.014)	0.051 (0.03)	0.248 (0.053)	0.936 (0.018)	-2.026 (0.05)	0.074 (0.024)	1.027 (0.028)	0.234 (0.01)
Chemistry	-17.424 (0.096)	0.231 (0.002)	0.066 (0.002)	0.163 (0.017)	0.272 (0.036)	0.994 (0.064)	1.234 (0.022)	-1.984 (0.078)	-0.038 (0.032)	1.428 (0.039)	0.419 (0.017)
Physics	-19.045 (0.117)	0.172 (0.003)	0.125 (0.002)	2.039 (0.024)	-0.029 (0.049)	0.073 (0.079)	0.822 (0.025)	-1.786 (0.1)	0.214 (0.034)	1.528 (0.043)	0.362 (0.017)
Applied Science	-9.651 (0.212)	0.071 (0.005)	0.007 (0.005)	-0.164 (0.056)	-0.167 (0.105)	-0.194 (0.208)	-1.209 (0.134)	0.745 (0.075)	0.703 (0.121)	9.969 (0.313)	7.412 (0.258)
BTEC National Award Applied Sciences	-8.746 (0.2)	0.066 (0.005)	-0.002 (0.005)	-0.177 (0.054)	0.102 (0.088)	0.715 (0.188)	-0.346 (0.098)	0.09 (0.076)	0.323 (0.127)	11.806 (0.354)	9.399 (0.297)
Mathematics	-21.85 (0.098)	0.059 (0.002)	0.338 (0.002)	0.862 (0.016)	0.048 (0.034)	0.47 (0.059)	0.315 (0.02)	-0.416 (0.038)	0.072 (0.029)	1.302 (0.035)	0.375 (0.014)
Psychology	-6.335 (0.045)	0.073 (0.001)	0.033 (0.001)	-1.231 (0.013)	-0.155 (0.024)	-0.249 (0.045)	-0.335 (0.019)	-0.791 (0.02)	-0.034 (0.024)	0.53 (0.016)	0.301 (0.011)
History	-7.981 (0.053)	0.109 (0.001)	0.01 (0.001)	-0.079 (0.013)	-0.426 (0.032)	-0.938 (0.054)	-0.251 (0.02)	-0.691 (0.025)	0.519 (0.027)	0.849 (0.024)	0.332 (0.012)

Table 7: log(odds ratio) parameter estimates and standard errors for the two-level logistic regression models [18]

[18] All estimates significantly different from zero at the 5% level other than those shaded.

To minimise bias, these estimates are produced using the 2nd order Penalized Quasi-Likelihood (PQL) procedure where possible, but for the both vocational science courses convergence problems meant that estimation is only possible using the 1st order Marginal Quasi-Likelihood (MQL) procedure (Rasbash, Steele, et al., 2009, pp 115).