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DOI:
10.1080/03057260802681821

Citation for published version (Harvard):
Gorard, S & See, B 2009, 'The early impact of SES on participation and attainment in science', *Studies in Science Education*, vol. 45, no. 1, pp. 93-129. https://doi.org/10.1080/03057260802681821

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The impact of socio-economic status on participation and attainment in science

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Abstract

In this paper we combine the findings from two recent studies relating to participation and attainment in school science - a re-analysis of existing official data for England (Gorard et al. 2008) and a review of wider international research evidence in the literature relevant to the UK (Gorard and See 2008). Although the secondary data are drawn mainly from England, the comprehensiveness of these datasets, together with our inclusion of a review of international studies on maths and science participation (such as Wobmann 2003, Marks 2007), provides a useful reference point for an international audience. The research was prompted by concerns over a reduction in the uptake of the physical sciences post-16 and especially in higher education (HE), and interest in ways of encouraging the study of science by students from less prestigious socio-economic status (SES) backgrounds. Such concerns are not unique to the UK (Berends et al 2005, Fullarton et al 2003, Khoury and Voss 1985, Yang 2003). Using large-scale official datasets we show that participation and attainment in science are stratified by socio-economic status (SES). Students from poorer families are less likely to take sciences at post-16 than many other subjects, and those who do are then less likely to obtain grades high enough to encourage further study of the subject.

No conclusive evidence has been found to explain this satisfactorily. Plausible reasons suggested in the literature include the relative scarcity of local opportunities putting off those who do not wish to study away from home, or the perceived time demands of studying science, and so the difficulties of combining part-time study and part-time work for those needing to continue earning while studying. Direct support from professional parents may also lead to greater participation in post-16 science for students from higher SES. Perhaps the simplest explanation is that participation in science at any level is often predicated upon success at the previous educational stage. There are clear differences in science attainment at age 16 between students of differing backgrounds, which could explain the subsequent differential participation. However, these differences are not dissimilar to those for all subjects. The largest gap presented in the paper is between students eligible and not eligible for free school meals (FSM). We also show that these patterns appear early in the life of children. At ages 7 and 11, attainment in the three core subjects (English Maths and Science) is negatively related to living in an area of deprivation. The paper ends with a discussion of suggestions for research, policy and practice, emerging from this review of the evidence.

Introduction to stratification in science

Formal full-time participation in higher education (HE) has increased substantially in England since the 1980s (Gorard et al. 2007), while both the relative and absolute numbers studying physics and chemistry are reported to have declined. The position of these disciplines, along with maths and other sciences including biology, are of concern to some commentators on HE. If the development of scientists is seen as key to economic, technical and intellectual progress then this decline could be very serious indeed. One way of understanding and perhaps remedying this decline is to consider those currently under-represented. In recent years much attention has focused on differences in participation by males and females, and policies and practices have been attempted that might encourage greater uptake of science in HE by female students. Further studies have been primarily concerned with differential patterns of participation and attainment by ethnic groups. The new work here focuses on the social, economic and family background of students, considering which groups are under-represented in science at school and beyond, and why.

Science education, for the purposes of this paper, refers primarily to the traditional natural sciences based on physics, chemistry and biology. Comparisons are also drawn, where appropriate, with two other typically compulsory curriculum areas of mathematics and English. However, this focus should not be allowed to suggest a lack of recognition that with subjects such as psychology and sports science, and a general increase in elements of science and technology in a wide range of subjects, science education entails far more than the traditional sciences (Bell 2001).

Participation and attainment in science education are here taken to refer to formal episodes, almost inevitably institutionally based or perhaps provided virtually by such an institution. This is because concern over learning in science is usually expressed in terms of certification. Again, this relatively narrow focus should not mislead readers about the widespread nature of science learning in vocational and general education, extra-curricular activities and most importantly via informal and personally-motivated learning. It is important to recall that scientific literacy, for example, could increase even where certification declines. Much of what many people learn is not taught, and almost none of that is certificated.

This paper considers science education in relation to students' socio-economic status (SES) and family backgrounds. SES for young people usually refers to their parental and family background as assessed by the occupational status, educational qualification, and income of their parent(s). Classifications of SES vary over time and place and between studies. Widely used systems have been based on occupational prestige, skill, the nature of work, educational requirements and even on social distance (as in the Cambridge CAMSIS scale). It is not the purpose of this paper to revisit debates about the measurement of social class. Our concern here is with the least privileged groups whatever classification is used. It is generally unwise to separate consideration of SES from considerations of sex, ethnicity, first language, health, disability, and geography. For example, the relevance of being middle-class can vary over regions, for different cultural backgrounds and even for men and women. Therefore, where possible, we include consideration of the interaction of social class with such other SES-related variables.

With existing datasets (see section below on rationale and limitations of datasets) and studies we are limited to the available SES variables. Different studies used different

indices of SES and not surprisingly produced different results. For example, Herrnstein and Murray (1994) used occupation, education and income as their definition of SES. Many researchers have criticised this narrow definition. Loury (1995), for example, came up with a list of other factors including peer influences in education plans and hence choice of subject, parental expectations and aspirations, time mothers spent in the labour market, family structure (two-parents versus single parent), number of siblings, birth order, religious denomination, grandparents schooling, age of mother on giving birth, quality of stimulation in the home environment, including emotional and verbal responsiveness of the mother, provision of appropriate play materials, time and quality of maternal involvement with the child, parental instigation of and participation in intellectual activities, parental affection, rejection and nurturance and parental wealth. Some of these factors may be related to Herrnstein and Murray's measures of SES. For example, parents with a higher education may be more likely to provide a more conducive environment in the home for academic performance, even though this may not always be the case. Fischer et al. (1996) introduced other social factors, such as family size, structure of family, and area of residence. Whichever combination of variables is used, few studies look at the interplay of these variables, and almost no current work in education factors in the contribution of the natural inherited talent of individuals. Whatever social variables we may use, the list is never exhaustive.

The paper is structured in reverse lifelong order, first outlining the stratification in entry to study of science at HE, then looking at progressively earlier phases of schooling, ending with pre-school and family background. The paper concludes with a discussion of the possible implications for research, policy and practice. Before that, however, we describe our sources of evidence and how we analyse them.

Methods and data

Review of available data

This paper is partly based on a re-analysis of data from the Pupil-level Annual Schools Census (PLASC) and National Pupil Database (NPD) in England for 2001/02 to 2005/06. The PLASC/NPD combination is almost certainly the best source of large-scale information on science education participation and attainment and SES available in England, even though it does not include parental occupation or income. The PLASC takes place in January of every school year from 2002 onwards, and contains a record for every pupil. It extends the annual school(-level) census collected previously using many of the same variables. These variables include eligibility for free school meals (FSM – see explanation below), ethnicity, sex, first language, whether a child is in care, whether they are identified as Gifted and Talented (G&T)[1], and whether they live in an area of high multiple deprivation (see explanation below). All of these could be useful as indicators of SES or of the impact of SES on performance in science. For the purposes of the analyses below, we use FSM and multiple deprivation as proxy indicators of SES, and we use the incomplete records of G&T to see to what extent there are low SES G&T students not taking science. Each

[1] 'Gifted and Talented' is the name of a programme intended to identify and stimulate the most talented students.

cohort consists of around 650,000 students in England. However, as with any measure of SES or achievement, there are limitations. Below we outline the rationale and limitations of using these measures.

FSM is an indicator of a student living in a family with an income deemed to be below the poverty line. Eligibility for FSM represents all pupils that are known to be living below the official poverty line in the UK, It applies to around 15% of students in England. The indicator is of those known to be eligible for free meals, either because they take the meals or from data collected for another purpose. There may be some students who are legally eligible but not known about, but we believe these to have been relatively rare until recently (Gorard et al. 2003a). This indicator has the advantages in comparison to family occupation or parental income of being simple, with a legal binary definition, largely unchanged over time, collected routinely, and with almost complete coverage. The major drawback of FSM is that it merely separates those living in poverty from the rest. However, if the focus of the analysis is on the most disadvantaged, as here, then this is not a significant problem.

Indices of multiple deprivation are constructed scores based on a number of figures available from the local area census of population, such as the number of adults out of work. Localities are then ranked in terms of the aggregate of these scores. They are an attempt to increase the quality of data available about the background of individuals. They have five main problems. First, they involve adding together figures for housing, health, employment and so on. There is no clear justification for this. Second, they tell us nothing about the individual other than the kind of small area they live in. Some of the most deprived families actually live in heavily polarised areas (such as inner London boroughs) which the average scores disguise. Third, by using multiple indicators (including, for example, average educational attainment of the local population) there is a danger of tautology in any analysis of educational outcomes. More people with no educational qualifications live in areas where more people have no educational qualifications etc. Fourth, one reason why measures related to locality are used is to avoid missing data and cases, but they actually introduce a new area of missing data – where the home postcode of the student is unknown. Even where this figure is known it depends on some contestable assumptions about the nature of domicile (Gorard et al. 2007). Fifth, population figures become increasingly out of date in the period between the national census every decade.

Whether a student is flagged as G&T is a far from rigorous procedure. Not all schools have identified G&T students (believing the scheme to be elitist), and those participating have used different approaches to identification. The identification is relative to the intake to each school (perhaps the most able 5% to 10% as suggested by prior attainment scores) and so any student might be deemed gifted and talented at one school but not at another. However, this variable can be used tentatively to highlight students, if they exist, of high ability not taking science and so help suggest whether this is related to SES.

Limitations of existing datasets

The NPD uses the same student identifier over time, and also the same identifier as used in PLASC, meaning that most records can be linked across years, educational

stages and between NPD and PLASC. It includes a range of variables concerning subject entry and outcomes at each Key Stage.[2] For example, it includes whether a student has entered one or a combination of science subjects at GCSE and A-level, their highest grade in each subject, their total examination points score, and their points score in sciences.[3] These are used in the analyses below. The points score is an arithmetic device based on imagining that examination grades are numeric and on an equal-interval scale (so that an A* grade at GCSE is worth 8 points and exactly twice as much as a D grade worth 4 points). Of course, they are not. In using these, and other existing data, we do not seek to endorse any such erroneous assumptions but can only use the best datasets and report what is available.

The difficulties of deciding whether a particular social group is proportionately represented in studying science are outlined in Gorard et al. (2008). These involve steps such as defining SES, what we mean by representation in science, and measuring the prevalence of the group in science and in the relevant population. Even deciding what the relevant population is can be a challenging task. A common problem for the relevant large scale datasets lies in data missing even from existing cases. The missing data, which can include not known, information refused, information not yet sought, and other non-completed often covers a large proportion of the students. One example is that other than 'white', 'missing' is officially the largest ethnic group among students in England (according to Higher Education Student Agency or HESA, the government body in England collecting and retaining official statistics on students). In fact, the unknown cases considerably outnumber all of the ethnic minority groups combined. Some of the ethnic minority groups are quite small, meaning that very small changes in their absolute numbers can make trends over time or differences between groups appear more volatile than they really are. Similarly, most datasets have a large proportion of cases with no occupational category. In fact, when non-responses are added to those cases which are unclassifiable by occupation (through being economically inactive, for example) then having no occupational category becomes the single largest classification among UK students (HESA). In 2002/2003 45% of first year undergraduates were unclassifiable in terms of occupational background according to HESA figures (Gorard et al. 2007).

The high proportion of missing cases in an analysis using such a variable could significantly bias the results being presented, even where the overall response rate is high. This means that any difference over time and place or between social groups must be such that it dwarfs the bias introduced by measurement errors, missing cases and changes in data collection methods. This is seldom acknowledged by commentators or analysts. Any analyst is faced with a judgement about whether there is indeed under-representation of specific social groups in science, and so whether to trigger a search for the cause. Perhaps most importantly, we must beware of making

[2] The National Curriculum for England is organised into blocks of years called 'key stages'. There are four key stages as well as a 'Foundation Stage'. The 'Foundation Stage' covers education for children before they reach five (compulsory school age). Key Stage 1 (KS1) covers education for children from aged 5-7, i.e. Years 1 & 2, KS2 for children aged 7-11, i.e. Years 3, 4, 5 and 6. KS3 are for 11-14 year olds in Years 7, 8 & 9 and KS 4 for children aged 14-16 in Years 10 & 11.

[3] GCSE is the most commonly taken qualification at age 16. A-levels and AS levels are the commonly taken qualification in post-16 education, with specialist science subjects, and routinely used as entry qualifications for higher education.

too much of small differences between groups relative to the missing data. Since the biases and compromises in the datasets are not random, this judgement cannot be assisted by the traditional panoply of statistical analyses, such as significance tests or confidence intervals because these address only the sampling variation due to chance (Gorard 2006a).

We have tried to make the tables in this paper as easy to read as possible. However, it is important for readers unused to secondary data analysis to realise how far most of these tables are from the structure of the original datasets, or from what is published officially. Cases have been sorted and matched across several different datasets before aggregating, re-classifying, cross-tabulation and correlation, for example. Where possible, decimal places have been avoided for readability, and to prevent an illusion of unwarranted accuracy. This means some columns or rows may appear to add to 99% or 101% due to rounding. The achievement gap used in this paper is calculated as the difference between two sets of point scores or frequencies, divided by their sum (see Gorard et al. 2001). Therefore a gap between scores of 30 and 20 would be 20% (10/50) whereas a gap between scores of 45 and 55 would be 10% (10/100). The achievement gap is an acceptable substitute for an effect size when the variance is unknown.

Synthesis of existing literature

In this paper we also try to explain the patterns of science participation by SES uncovered by our secondary analysis of the official datasets described above. To that end, we provide a précis of a review conducted by the authors of 1,083 relevant publications (Gorard and See 2008). Our systematic search of ERIC and Psychinfo databases was for pieces of research, written in English, relevant to school participation/achievement in the UK, and involving at least one of science and SES. Although the emphasis is primarily on UK-based studies, international literature, particularly those based on international comparisons (such as TIMSS and PISA) and powerful studies from the US, Australia and some European countries, are also considered in our synthesis. We conducted similar searches using Google Scholar, and hand searches of generic and science-based education journals. The result is a mixture of peer-reviewed articles, grey literature (e.g. technical reports, working papers and unpublished conference papers), presentations, and student theses. To these we added some of our own work and relevant pieces already known to us from our own work. From this initial set we then applied some exclusion criteria. We naturally excluded anything repeated in form or substance, that on closer inspection was not relevant, and anything that was not a research report or review of research.

Since the nature of curriculum subjects, the breadth of choice in the curriculum, the standard of examinations, the structure of society, the economic rewards for science and a host of other factors are liable to change over time, it is preferable to focus on recent work. For example, elements of science and technology have merged with other subjects (Bell 2001) and the content of syllabuses has also changed. In England, the trend is now towards social geography rather than physical geography (Birnie 1999). In A-level maths there is a shift from pure to applied maths (Hoyles et al. 2001). Thus, our interest focuses on studies conducted in the decade 1997-2007.

We summarised the evidence in each paper - making a subjective judgement of the quality of the study, the quality of its reporting and the link between the evidence presented and the conclusions drawn. Only a few further studies were excluded at this stage. Instead, we reported the studies and any generic defects or omissions in the literature found (bearing in mind the partial nature of the search).

As with any review, we encountered problems in identifying high quality research in this area. Of course, several of the pieces picked up by electronic search turned out to mention one or more of the key search phrases without anything substantial that is relevant to the study. Of the remaining pieces that are relevant to the study, many were not actually research-driven – with no empirical evidence presented. A further substantial proportion did not describe the research in sufficient detail to allow a judgement to be made about its quality. In the minority of pieces left, which represent the best and best reported of the work that we encountered, there are some generic and sometimes intractable problems for a reviewer. Our estimate is that around one third of the pieces read were both comprehensible and based on research. Even so, the majority of these displayed major flaws. Our experience suggests that this is no worse in science education than in other areas of education research – perhaps even a little better. The most common generic defect in research reports is the link between the evidence presented and the conclusions drawn from it. There are a number of repeated problems, including lack of controlled interventions to test what works, lack of suitable comparators even in correlational and observational designs, and the exclusion from research of those not participating in science even in research about non-participation in science. There is often little clear sense of the numeric pattern that the literature is attempting to explain. It is, therefore, sometimes difficult to judge the worth of an attempted explanation in the literature since we are not sure what it should be an explanation of.

Care needs to be taken when reading about modelling, via regression and related techniques. Simply allocating a variable as ‘dependent’ is not any assessment of causation at all, even though frequently portrayed as such in the literature. One cannot test causation in this manner, and mention of effects, impacts, influences and so on in reports tend to go way beyond what is warranted by the data. There is a tendency to dredge existing data for patterns, running variant analyses until a clear result emerges. Readers must be very clear that this process is very different to any kind of rigorous test. The models are very sensitive to the precise order of entering the explanatory variables. In many cases, variables act as proxies for others. If an analyst enters social class first then the importance of prior attainment declines, if they leave social class until later then the apparent importance of ethnicity increases, and so on.

Few of the claims made about science in the literature were contextualised to show that the situation was specific to science. There is little scepticism in studies of attitudes, preferences and choice. Where studies do not have the students’ revealed choices as well as their attitudes or preferences concerning science we cannot say how accurate or influential the latter are. Where student choices are revealed beforehand there is a danger that reference to attitudes or preferences becomes a tautology. It is often not clear when students are asked about attitudes to science whether their response is about the school subject or science as a profession. Perhaps most importantly, ideas from in-depth, observational and modelling studies must be tested via experimental designs. This is the only ethical way forward for research

seeking to make causal claims. It leads to the kinds of evidence that policy-makers and practitioners need (Gorard and Cook 2007).

Given these methods and limitations what does the remaining evidence in our literature review say about the stratification of entry to studying science at HE and earlier?

Science and entry to higher education

The problem of falling participation in physics and chemistry is usually most starkly portrayed on application and acceptance to HE. For example, according to UCAS data, applicants to HE in the UK rose from 402,000 in 2002/03 to 445,000 in 2005/06, whereas applicants for study of physical sciences only rose from 12,797 to 13,159 (and acceptances for all four figures were in the same proportions). Thus, in recent years participation in physical sciences has been maintained, but the number of science students has fallen as a proportion of the total. Put another way, the recent widening of participation in the UK has not included the physical sciences.

Although general patterns of application to HE in the UK are already skewed towards the more prestigious occupational groups (Gorard et al. 2007), in the physical sciences the situation is even more extreme (Tables 1 and 2). In 2002, for example, while 18% of all HE applicants were from higher managerial backgrounds this figure rose to 25% for applicants to the physical sciences. Over the time period represented, there is a slight decline in applications by the higher managerial group and an increase in those whose background is unknown. Whether the latter is due to genuine societal movements, changes in classifying occupations, changes to fee regulations, or concerns by applicants that widening participation policies will disadvantage the more privileged, is not clear – but the table does not provide unequivocal evidence that participation is widening, either generally or in the physical sciences.

Table 1 – Percentage of HE applicants by occupational class, UK, 2002-2005

	2002	2003	2004	2005	2002	2003	2004	2005
Occupational class	All applicants				Physical science applicants			
Higher managerial	18	17	17	16	25	24	24	22
Lower managerial	25	25	25	24	28	28	28	26
Intermediate	13	12	12	12	14	13	14	13
Small employers	6	6	6	6	6	6	6	5
Lower supervisory	4	4	4	4	5	5	5	4
Semi-routine	11	11	11	11	10	9	9	9
Routine	5	5	5	5	4	4	4	4
Unknown	19	21	20	23	9	11	10	16

Source: UCAS

Note; a new classification for occupations following the 2001 Census of Population means that figures up to 2001 and from 2002 onwards are not directly comparable. Earlier figures are based on the purported level of skill or training involved in the occupation with a further division between manual and non-manual tasks. The newer occupational classes are based on the purported level of management of others, and the flexibility required by the job. They are both attempts to get at the same underlying structure of occupational groups. For more on both definitions, see http://www.ons.gov.uk/about-statistics/classifications/current/ns-sec/glossary-of-terms/index.html.

Table 2– Percentage of HE applicants by social class, UK, 1998-2001

	1998	1999	2000	2001	1998	1999	2000	2001
Social class	All applicants				Physical science applicants			
Professional	12	12	12	12	16	17	18	17
Intermediate	38	37	37	37	41	41	41	41
Skilled manual	15	15	15	15	15	15	14	15
Skilled non-manual	12	12	12	12	11	11	11	12
Partly skilled	8	8	8	7	7	7	7	6
Unskilled	2	2	2	2	1	1	1	1
Unknown	12	14	13	15	7	7	7	8

Source: UCAS: the body responsible for handling UK applications to HE - http://www.ucas.ac.uk/

Other than that, so far as we can tell given the change in recording from 2001 onwards, the social class of applicants to university remains largely unchanged over time (from the mid-1990s onwards). In addition, over this period of growth in the numbers in HE, any small changes towards a more balanced class has taken place in the early to mid-1990s before the era of purported widening participation. In fact, a simple summary would be to say that increasing participation also tends to widen it. However, the analysis presented here is not sufficient alone to establish this because these figures need to be placed against the background of changing class structure in the relevant population (whatever we decide that is).

Table 3 gives some idea of the multiple problems involved in deciding whether a particular social group is over- or under-represented in HE. Perhaps most obviously, the proportion of cases (38%) with an unknown occupation (for a number of reasons) is even higher among the general population than among HE applicants (around 20%). If we ignore these and calculate the percentages for those with a reported occupation then we artificially inflate the remaining figures and so may miss the stratification in HE. For example, 62% of the population report an occupation and 17% have a lower managerial occupation. This means that 27% (17/62) of the population with known occupations are lower managerial, which is the same proportion as HE applicants with the same background (as in Table 1). Perhaps the elevated social classes are not over-represented in HE. Then again we also have missing values for the application data, and perhaps we should not use the population of all ages as our comparator for an HE system with a lower average age anyway. We also need to define the domicile of both the population and HE applicants carefully, decide whether to use the domicile of the applicants or their parents, and so on. It is very tricky to decide whether a specific social group is proportionately represented in HE – much trickier than commentators usually suggest. More details of this kind of analysis are given in Gorard et al. (2007).

Table 3 – Percentage of heads of households by occupational class, UK, 2001 census of population

Higher managerial	10
Lower managerial	17
Intermediate	6
Small employers	7
Lower supervisory	8
Semi-routine	7

Routine	7
Unknown	38

Source: National Statistics – http://www.statistics.gov.uk/

In addition, on exit from school, there have long been reported differences in attitude towards studying science between ethnic groups in the UK, with Asians favouring medicine-related degrees, engineering or maths compared to their white peers, while Afro-Caribbean students prefer degrees in social sciences (Taylor 1993, Modood 1993). Woodrow (1996) suggests that this was partly because of the influence of Asian parents on student career choice. Asian families tended to favour careers with longer term advantages, whereas whites tended to look for immediately attractive choices where personal enjoyment and/or perceived ability may be a more important factor. It is important not to exaggerate either the scale or uniformity of these relatively small differences between groups. Traditionally, Indians are the high achieving ethnic minority group in the UK. They are more likely to be in the medicine-related professions. This is not the case, however, for Bangladeshis and Pakistanis in the UK. Similarly, in the US, Xie and Goyette (2003), using data from the 1988-1994 National Educational Longitudinal Survey, found that Asian American youth tend to choose occupations with a high representation of Asian workers and high average earnings/education, relative to whites, even after controlling for socio-economic background and academic performance.

We can say, in general, that those who apply for (and also those who obtain places in) science subjects, and not just in the physical sciences, have a higher occupational class profile than the general student population (and probably even more so than the general resident population). Given that the clear majority of HE applicants (i.e. those for whom we have data in official statistics) are traditional-age students, we need to consider the previous phase of education in order to help understand this pattern. In general, students do not take physical sciences at university without also having studied them successfully for Key Stage 5 (KS%: A-level or equivalent, a qualification traditionally taken at age 18). The stratification starts there.

Science and post-16 participation

Only around one fifth of students in England who continue to study after the age of 16 take at least one science or maths subject. The figures for physical sciences have declined somewhat since 2001/02, being largely replaced by newer science subjects such as technology and sports science. As in the analysis at HE, those continuing to KS5 are generally stratified by SES. However, official datasets do not routinely collect occupational backgrounds for A-level and equivalent students. This means we have no direct comparison and so no way of knowing whether the situation is better or worse at KS5 than at HE. Although we do not have parental occupation figures for these data it is clear that students taking sciences (or maths) are substantially less likely to be from families living in poverty, as assessed by eligibility for free school meals. It would seem reasonable to conclude that the stratification of entry to study sciences at HE is already largely present in the decision to study science at KS5.

Table 4 shows this expected pattern of stratification in science entry at KS5 in England. Male students are more likely than female students to take both science and

maths. Chinese are more likely to do so than white British (the most prevalent ethnic group) and Gypsy/Romany (the lowest participating group). Those identified as Gifted and Talented are more likely to take science or maths in contrast to others at KS5. In addition, of course, these groups are also far more likely to take science than the rest of their population age cohort who are not studying to KS5. FSM, as a measure of SES, is clearly an important characteristic, with those living in poverty less likely to study science even among those who stay on at KS5.

Table 4 – Percentage taking science and maths, KS5, all entrants, England, 2005/06

	Science	Maths	Science or maths
Male	21	13	24
Female	15	7	18
White British	17	9	20
Chinese	29	30	38
Gipsy/Romany	11	4	11
"Gifted and Talented"	24	18	29
Not "Gifted and Talented"	17	9	20
Non-FSM	18	10	21
FSM	12	6	14
Overall	16	9	19

Source: NPD/PLASC

Note: Science here includes electronics, environmental science, geology and computer science, but not psychology.

This gap in participation widens in terms of eventual attainment at KS5, as represented by A grades at A-level (Table 5). Not only are students from poorer families less likely to take sciences, but those that do are far less likely to obtain high grades (of the kind that might encourage further study of that subject). This pattern largely explains the pattern of participation HE, encountered above.

Table 5 – Percentage gaining A grade at A-level, all KS5 entrants, England, 2005/06

	Biology	Physics	Chemistry	Maths	English Literature
Male	1.5	2.0	1.9	2.7	1.9
Female	2.2	0.5	1.7	4.7	3.3
White British	1.8	1.2	1.5	3.2	2.7
Chinese	5.3	4.6	6.6	15.8	1.4
Gipsy/Romany	0	0	0	0	0
"Gifted and Talented"	5.4	4.1	5.5	10.6	6.3
Not "Gifted and Talented"	1.6	1.0	1.5	3.0	2.1
Non-FSM	2.0	1.2	1.9	3.7	2.6
FSM	0.7	0.4	0.6	1.6	0.8
Overall	2.0	1.2	1.9	3.8	2.2

Source: NPD/PLASC

Note: The A grade is the highest awarded. An E grade is the lowest pass.

How does this stratification arise? To the extent that participation in learning opportunities depends upon the actions of individuals, a conventional model of how and why people continue in education is based upon human capital theory. Individuals are deemed to participate in post-16 learning according to their calculation of the net economic benefits to be derived from education and training (Becker 1975). Therefore, in order to promote wider access to learning opportunities for all, government policy tends to focus on the removal of the impediments or 'barriers' which prevent people from participating in education who would benefit from doing so (Dearing 1997, Fryer 1997, Department for Trade and Industry 1998, Kennedy 1997, National Audit Office 2002).

There are institutional barriers, created by the structure of available opportunities, and dispositional barriers in the form of individuals' motivation and attitudes to learning (Burchardt et al. 1999). However, the most obvious barriers are situational, stemming chiefly from the life and lifestyle of the prospective learner (Harrison 1993). There are problems such as buildings not adaptable to handle physical disability, or lack of transport to colleges and specialist facilities for students in rural areas (Hudson 2005). Transport is a barrier that might apply to all forms of participation (Hramiak 2001). Proximity to home and convenience for travel were strong factors influencing learners using drop-in centres (provided by 'learndirect'), according to Dhillon (2004).

The most commonly cited barrier to educational participation post-16, relevant to SES, is the relative cost of education. Many students continue with extended education because they report believing, in accord with human capital theory, that they will gain in the long-term through enhanced earnings (Glover et al. 2002). Others leave for the same reason; they see education as a poor alternative to earning money in a job (Ulrich 2004). But perhaps more important than these motivations, is a calculation of the cost of education. The costs of continuing in education can be of the direct kind, such as fees, and they can be indirect, such as the costs of transport, child-care, and foregone income (Hand et al. 1994). The costs of study may disproportionately affect potential students from low-income families and non-traditional students in general (Education and Employment Committee 2001, Metcalf 2005). In one study, those who were most debt averse tended to be from low income social classes, lone parents, Muslims, and black and ethnic minority groups (Callender 2003).

This metaphor of barriers to participation is an attractive one that apparently explains differences in patterns of participation between socio-economic groups, and also contains its own solution – removal of the barriers. However, there is little clear evidence of their impact in creating stratified access, and a consequent danger that they tend towards tautological non-explanations at the expense of more far-reaching institutional, lifelong and societal change (Gorard and Smith 2007). If cost is a barrier then removal or reduction of the cost should lead to increased participation from lower-income groups. This is the logic underlying financial support packages such as EMA (Education Maintenance Allowance), grants, fees remission, and means-tested bursaries, but there is little direct evidence that these approaches are differentially effective for the groups for whom they are intended (Forsyth and Furlong 2003, Taylor and Gorard 2005, HEFCE 2005).

Plausible as these ideas about barriers sound, it is important to recall that the research evidence is almost entirely based on the self-reports of existing participants in education. Whatever those participating say about finance, for example (and it obviously has not totally prevented them from accessing education), non-participants usually cite other reasons for not continuing with formal education. Most importantly, although it seems plausible that barriers such as cost are differentially off-putting for students of different occupational backgrounds, it is not clear why this should be related to science in particular. Perhaps it relates to the relative prevalence of local opportunities putting off those not wishing to study away from home, with traditional sciences more likely to be available in old and civic universities. Perhaps the perceived time-demands of studying science leads to difficulties in combining part-time study and part-time work. Perhaps it is the direct support of professional parents that leads to greater participation in post-16 science by their children (Simpson 2003). It might be that science, as taught, now represents a middle-class European- and US-dominated sub-culture (Lemke 2001), making it unfamiliar to lower SES students (Aikenhead 1995). Students who decide to take or not take physical science (in Australian high schools) often report very similar attitudes to science (Lyons 2004). It is not the attitudes that led to their choice, (Bicjley and Howley 2003; Eggleston 1997; Khazzoom 1997; Shuttleworth and Daly 1997; Kalmijm 1994) but more the influence of their family.

In general, there is a pattern of typical learning trajectories which encapsulate individual education and training biographies. Some people leave formal education at the earliest opportunity. Some of these leavers return to formal learning at some time as adults, but a high proportion do not. Other people continue into extended initial education, but never return to formal learning once this is over. Others remain in contact with formal learning for a large proportion of their lives. Which of these trajectories, from lifelong non-participation to lifelong learning, an individual takes can be accurately predicted on the basis of characteristics which are known by the time an individual reaches school-leaving age. Replicated analyses have shown that the same determinants of post-compulsory participation appear each time (Gorard et al. 2003b). This does not imply that people do not have choices, or that subsequent barriers have no impact at all, but rather that these choices occur within a framework of opportunities and expectations that are determined by the resources which they derive from their background and upbringing. The selection of individual educational experiences themselves reflect learner identities built up over the life of the individual Selwyn et al. 2006).

Student characteristics

Qualifications and route at age 16, and subsequent life events, can then make much less difference, perhaps because a learner identity has already been formed, with a subjective view of the apparently available opportunities that either includes or excludes participation in learning. Gorard and Rees (2002) entered variables measuring five determinants - time, place, sex, family and initial schooling - into a logistic regression analysis in the order in which they occur in real life. Those characteristics which are set very early in an individual's life, such as age, sex and family background, predict later learning trajectories with 75% accuracy. Family background is influential in a number of ways, most obviously in material terms, but also in terms of what is understood to be the 'natural' form of participation. In one

large study, for a number of those who had participated actively in post-school learning this is seen as a product of what was normal for their family or, less frequently, the wider community, rather than their own active choice (Gorard et al. 1999).

Sex differences in science participation have been widely researched (Fullarton et al. 2003, Murphy and Whitelegg 2006, Mwetundila 2001, Simpson 2003, Tinklin et al. 2003, Darcy 1994), with females having a generally lower rate of participation than males, particularly in the physical sciences. This has been attributed to teachers' expectations, the types of career aspirations for girls and lack of female role models. NFER (2006) found that boys were more likely than girls to express interest in quantitative fields of study. Boys were more likely to express interest in at least one area of SET (science, engineering and technology), with technology being more popular than science or engineering.

One Dutch study using large cohort data and multilevel analysis found that the choice of science and maths subjects by girls is more influenced by their family background than the choice of boys (van Langen et al. 2006). An older study by Peng and Jaffe (1979) showed that family background, number of mathematics courses taken in high school and success orientations were important for men but not for women. There was also evidence that among women, there were differences between those who chose a quantitative field of study and those who did not (Ethington 1988). Women who chose a quantitative field of study were more likely to have a background of high school advanced science and maths courses, and what the Ethington refers to as higher maths and science self-concepts. Parental educational level and the desire for control, prestige and influence were other influential factors. Common among all of the above factors was high mathematical achievement.

In a review of 177 studies that seek to explain a declining number of girls taking post-16 physics, Murphy and Whitelegg (2006) concluded that girls' perceptions about their own competence in maths and physics, relative to boys', are important determinants of their decisions to continue to study physics. For girls, interest and enjoyment also influence their subject choices more than future career options. The decline in interest in physics relative to other sciences through schooling is more so for girls than for boys. Perhaps this is due to early development of attitudes to maths, with boys generally having more positive views, which gave them the confidence to choose academic mathematics courses later (Lamb 1997). This effect, however, can be mitigated by socio-economic background. For example, girls from high socioeconomic backgrounds, particularly those with professional or managerial parents, were more likely to retain their confidence in their math skills and thus to select post-16 maths options.

Another reason why physics may be more popular with boys is because the method of approaching problems and investigations in physics is more closely related to the activities boys experience outside school, and these are often activities culturally defined as masculine. Sadker and Sadker (1994) suggest that traditional self-concepts and real-life opportunities merge such that men become 'technicians' adept at math and science and women become 'people persons' adept at human relations. According to Murphy and Whitelegg (2006), girls are less likely to see themselves in physics and physics-related careers. However, such perception can be countered, according to

this account, by changes in the curriculum and in pedagogy. Context-based courses alter how physics content is organised, and may impact positively on overall performance, and on girls' performance relative to that of boys.

Impact of schooling

In the Gorard and Rees (2002) model, adding the variables representing initial schooling (such as school type, qualification level obtained, age of leaving) increases the accuracy of prediction to 90%. One possible explanation for this finding is that family poverty, lack of role models, and a sense of 'not for us', coupled with poor experiences of initial schooling can act to create this kind of lifelong attitude to learning – a negative learner identity. In this case, the obvious barriers such as cost, time and travel become largely irrelevant. In the same way that most of the population is not deterred from higher education by lack of finance (largely because most young people with the requisite entry qualifications already attend HE – see Gorard 2005), so most non-participants in basic skills training are not put off by 'barriers' but by their lack of interest in something that now seems school-like and imposed.

Schoon et al. (2007) suggest a school effect; one way of encouraging more students to take up science post-16 is to make school experiences more relevant and engaging for young people. Smyth and Hannan (2006) found that the proportion of students taking science subjects differs between schools, even controlling for the profile of students. It could be the quality of the individual teacher of pre-16 science that matters (Osborne et al. 2003).

'Success' or 'failure' at school affects the choice of what to do post-16 – and there even appears to be a school effect on choice (Pustjens et al. 2004). Positive experiences of schooling are crucial determinants of enduring behaviour in relation to subsequent learning. In contrast, those who 'failed' at school often come to see post-school learning of all kinds as irrelevant to their needs and capacities. Participation in post-compulsory education is not perceived to be a realistic possibility, and even work-based learning is viewed as unnecessary. Whilst this is certainly not confined to those whose school careers are less 'successful' in conventional terms, it is a view almost universally held amongst this group (Selwyn et al. 2006). People develop a subjective opportunity structure that seems to filter the actual opportunities available into only those suitable for 'people like us'.

For those who do continue immediately post-16, the low uptake in sciences, particularly physical sciences, after GCSE has been attributed to their perceived difficulty relative to other subjects in successive waves of the Youth Cohort Study (Cheng et al. 1995).[4] Several other studies have identified students' perception of science as a difficult subject as being a determinant of subject choice at A-level or equivalent (Crawley and Black 1992, Harvard 1996). Fitz-Gibbon (1999) suggests on the basis of value-added analysis that it is actually (or was then) harder to get a high grade in A-level at science and maths in comparison to other subjects, other than modern languages. It is, of course, notoriously difficult to establish comparability

[4] The Youth Cohort Study (YCS), run by the Office for National Statistics in the UK, is a series of longitudinal surveys that contacts a sample of an academic year-group or "cohort" of young people in the spring following completion of compulsory education and usually again one and two years later.

between subjects or standards over time (Gorard 2000). Nevertheless, when confronted with a choice, students may choose a lower risk option (where risk is defined in terms of poor qualification outcomes) even though the 'rewards' in terms of occupation and income may be less (Kahneman and Tversky 2000).

But perhaps none of these reasons is needed, if post-16 participation in science depends on prior attainment as it does with HE participation.

Prior attainment

Of course, students with the lowest KS4 attainment scores (or none at all) are less likely to continue with post-16 full-time study – whether of science or not. Changing the nature of opportunities available post-16 tends to have no impact on the non-participants. The total proportion of the 16-year-old cohort remaining in education, government schemes, and employment-based training combined has remained constant for decades, even though the balance between routes varies according to the local history of funding and availability (Payne 1998). Furthermore the proportion remaining in education and training continues to be stratified in terms of social class, ethnicity and region (Denholm and Macleod 2003).

Since science is seen as a hard choice at A-level or equivalent, the most useful predictor of participation post-16 is again attainment at age 16, especially in science and maths. Mathematical and language skills are important predictors of science uptake (Uerz et al. 2004). Traditional science, unlike psychology for example, is not taken as an additional new subject but as one in which the student has not failed before. To some extent this is a matter of choice, but it is also often a criterion imposed by schools and colleges. Either way, it leads to physical sciences being dominated by those with high GCSE-level attainment (Osborne et al. 2003), or equivalent (Uerz et al. 2004).,which is in turn linked to high attainment at each previous Key Stage, and to social class background. Those taking maths or science in any combination have, on average, higher prior attainment scores than other students taking A-levels or equivalent (Table 6). Perhaps their attainment at KS5 is partly based on talent, as evidenced by their prior KS4 score, and so deserved rather than necessarily on privilege and so undeserved (Rawls 1971).

Table 6 – Prior and post attainment points scores, KS5, all entrants, England, 2005/06

	Mean total prior attainment score (KS4 points)	Mean total post attainment score (QCA points)
Science	484	844
Not science	427	663
Maths	487	925
Not maths	434	674
Science or maths	482	848
Neither science nor maths	424	648

Source: NPD/PLASC

Note: Prior attainment scores are based on KS4 (GCSE, GNVQ and others). For example, an A* grade at GCSE is counted as 58 points, a C grade as 40, and the lowest pass at G grade as 16. QCA points are based on A-level scores and equivalents, including vocational qualifications. For example, an A grade at A-level is counted as 270 points, and the lowest pass at E grade as 150 points.

To a considerable extent, changes in the science curriculum and pedagogy combined with socio-economic developments have been associated with a decline in the gender gap for participation in sciences. Why is there not such a clear position for SES? Perhaps, first this is because as shown above the pattern for participation and SES is not as clear as it has been for participation in science and sex. SES has a less stable, but more multinomial and non-biological definition than sex. And the problem of SES and attainment crosses the whole curriculum. It is not specifically a science problem. In nearly all large-scale, cohort and longitudinal studies, if prior attainment by age 16 is taken into account in any analysis, then there is a very limited role indeed for SES in subject choice (e.g. O'Connor et al. 1999). So we continue by looking at participation and attainment in pre-16 science.

Science and pre-16 participation

As expected, there are clear differences in overall attainment in sciences at KS4 between students of differing backgrounds (Table 7). However, these differences are no larger than and often much smaller than the differences for all subjects. Whatever the problem is, leading to the differential attainment of social, ethnic and economic groups, it is certainly not one that is specific to science. The general patterns are the same as for science. Maths is like science in having only a very small difference between scores for boys and girls, and so is unlike English. Gifted and Talented (G&T) status makes markedly more difference to grades in English Literature and maths than science. The large gap between gifted and talented students and others is expected if the identification of G&T has been even moderately successful. It is what G&T means, after all. So what is interesting here is the relatively small gap in science. The gaps between ethnic groups are also large but based on very small numbers for the minority groups. Therefore, perhaps the most worrying gap in all these subjects is between students eligible and not eligible for FSM. But again these are not appreciably larger in Science, so perhaps SES is not the problem for science that some commentators believe.

Table 7 – Mean capped points scores (all subjects and sciences) and percentage attaining grade C or above (maths and English), all students, KS4, England, 2005/06

	All subjects	Science subjects	Level 2 maths (%)	Level 2 English (%)
Male	338	33	50	49
Female	378	34	52	64
White British	360	34	52	57
Chinese	455	41	81	67
Gipsy/Romany	146	14	7	8
"Gifted and Talented"	501	46	89	91
Not "Gifted and Talented"	308	33	48	54
Non-FSM	373	35	55	61
FSM	266	25	27	31
Overall	359	34	52	58

Source: NPD/PLASC

Note: The figures for all subjects and sciences are based on GCSE points. In 2005/06, an A* grade is worth 58 points, a C grade is 40, and a G grade is 16). So, the average science score is equivalent to a grade D at GCSE. The points are capped in the sense that they represent the total of the best eight scores at GCSE or GCSE equivalents. These figures for maths and English are based on the percentage attaining at least grade C or equivalent in GCSE. Unfortunately, from 2005 the NPD discontinued the point scores for maths and English. This means that the figures are not directly comparable to those for science.

Insofar as it is possible to compare scores over time, given the inevitable changes in measuring, these gaps between sub-groups are at around the same level as they were in 2001/02 when the PLASC was started (Table 8). In 2002, the achievement gap between FSM and non-FSM students in the point score attained in science was 17% (1.3/7.7). In 2006, the achievement gap for the score in science subjects (and so not the same indicator) was 17% (10/60). This 17% gap between FSM and non-FSM is remarkably constant both over time and across all subjects.

Table 8 – mean uncapped points score, all students, KS4, England, 2001/02

	All subjects	Science subjects	Maths	English
Male	33	4.3	4.3	5.2
Female	37	4.4	4.3	4.5
White British	35	4.4	4.3	4.9
Non-FSM	37	4.5	4.5	5.0
FSM	25	3.2	3.2	3.8
Overall	36	4.5	4.3	4.9

Source; NPD/PLASC

Note: the points scores in 2002 are the sum of all eligible qualifications, and so more affected by entries than in 2006 where the points were the sum of the 'best eight' scores. They are also based on a different counting system, where an A* grade at GCSE is counted as 8 points, a C grade as 5, and the lowest pass at G grade as 1. It also means that the absolute levels cannot be compared with 2006. There is no indication of G&T. The ethnic groups are different to 2006 – all white categories are together and there is no category for Gipsy/Romany.

Table 9 shows the same overall patterns as Table 7. It is a partial view based only on the highest grade in one year. On this indicator biology is no easier than physics or chemistry, and this applies to girls as well as boys, and to every sub-group presented. An A* grade is more likely in double award science than the single subjects shown. Maths is included as a comparator. The results for maths are closer to double-award science, but generally higher for all sub-groups. The gap between those who are gifted and talented and the rest makes sense, because that is what gifted and talented implies. There are also clear differences in overall attainment as expressed by points scores in sciences at KS4 (separate sciences, and single and dual award, or equivalent) between students eligible for FSM and not. This makes less sense. However, these differences are no larger than the differences for all subjects. Whatever the problem is, leading to differential attainment by SES, it is certainly not one that is specific to science. It just seems to convert into an issue for science at HE level.

Table 9 – Percentage of entrants achieving A* grade in science subjects, entrants, KS4, England, 2005/06

	Double-award	Physics	Chemistry	Biology	Maths
Male	2.7	1.2	1.0	0.9	3.4

Female	3.6	0.7	0.8	0.8	3.4
White British	3.1	0.9	0.8	0.9	3.3
Chinese	9.5	5.1	5.5	4.5	20.1
Gipsy/Romany	0	0	0	0	0
"Gifted and Talented"	12.9	4.0	3.9	3.8	15.1
Not "Gifted and Talented"	2.0	0.6	0.5	0.5	2.1
Non-FSM	3.5	1.1	1.0	1.0	3.9
FSM	0.6	0.1	0.1	0.1	0.6
Overall	3.7	1.6	1.6	1.5	4.4

Source; NPD/PLASC

Notes: Missing data explains apparent discrepancies between each result and the overall. For example, those not recording a sex of student actually obtain more A* grades than either female or male. This is an illustration of the warnings given in text about the impact of missing data – exacerbated by the need to link cases across datasets. Around 10% of cases are unmatched by sex and FSM. These 65,000 students appear to have higher than average attainment.

Double-award is a double weight qualification but based on combined assessment of all three sciences.

Ignoring missing data (around 130,000 cases have one or both FSM or G&T values missing), 7% of gifted and talented (G&T) are eligible for FSM, which is much lower than the national figure of 13%. Of those eligible for FSM, 6% are listed as G&T compared to 11% G&T overall. Considering only those identified as G&T, it is clear that their results are less patterned by SES in the form of FSM than in Table 7. Two points emerge from Table 10. The difference in attainment (on this indicator) between students living in poverty and the rest is the same in science as it is in all subjects. Students not living in poverty achieve around 17% higher capped KS4 points scores. But for those identified as gifted and talented, the gap drops to 6 or 7%. Insofar as the very imperfect G&T variable can be used as a valid indicator of ability, this finding suggests that much of the difference in Table 7 is attributable to differences in revealed ability at school rather than SES *per se*. The purpose of the Gifted and Talented programme is to identify students with capability regardless of their origin or current situation. They are intended to be the students with great potential. It seems that either these students are disproportionately not in the poorest 13% of society or the programme is failing to identify them correctly. Possibly both. The picture for English and Maths is fairly similar.

Table 10 – Achievement gap, FSM and non-FSM students, KS4, England, 2005/06

	Non-FSM	FSM	Gap
G&T all subjects	505	451	5.6
G&T sciences	46	40	6.9
G&T maths	92	79	7.6
G&T English	90	77	7.8
All students all subjects	373	266	16.7
All students sciences	35	25	16.7
All students maths	55	27	34.0
All students English	61	31	33.0

Source: NPD/PLASC

Note: these scores for science and all subjects are points scores, for maths and English they are the percentage in each group attaining at least grade C or equivalent in GCSE. Therefore, the gaps are not directly comparable across subjects.

Note: the achievement gap is calculated as the difference between two capped point scores or frequencies divided by their sum (see Gorard et al. 2001).

One of the most established findings of education research is that social class and attainment at school are linked. Students from more prestigious social class backgrounds tend to obtain higher marks and examination grades irrespective of the subjects studied. Thus, students from more prestigious social class backgrounds tend, on the average, to perform better in pre-16 science subjects than their peers (Hogrebe et al. 2006). However, to a large extent this is nothing to do with science itself (Pong 1997). It is an international phenomenon appearing in science, literacy and numeracy (Marks 2007). It was usually not made clear in any of the literature found in our review whether the situation is the same, better or worse for the sciences as in any other subject areas. There is nearly always a missing comparator. SES is also only one of several related measures of individual background. It is clearly a factor in attainment but the overall research evidence is complex and conflicting on why and how this relationship works (Erebus International 2005).

Determinants of science participation, as portrayed by international studies

Analyses of international tests such as TIMSS have suggested that home background is a determinant of pre-16 achievement in science across most countries. Students with parents of more prestigious socio-economic status, living in homes with modern possessions and more books outperformed others (Mwetundila 2001). Yang (2003), using TIMSS data, reports a relationship between family ownership of possessions and attainment in science and maths. But parental occupational class as a measure of SES is a useful predictor of student performance in literacy and numeracy as well, at least in Australia (Rothman 2003). Those students most interested in taking science tend to be high achievers, interested in eventual university education, and also in practical work (NFER 2006). Physics and chemistry as separate subjects have been more likely to be taken by academically able students, especially middle-class males from independent schools (Lightbody and Durndell 1996). General science (including combined, dual and single awards), on the other hand, has traditionally been studied more by lower-attaining students, girls, and those from working-class backgrounds (Cheng et al. 1995).

Gender stereotyping

There have been suggestions that gender stereotyping may be an explanation for the low participation of girls in physical sciences. Students in single-sex schools may be less likely to hold stereotypical views about science subjects compared to students in co-educational schools (Gallagher et al. 1997). Many strategies have been suggested to encourage girls to take up physical sciences. One of these involves teaching these subjects in segregated classes. In one small case study students were segregated for biology classes in their 3rd and 4th year in Scotland, but continued co-educationally in other classes (Airnes 2001). The results suggest that boys are not disadvantaged by single-sex classes, but girls do not benefit from single-sex classes either. Reviews have similarly not shown any positive benefit of single-sex schools on educational attainment or participation in science (Shuttleworth and Daly 1997, Airnes 2001).

Decreasing interest in science

Decreasing interest in science is another possible explanation of low participation in secondary schools. Research has shown that students' interest in science decreases as they progress from primary to secondary schools (Schoon et al. 2007). Murphy and Beggs (2001) suggest possible reasons for this change in attitude. These include lack of experimental work. Almost all of the children in their study indicated that they liked doing experiments which were described as fun and enabled them to find out things for themselves. This is consistent with other studies (Campbell 2001, Ponchaud 2001, Bricheno 2000) which also found that when asked what they liked about science, students often referred to 'doing experiments' and 'finding out new things'. Another reason for reduced popularity suggested by Murphy and Beggs (2001) was intensive preparation for national tests at Key Stage 2 – which only involve the core subjects of science, maths and English. The children in their study explained that 'covering the same topics over and over again' in preparation for the test was 'boring'. Also curriculum content which has no relevance to the children's lives could be de-motivating. There is a suggestion that there have been shortcomings in teachers' knowledge of science in the upper years (OFSTED 1995). This led to an overemphasis of acquisition of purported knowledge at the expense of conceptual development.

Most students, when making a choice of subjects, report recognising that science is important even when they do not wish to study it further. However, science is generally seen as less important to them for a future job than English or maths (NFER 2006). In addition to future utility, students' perceived aptitude at a subject and, of course, enjoyment are the most commonly cited reasons for choosing a subject to study. In Sweden, Jidesjö and Oscarsson (2005) found that many of the items traditionally taught in science classes were on a list of things students do not want to learn. Science facts were at the bottom of the students' list. Instead students want to learn about things we cannot yet explain; they are more interested in debate and discovery. This shows a misunderstanding of the nature of science that, presumably, stems from its teaching focus on facts, and might even argue that teaching what is termed 'science' in schools is counter-productive if the purpose is to encourage later participation.

In our opinion, the importance of attitudes to science in determining future participation and attainment is exaggerated. For even though science is stratified by social class (as evidenced by this review so far), Breakwell and Beardsell (1992) found that class was negatively associated with attitude towards science - children from lower social class having more positive attitudes. These simply do not translate into educational actions in the future. Most studies of attitudes to science do not look at the link between attitudes and take-up. Those that do, like Breakwell and Beardsell (1992), find no link. Meta-analysis of research suggests that there is only a moderate correlation between attitude towards science and achievement (Weinburgh 1995). On the other hand, measures used in the TIMSS study (Beaton et al. 1996) have found a consistent relationship between attitude and achievement. Oliver and Simpson (1988) using a longitudinal study found a strong relationship between three affective variables - attitude towards science, motivation to achieve and self-concept of own ability - and achievement in science. The problem with studies like this is that they are effectively retrospective – asking students who have now succeeded or failed at science what they think of science as a subject.

It may be that attitude to science is a determinant of subsequent participation, but there is a danger of tautology if attitude is measured as it is by Jovanic and King (1998) and others in terms of revealed preferences (i.e. choices). A review by Osborne et al. (2003) reports that attitudes to science are themselves, in turn, influenced by early childhood experiences of science and success or otherwise in junior science courses. Perhaps it is simply a case of if at first you don't succeed, you don't succeed – in science. A further problem with these studies on students' attitude towards science is the measurement of attitude itself. There is no single measure. Different studies used different measurements, ranging from attitude scales (for example, 'Science is fun', 'I would enjoy being a scientist', 'Science makes me feel like I am lost in a jumble of numbers and words'), subject preference, interest inventories where respondents are presented with a list of items and they indicate which ones they are interested in, and subject enrolment (Osborne et al. 2003). It is not clear whether the attitude is to science in society, scientific progress, science in education, or the students' own participation in non-compulsory science. Much of all UK research on science education is about attitudes and motivation in classrooms, and is not linked to subject entry or revealed choice (Wright 2006). There is no clear established non-tautological link between attitude and either take-up or attainment pre-16.

School factors

International studies show that attainment at school in maths, science and literacy is related to student characteristics such as sex, whether they were born in the country where they attend school, whether they live with both parents, and whether either parent was born in the country, number of books at home, parents' educational level and degree of geographical isolation of home (Fuchs and Wobmann 2004). But it is also just as closely related to school factors including instruction time, and the teachers' sex, educational level and years of experience (Wobmann 2003).

The student experiences gained during initial schooling appear to be an important factor in shaping long-term orientations towards learning, and in providing the qualifications necessary to access many forms of further and higher education. State-funded compulsory education for all children is an intervention intended to equalise life opportunities and remedy inequalities such as the number of books at home or the reading ability of parents. However, because this intervention is universal in the UK and is now so mature, it is very hard to decide what effect it has had on educational mobility. Elsewhere, school systems with early tracking of students by ability, or with high levels of fee-paying provision, or covert selection on the basis of faith or curricular specialism, or differential local funding arrangements, tend to have stronger links between SES and attainment than egalitarian ones (Haahr et al. 2005).

There are other studies and reviews suggesting that the organisation of schooling can make some difference to reducing the link between status and attainment. Miller-Whitehead (2002) illustrates that class size can militate against the effect of SES (as measured by eligibility for free or reduced school lunch) on eighth grade students' science achievement. In a comparison of within school variance in 14 year-old achievement attributable to family background between US, England and Sweden, (Burstein et al. 1980) found that this was similar in each country. The extent to which

family SES advantage is rewarded within an educational system appears to be resistant to change. However, between-school variance differed between countries, and the researchers attribute this to cross-national differences in the social policies governing education (see also EGREES 2005). Comprehensive, centralised, equitably-funded school systems tend to produce both better outcomes overall but also smaller attainment gaps between rich and poor, and high and low attainers (Burstein et al. 1980). In Finland, for example, there is deemed to be higher equality of educational opportunity than in Germany (Domovic and Godler 2005) and the influence of family SES on test performance in scientific, mathematical and reading literacy is noticeably lower than in Germany.

There are distinctive patterns of subject uptake at GCSE between schools which are not explained by student-level characteristics such as parents' social class or by the clustering of these same variables at school level (Davies et al. 2004). This residual variation could, of course, represent unmeasured qualities of the teachers and local practice. There is a suggestion that there have been shortcomings in teachers' knowledge of science in the upper years (OFSTED 1995). These shortcomings of staff may be stratified between schools and types of schools. If admissions tutors at HE prefer separate subject GCSEs in science (i.e. distinct physics, chemistry, and biology courses) compared to dual award (i.e. general science) and the former is more common in selective and independent schools, then this could be a lever towards social polarisation in later careers.

Some studies claim that there is a school mix effect on achievement and even participation. For example, Pong (1997) reports that attending a US school with a high concentration of students from single-parent and step-families is detrimental to a student's eighth grade achievement, over and above the impact of themselves living in a single-parent family or step-family. Both measures are related to an average lowering of maths and reading achievement. Perhaps schools with high concentrations of students from less prestigious occupational backgrounds, which might be associated with such 'non-traditional families' in the US, are also more likely to have low teacher morale and few material resources. In the US, maintained schools are largely funded via local taxation, and this exacerbates rather than reduces the material disadvantage of poorer families.

Some authors, however, remind us that schools are not very good at breaking the link between SES and attainment (Gorard 2000). A review by Robinson (1997), for example, shows that organisational practices such as class size, teaching methods, homework policies make no difference to this link. The kinds of weak associations found in studies like Wobmann (2003) would be expected in any large dataset. The apparent impact of individual characteristics aggregated at school levels is more likely to be due to measurement and modelling error or even neighbourhood effects (Gorard 2006b).

Parental influence

Closely linked to social class is parental involvement. Parental involvement can mean many things ranging from participation in school activities, attending parents-teacher evenings, helping children with homework or checking homework to discussing school work in general. Recent studies in the UK have shown that the higher the

social class the more evident is parental involvement (Harris and Goodall 2006). A DfES (Department for Education and Schools) report (Moon and Ivins 2004) found that although more parents in unskilled manual jobs or on state benefits reported being involved in their child's schooling, these reports mostly concerned school trips and helping with dinner duties.

In international studies such as TIMSS and PISA, measures of SES included the number of books at home, where parents were born and parental involvement. For example, Wobmann (2003) found that students' performance in maths and science was strongly positively related to their parents' educational level and the number of books at home. Marks (2007) compares the influence of father's and mother's education and occupation on student performance in literacy and numeracy using data from 30 countries, and shows that the impact of mother's socioeconomic characteristics (education plus occupation) on student performance is comparable to that for father's in most countries.

The social class of students' families is loosely related to the pattern of subject choice at school (Bickel and Howley 2003). In Northern Ireland, for example, students from less prestigious socio-economic backgrounds are less likely to study science at GCSE level (Shuttleworth and Daly 1997). In Scotland, social class is one factor - with sex, prior attainment, and school attended - related to the choice of subjects (Croxford 1994, 1997).

In the US, mothers with no formal employment seem to encourage their children to pursue non-technical (non-science) majors, while working mothers with more prestigious occupational status seem to encourage study of technical majors (Kalmijm 1994, Khazzoom 1997). Eggleston (1977) suggests that participation in science by more prestigious social groups may reflect parental encouragement, a more academic school environment and social selection. Students from less prestigious backgrounds may suffer actual and material deprivation as well as lack of parental advice and support, according to Shuttleworth and Daly (1997), and these may discourage them from taking up science. These studies have attempted to explain the relationship between SES and subject choice – perhaps believing the link to be stronger than it is. For the most part, these are little more than speculations and do not explain why science as opposed to languages or humanities should be specifically affected in this way. Schools in Northern Ireland are historically highly segregated by religion and ability which leads to high social segregation as well. Clustering low attainers in poorly performing schools with low teacher expectations may lead to discouragement of entry to the science subjects, traditionally seen as difficult. But, since Shuttleworth and Daly did not include prior attainment in their analysis, it is perhaps simpler to explain their findings as being that students who were not expected to perform well in GCSE, often clustered in specific schools, may be discouraged from taking up separate sciences in their options or from taking the terminal examinations.

Some US studies suggest that parents from less advantaged households are less likely to be involved in the help and supervision of childrens' work at home, and in school activities and support (Zill 1994). These differences are over and above the influence of parental education and income. Shaver and Walls's (1998) study on eighth graders' mathematics and reading achievement, concluded that parental involvement, regardless of the child's gender or SES, was a positive influence on academic

success. Wang et al. (1996) show that parental education and encouragement are strongly related to seventh grade students' performance in mathematics. They obtained significant predictors of mathematics achievement using backwards elimination. Similar results appear in Cotton and Wikelund (1989). Again, however, we have no way of knowing the causal model here. As parents' perceptions of their children's ability deviate, in a positive or negative direction, from teachers' perceptions, parent involvement diminishes. This study uses teachers' and parents' perceptions of students' ability, rather than their actual performance, and it uses no measure of SES.

Many US studies have shown that, irrespective of a child's background, parental involvement has a positive impact on academic achievement (Wang et al. 1996, Epstein et al. 1997, Shaver and Wallis 1998, Dryfoos 2000, Starkey and Klein 2000). In a 4-month intervention experimental study using maths kits for home use, Starkey and Klein (2000) found that children in the experimental group whose mothers were taught how to use these kits developed greater maths knowledge and skills than those in the control group. A US Department of Education report (1997) found that students whose parents are involved in their school work are more likely to take challenging mathematics courses early in their academic careers. Patel (2006) suggests that parental involvement has beneficial effects during the middle school years, particularly with respect to maths achievement.

A study by Jeynes (2005) on the effects of parental involvement on the academic achievement of African American youth, found that the apparent importance of parental involvement on educational outcomes disappeared when variables for SES were included in the analysis. It is possible that social class rather than parental involvement as such explains differences in academic performance. Supporting this finding is a study by Okpala et al. (2001) which indicates that expenditure on instructional supplies per student and parental volunteer hours were not significant in explaining test scores. Low family income was related negatively to students' academic performance in mathematics. Better educated middle-class parents are apparently more able to provide the guidance and home environment conducive to study than less educated parents. Some commentators would say that these variables represent cultural capital. In the US, Hogrebe et al. (2006) used participation in free or reduced school lunch programmes as an indicator of parental poverty. It was clearly, but not invariably, linked to low attainment in science.

Parents are both a source of information for students choosing courses at school and also reported to be a major influence on that choice – where such choice is possible (see below). Thus, the occupational and educational status of parents could be a factor in any relationship between SES and subject choice (Sadker and Sadker 1994). Mothers with a more prestigious occupation are more likely to encourage the choice of a technical major (such and maths and science) over a nontechnical major. Lara-Cinisomo et al. (2004) found that the most important factors associated with the educational achievement of children are socio-economic ones. Mothers' educational level, in particular, was an important variable influencing performance in maths. More than 90% of students whose mothers completed a college education scored in the high and middle ranges on the maths test, while 40% of students whose mothers had no more than a high school education had low scores on the maths test. Even in poor neighbourhoods, students are likely to perform well in reading and maths if they

have well-educated mothers, and even when mothers' reading scores are held constant.

Over time, in the US, the general educational level of parents has gone up and families have become smaller with greater income per head. If, as has been suggested, SES is a determinant of attainment in school subjects, including science, then changes in the SES composition of society ought logically to influence attainment, and changes in patterns of attainment ought to be at least partly explicable in terms of changes to SES. Using longitudinal data, Grissmer et al. (1994) and Grissmer and Flanagan (1998) not only found the usual association between SES and attainment, they also found a correlation between social changes to family structure/income and the SES gap in attainment. Hedges and Nowell (1998, 1999) found similar patterns, with family background characteristics accounting for roughly one-third of the achievement gap, but they also found that the precise nature of the link between background and attainment varied between cohorts. The latter brings the earlier conclusion into doubt. The change over time could be due to changing families or a wider change (disruption) in the link between families and attainment.

Cook and Evans (2000) found similar results for the convergence in attainment between black and white students in the US. Around 25% of the change in achievement gaps for reading and maths was explained by changing family and school characteristics. They argue that the remainder is due to changes within schools. However, the measure of school characteristics used by Cook and Evans (2000) was limited in that they merely assume 'school quality is the effect that attending a given school has on student performance after controlling for the student's observable characteristics' (p.732). Whereas, of course, the variation left unexplained after controlling for student background cannot be simply attributed to school quality. Much of this variation will be error, such as problems of assessing achievement or measuring background. Some will be due to missing background variables (such as prior student motivation). Some will be due to processes other than at school level. And so on. Another limitation of their study was that they could only use parental educational attainment as a measure of family background as their dataset does not include family measures such as parent income, occupational status and other family characteristics (Berends et al. 2005).

The interaction of all these variables also needs to be considered. For example, Wang et al. (1996) found that in the US parents' involvement with children's homework had a negative relationship with achievement. It is difficult to interpret this result if parents' educational background is not known. If parents are not highly educated, they may not be able to help their children with their homework. It is also possible that parents are more likely to help their children with their homework if the children are struggling. How parents are involved can also make a difference. In some studies it is not clear what kind of parental involvement is being studied. Ho and Willms (1996), for example, found that parents talking with their children about school and planning their education programmes had more effect on student achievement than merely volunteering for and attending school activities. Ma (1999) found that the effect of parental involvement varies depending on the grade level and the kind of parental involvement. For example, volunteer work for school is the most important school-level variable in the early grades (8-10), but home discussion is especially important

in the middle grades (10 and 11). The effect of home-school communication, on the other hand, has a short-term but strong effect in grade 9.

Prior attainment (again)

In England, as elsewhere, students are somewhat restricted in their choice of subjects at age 14. This reduces variation between students. The 14-16 National Curriculum requires them to study science. Further, there are clear differences between school uptake of different subjects which are unrelated to SES, such as availability of staff and traditions of offering combined or separate sciences. Given the fact that prior attainment anyway tends to predict both later participation and subsequent attainment, these factors all mean that SES does not seem that important in pre-16 subject choice of science or not. In the US, O'Connor et al. (1999) using the 1988-1992 National Education Longitudinal Study found that prior attainment (especially in maths) was the best predictor of uptake in higher levels of mathematics and science, irrespective of family structure and sex of the student. Several other studies confirm this. The results of an analysis of PISA 2003 data (Schulz 2005) confirmed previous studies that suggest that students' perceptions of their own ability to solve tasks in mathematics is an important predictor of their career choice and hence choice of subjects. If prior attainment is taken into account in any analysis, then there is a very limited role indeed for SES in subject choice.

Across all curriculum subjects, prior attainment has been shown to be one of the best predictors of subsequent school achievement. It is this fact that underlies attempts to construct value-added measures (Gorard 2006c). And prior attainment is closely related to ability. The relationship holds irrespective of other factors like sex and family structure. In the SISS and TIMSS studies, prior verbal ability was a key determinant of achievement in the science tests (Mwetundila 2001). Mathematical and language skills are relevant contributory factors in predicting the choice of science subjects in secondary education (Uerz et al. 2004). However, cohort studies also suggest that these skills are themselves predicated on sex and family composition variables related to SES. The social class of students' families is also loosely related to the reported (rather than revealed) future careers of students in Year 9 (or Grade 8, i.e. students aged 13-14) (NFER 2006). Those interested in a career in science and technology, but not engineering, tended to be from more prestigious socio-economic backgrounds. This means that participation in specialist science subjects pre-16 tends to be lower among students from families with manual than non-manual occupations, especially for physics and chemistry, even when participation grows, and sometimes in spite of curriculum change (Croxford 1997).

As mentioned before one of the reasons often cited for not choosing science, particularly physical sciences after KS3 is the perception that it is a more difficult subject relative to other school subjects (Hendley et al 1995). Only 29% of students in one study reported that science was easy in comparison to other subjects (NFER 2006, see also Croxford 1997). These perceptions of relative subject difficulty are, in turn, linked back to SES and prior attainment. Those students most interested in taking science tend to be high achievers, interested in university education, and also in practical work (NFER 2006).

Some studies suggest that students' attitude towards science is already shaped in their primary school years (Khoury and Voss 1985, Murphy and Begg 2001, Jidesiö and Oscarsson 2005). The argument then is that if students see science as irrelevant and difficult from early childhood, then they are less likely to take up the subject in their secondary school.

Early childhood experience and science participation

Families are universally acknowledged as a key determinant of educational performance in schooling and later education (Gorard et al. 1999). In compulsory education, similar educational routes regularly occur within families. For example, the occupational or class background of parents is routinely used as an explanatory factor in analyses of children's educational attainment or progress through the compulsory educational system (Halsey et al. 1980). Similarly, the influences of ethnic background are recognised as being mediated through families (Wilson 1987). The kind of stratification we have shown so far among young adults and secondary students starts with early childhood and before. Findings from two British cohort studies (Schoon et al. 2007) suggest that there is a persisting sex imbalance both in terms of aspirations and occupational attainment. Their study shows that interest in and attachment to a science-related career are formed early in life, often before the end of primary education. School experiences, in particular, appear crucial in attracting young people to a career in science.

Tables 11 and 12 show that there is a small negative relationship between living in an area of deprivation and the KS1 and KS2 results in all three core subjects. The differences between the results of the most and least deprived areas are relatively small. One reason for this could be that the attainment measures are threshold levels expected for all students. Only a minority do not reach this level, but many may reach a much higher level not used here. What is more noteworthy is that the gap in science between the richest and poorest areas is 9% at both KS1 and KS2. This is substantially less than Reading (12%) and Writing (14%) at KS1 and English (14%) at KS2. It is also less than Maths (14%) at KS2. This is largely due to higher scores among students from poorer areas in science rather than lower scores among those from richer ones. The same is true for Maths (7%) at KS1. Insofar as these threshold figures are useful, they suggest that SES makes less of a difference to science attainment at KS1 and KS2 than in other subjects.

Table 11 - Key Stage 1 results 2007, percentage reaching expected level, England, by deprivation of area of residence

IDACI decile	Eligible pupils	Reading	Writing	Mathematics	Science
0 - 10 % most deprived area	71,372	73	68	83	80
10 - 20 %	63,050	77	72	85	83
20 - 30 %	56,797	79	75	87	85
30 - 40 %	52,560	82	79	89	88
40 - 50 %	49,981	85	81	91	90
50 - 60 %	48,905	87	84	92	92
60 - 70 %	49,512	89	86	93	93

70 - 80 %	48,963	90	88	94	94
80 - 90 %	48,880	91	89	95	95
90 - 100 % least deprived	49,707	93	91	96	96

Notes: Includes pupils with valid postcodes only. Income Deprivation Affecting Children Indices (IDACI)- each small area in England is given a score between 1 and 32,482, 1 being the most deprived. The expected level of attainment at KS1 is referred to as level 2.

Table 12 - Key Stage 2 results 2007, percentage reaching expected level, England, by deprivation of area of residence

IDACI decile	Eligible pupils	English	Mathematics	Science
0 - 10 % most deprived area	71,895	68	66	79
10 - 20 %	64,390	71	68	81
20 - 30 %	59,211	74	71	83
30 - 40 %	56,084	77	73	86
40 - 50 %	53,676	80	77	88
50 - 60 %	52,506	83	79	90
60 - 70 %	52,587	85	81	91
70 - 80 %	52,514	87	83	92
80 - 90 %	51,926	89	85	94
90 - 100 % least deprived	52,312	91	88	95

Notes: Includes pupils with valid postcodes only. Income Deprivation Affecting Children Indices (IDACI)- each small area in England is given a score between 1 and 32,482, 1 being the most deprived. The expected level of attainment at KS2 is referred to as level 4.

Key associations with a child's educational attainment in the early years include parental education and income (Feinstein et al. 2004). Occupational status and family size are also relevant but the causal pathway is less clear here. Once parental income and education are accounted for, then measures such as family structure, maternal employment or teenage motherhood are not important, in isolation, as determinants of child attainment. One explanation for this pattern relies on an assumption of the inheritability of 'talent' – a combination of ability/aptitude and willingness to work hard, as defined by Rawls (1971). If, in general, science is seen as a relatively difficult subject, and those who choose it tend to be higher achievers, and also tend to come from more prestigious occupational family backgrounds, perhaps the underlying explanatory variable is talent. If parents are talented then they may be more likely to have higher levels of attainment and income, and they may be more likely to pass this talent on to their children. If talent is inherited from parents as well as nurtured by an educated, well-resourced home environment then this could explain the overall pattern. Another explanation would be that the income and education of parents affect their beliefs, values, aspirations and attitudes, and these are 'transmitted' to their children via proximal interaction. In fact, of course, trying to separate out these types explanations is almost impossible on the basis of the kinds of data available to us in this review.

If very young children (aged four and five) are given new mathematical problems, some with and some without scaffolding to help, those from the highest SES families

have markedly higher rates of success compared to children from middle and lower SES families (Ginsburg and Pappas 2004). The actual strategies used by the children to try and solve the problems did not appear, to observers, to differ between the SES groups. The researchers concluded that common biological inheritance and a common environment rich in opportunities for mathematical learning insure the development of basic mathematical competence in most children. However, those from high SES families simply appear better at solving problems from a young age. This does not solve the issue of whether this ability is innate or nurtured in the early years. Wallace (2005) reviews psychological research on intelligence and finds that children from lower SES families score, on average, lower than those in middle and higher SES families. One suggested explanation is that it is part genetic and part a result of certain environmental components that appear more often in poverty – presumably poor early diet among them. If true, then early welfare and educational interventions might be effective in reducing the difference.

Some studies, particularly in the past, have emphasised the role of inherited talent in the reproduction of family educational attainment (Herrnstein and Murray 1994). Some, more recently (but see Layzer 1974), have emphasised the role of early family life and environmental stimulation. After controlling for socioeconomic status, there is some evidence that even minimally increased parental involvement had a positive impact on preschoolers' early development and mastery of basic skills (Marcon 1999). Capron and Duyme (1989) presented a full cross-fostering study dealing with IQ scores, where only children born to biological parents from the most highly contrasting SES and adopted by parents with equally contrasting SES are included in the study. They reported that children born to high-SES parents scored higher than children born to low-SES parents but that children adopted by high-SES parents scored higher than children adopted by low-SES parents. So perhaps there is evidence of both.

Some studies have suggested an interaction effect, such that the proportions of ability (IQ scores) variation attributed to genes and the environment vary with SES itself and in a non-linear fashion. Using a sample of 7-year-old identical twins Turkheimer et al. (2003) reported that in impoverished families, 60% of the variance in IQ scores is accounted for by the shared environment, and the contribution of genes is close to zero; in affluent families, the result is almost exactly the reverse. There have even been suggestions that the apparent role of heredity decreases with age. Gottfredson (2004) claims, on the basis of correlations only, that hereditary general ability is the basis of early inequalities, but that as children learn to adapt and adjust to their environment the relative importance of this ability declines. If true, this suggests a key role both for family and for education.

On the other hand, ideas of inherited innate ability have become less clear over recent decades, and politically it has become more difficult to maintain a thesis based on suggesting that the more advantaged in society hold their position based on even a small slice of merit. The idea of IQ as an innate general cognitive ability is now largely abandoned within psychology (Nash 2005), and it only ever had an instrumental definition (like attitudes to science) meaning that it is in danger of leading to tautology.

Discussion

What this review of evidence shows is how difficult it is to establish causal relationships with numeric data re-examined *post hoc* rather than generated for a specific purpose through intervention with randomisation of cases to treatments. And what the in-depth studies appear to do is largely to replicate evidence of the link between SES and attainment (in science and more generally) using small-scale and less complete data (than PLASC/NPD for example). What most studies do not attempt to do is to try to explain the link other than by speculation. The pattern is reasonably robust and clear. What is much harder to find is a suitable explanation for the pattern. Therefore, in spite of the proliferation of research in this area, numerous theories (speculations really) still abound and no conclusive evidence has been put forward as to how exactly socioeconomic status impacts on students' academic achievement or their uptake of post-compulsory science subjects.. In the absence of trials, very little research goes further than speculation in explaining why this link exists. Perhaps the latter is the wrong question. Perhaps we should query why prior attainment (linked to SES) is deemed so crucial in the study of science.

At present, we have a system in England in which science, as narrowly defined, is a core subject from primary stage onwards. Once students are faced with a choice of how to study science (usually at around age 14 in England) or whether to study science at all (usually post-16), there is a dropping off of participation, especially in physics and chemistry. This is not a new phenomenon and no evidence has been presented that it has worsened over the last decade. But the drop-off is stratified to some extent by SES measures, which also relate to prior attainment. As far as we can tell the situation is not unique to science. There is a role for schools and teachers in inspiring students to continue with study of science but the studies presented here only allow this role to be a small one. In general, students are not encouraged to continue with science unless they have been successful in previous stages faced with often very different interpretations of what science is. Is this what is intended?

If prior attainment in science (or indeed any subject) is used to determine future participation (and attainment), and because we know that SES and attainment are linked, then the situation we find is as expected. Science is seen as a hard subject post-16 and so whatever the benefits, human capital theory would predict low uptake. In addition, using a stratified and stratifying variable like qualification (ability, aptitude, attainment) to select students means that the student body will be stratified by SES. At age 16, the differences in attainment between social groups are no larger in science than in all subjects. But many other subjects do not require, or appear to require, such a high level of KS4 attainment in order to continue study.

It is not reasonable to expect science teachers to overcome this society-wide stratification in isolation. Clearly, if there is a school effect on aspirations the evidence strongly suggests that we must create as mixed a system as possible. Schools must not reinforce stratification even if they cannot do much about reversing it. This mix also applies to sex. There is no real evidence that separating the sexes leads to any overall gain (but this could be the subject of a series of teaching experiments). If the purpose of studying science is not merely to enter HE and become a scientist, then several other possibilities arise. Perhaps prior attainment should not be used. It is possible in the future that the routine use of this stratifying

variable will be deemed as unfair as selection by sex, class, ethnicity, sexuality, disability and age are now (all once deemed acceptable) (Walford, 2004). We do not allow discrimination by sex, ethnicity or class but we do allow it in terms of a variable that is stratified by sex, ethnicity and class. Why should one be denied the possibility of studying in the future a subject because one had not done very well at a similar sounding subject in the past?

Of particular relevance to the UK is the reported lack of specialist teachers, which might affect the quality of teaching. Yet, in England one of the biggest employers of those continuing to study science and maths post-16 is the teaching profession (Gorard et al. 2006) – teaching for a large part the next generation of teachers, and so on. Students can be put off future study of a subject by the repetition from earlier stages and rote learning at low levels (QCA 2004). Osborne and Collins (2000) sound the caution that modern curricula for science, with an emphasis on relatively straightforward undemanding tasks, such as recall and copying, present a lack of intellectual challenge which may have the opposite effect to that reported for the 1980s and 1990s, now appearing dull and unchallenging to some students. So, should one even have to continue study of science pre-16 if one can go back to it afresh post-16? Perhaps non-compulsion at an earlier stage of schooling will lead to greater interest later. Ironically, it is possible that making science a core subject, like mathematics, is at least partly responsible for its later stratification.

Acknowledgements

The authors would like to thank the Royal Society for funding the research underlying this paper, and our colleague Emma Smith for help in preparing the figures for Tables 1 and 2.

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