THE ROYAL SOCIETY

CELEBRATING 350 YEARS

Exploring the relationship between socioeconomic status and participation and attainment in science education

SES and Science Education REPORT

June 2008

twenty ten and beyond | 350 years of excellence in science

ISBN: 978-0-85403-699-8

The Royal Society would like to thank Sir Ewen Fergusson and the Gatsby Charitable Foundation for their kind support of this project.

This report includes commissioned work and views expressed at a seminar, and therefore does not necessarily represent the views of the Royal Society.

The Education team
The Royal Society
6–9 Carlton House Terrace
London SW1Y 5AG
tel +44 (0)20 7451 2500
fax +44 (0)20 7930 2170
email education@royalsociety.org

Further copies of the report can be requested from the above address or downloaded from the Royal Society's website at www.royalsociety.org/education

Cover Design by Franziska Hinz, London
Layout Design by Jo Moon, m:Design, London

Contents

Introduction

The UK education system should strive to ensure that all young people can be successful in science[1], and that those with motivation and talent should be able to achieve excellence. Where there is good evidence that some groups of young people are not getting sufficient opportunities for success, action needs to be taken. Investigations into the relationships between a young person's gender or ethnic background and their performance in science at school have identified key groups who appear to be at a particular disadvantage and have led to the implementation of supportive strategies. But the question of whether socioeconomic status (SES) is preventing some young people of talent achieving their potential in science remains relatively unexplored.

Changes in society, our economy, the school system and science itself have rightly raised questions about how well science fits into our broader aims for education. England has a state system of free education aimed at entitling all young people to high-quality teaching and learning regardless of their background and situation. Are we successful in this aim? The complexity of answering this question has generated a significant amount of debate among educationalists, policy makers and the science community over recent years.

Who is achieving and participating in science and who isn't? This apparently simple question is based on some highly disputed assumptions about how we divide society into groups, how we measure achievement and participation, and how we accept that many do not achieve or participate because their abilities and interests lie elsewhere.

Quite rightly the science community has looked within itself – at students and staff at universities and within the wider science-based workforce – for evidence of unequal opportunities. It is perhaps understandable therefore that the focus has been on the role of gender, and more recently ethnicity, in influencing a person's progress with and in science. In particular, evidence as to the underrepresentation of women in physics and physics-related subjects has led to a significant amount of attention being paid to developing a physics curriculum and style of physics teaching which could encourage more girls to engage with the subject. Studies on ethnicity have encountered more problems, not least because of changes with respect to classification, but also due to an unease in assuming a direct relationship between ethnicity and educational achievement.

The Royal Society has taken a keen interest in these issues for some time. In 2005 we commissioned a report on 'Science, Engineering and Technology and the UK's Ethnic Minority Population' from Paul Jones and Peter Elias at the Warwick Institute for Employment Research and in 2007 we embarked on a series of 'State of the Nation' reports aimed at collecting and analysing data on key indicators of success in science and mathematics education in the UK. From this work, and drawing on the significant body of research into inequality in education as a whole, we have often returned to one particular question: is SES preventing some young people of talent achieving their potential in science and science-related careers, and what can be done about it? This project therefore aimed to identify what evidence was available to help answer these questions and, where found, to assess the validity of that evidence as a basis for further action.

The issue of SES – or more precisely the issues of poverty and of social class – has never been fully explored in relation to science education. In England in particular, where our increasingly diverse school system undoubtedly differentiates some young people on the basis of previous attainment, location and ability to pay, it is perhaps surprising that relatively little reliable research has been done on whether these differences are having a notable impact on the outcomes of science education.

Is there any statistical evidence from primary data that those of lower SES are disadvantaged when it comes to achieving and participating in science? Is there any evidence in the research literature to explain any differences emerging from the data? What is currently of concern among today's young people, parents and teachers with regard to the opportunities science holds for them? To begin to answer these questions the Society commissioned Professor Stephen Gorard and

1 The word 'science' is taken to mean either combined science or the separate sciences as taught in schools and colleges. Where more precise definitions have been used in reported data, these definitions are made clear in the report.

colleagues from the University of Birmingham to analyse available datasets and review published literature, and Dr Stuart Bevins and colleagues from Sheffield Hallam University to undertake some focus-group work with pupils, parents and teachers from schools in different areas of affluence. Their emerging conclusions were discussed at a seminar attended by leading educationalists and the researchers' final papers are included in this report.

The objectives of the commissioned work were specifically to: probe available, relevant datasets for evidence of a link between SES and participation and attainment in science; search for evidence explaining any link by reviewing published literature, focusing on studies that are empirically grounded and that claim to make generalisations from their findings; and talk directly with young people, parents and teachers about their perceptions of this issue. The potential scope for this project was very large, hence the decision to restrict our analysis of data to English schools[2] and the main science subjects and qualifications.

The purpose of this project was to provide a starting point for more work in this area, not a finishing point. We hope therefore that the report is widely discussed in the science education and policy communities, some of the conclusions challenged and some of the recommendations taken on board by educationalists and policy makers. We would particularly welcome the views of stakeholders in other subject communities as the research suggests most of the issues revealed are not unique to science. The Society does not underestimate the complexity of this issue, nor the limits on how the education system can deal with some of the inequalities prevalent in our society today. However, we feel it is unacceptable to deny there is a problem, or reject any action simply because of the difficulties inherent in understanding and changing the relationship between socioeconomic disadvantage and educational achievement.

2 Whilst most of the data, particularly those relating to attainment, refer to students in English schools, data regarding post-16 participation in A-level will also include students in English sixth form and further education colleges.

Summary

1. This Summary draws from three commissioned papers published in this report, and highlights the authors' key findings as well as conclusions and recommendations emerging from an expert seminar. Much published research writing presents no new empirical evidence and a further substantial proportion does not describe the research in sufficient detail to allow a judgement to be made about its quality.

How are data on socioeconomic status (SES) measured and collected?

2. **Data on SES are measured and collected in a number of ways.**
SES is a measure of an individual's or family's relative economic and social ranking. A young person's SES may be constructed from a number of variables related to their family's income, parental education and occupation, or indicated by a proxy measure such as a young person's entitlement to Free School Meals (FSMs) or an indicator of deprivation in the local area. National data on SES are collected annually in English schools as part of the Pupil-Level Annual Schools Census (PLASC). Each young person's participation and attainment in national tests and qualifications such as GCSE and A-level are meant to be recorded in the National Pupil Database (NPD). The PLASC and NPD can be linked due to the use of Unique Pupil Numbers (UPNs) and therefore, in theory at least, national datasets hold a wealth of information about how young people from different socioeconomic groups perform in science education. The Higher Education Statistics Agency (in conjunction with UCAS) holds data on the HE subjects applied for and then taken by all first time undergraduates, contextualised by gender, ethnicity, UCAS tariff points and, where provided, parental occupation.

3. **Conclusive interpretation of data on SES is compromised by incomplete datasets, inconsistent definitions of variables and inadequate rigour in much reporting of analysis.**
There are significant difficulties in determining the existence and strength of any links between SES and participation and attainment in science at school and beyond. These include substantial omissions in existing datasets, and no widely agreed or enduring definition of SES that would enable subject tracking and data collection to be consistent over time and place.

What is the evidence for links between SES and participation and attainment in science among young people?

4. **There is strong evidence of a link between SES and attainment in science among 5 – 11 year olds, but the effect is less than in some other subjects.**
Figures indicate that there is a negative relationship between living in an area of deprivation and science attainment at Key Stages (KS) 1 and 2 (5-11 year olds) but that the effect is substantially less than in reading and writing at KS1, and in English and mathematics at KS2.

5. **At GCSE level, students from lower SES backgrounds are less likely to attain highly in science than those from higher SES backgrounds. This effect is seen in other subjects, but may be more persistent over time in science.**
There are clear differences in overall attainment as expressed by points scores in science at KS4 between students of differing SES backgrounds as measured by entitlement to FSMs, but these differences are not specific to science. Gaps in attainment between groups eligible for FSMs and those ineligible remained at around the same level between 2001/2 (when the PLASC was started) and 2005/6 (the latest year for which data are available).

Using the NPD and PLASC, the multiple index of deprivation (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) does not seem to explain much of the important SES variation known (by other analyses) to stratify attainment at KS4. Nevertheless, the general link between attainment and SES as assessed by deprivation of area of residence appears to have declined between 2001/2 and 2005/6 across all subjects, but remained at the same level for science.

6. **Physics and chemistry GCSEs are more likely to be taken by those from high SES backgrounds.**
   At GCSE, physics and chemistry as separate subjects are more likely to be taken by academically able students, especially middle SES males from independent schools. Combined, dual, single and general science, on the other hand, are studied more by lower-attaining students, girls and those from lower SES backgrounds. These patterns are likely to be due to a combination of individual and family choices, school-imposed choice criteria and guidance, and the availability of relevant expertise in specific schools.

7. **The Gifted and Talented programme may not be entirely successful in identifying young people from low SES backgrounds who have yet to reveal their ability in science.**
   If missing data is ignored, 7% of pupils identified as Gifted and Talented (G&T) at KS4 are eligible for FSMs, which is much lower than the KS4 population figure of 13%. Considering only those pupils identified as G&T at KS4, the attainment gap between students living in poverty and the rest is slightly larger in science than it is in all subjects combined.

8. **At A-level the link between attainment in science and SES is weaker than it is at GCSE level, mainly due to lower uptake of science subjects by post-16 students of low SES background.**
   Since students at A-level or equivalent are generally selected on the basis of high prior attainment, by themselves and/or by their school or college, it is not surprising to find that those from low SES backgrounds are less likely to continue into science and/or mathematics at A-level than others. At A-level the link between science and SES (as measured by FSMs) is smaller than it is at GCSE. The situation is not unique to science and while there are commonly agreed barriers to participation in any post-compulsory education, such as financial situation, overcoming such barriers may be necessary but not sufficient to encourage participation.

9. **Undergraduates studying science at university, particularly physical sciences, are more likely to be from high SES backgrounds, though the proportion of those from low SES social groups is increasing slightly.**
   The SES status of applicants to university remains largely unchanged over time (from the mid-1990s to 2005) with a slight increase in the proportion from low SES social groups, and this applies to each of the main groups of science subjects offered at university. In general, those who apply for and obtain places in science subjects, but not mathematics, have a higher SES than the general student population. Physics applicants and students tend to have a higher SES background than those studying biology or mathematics. The pattern for acceptances is the same as for applicants in terms of social and occupational class from 1994 to 2005, and so it seems that the admissions process as a whole does not lead to any further stratification of the student body.

What might be causing SES to have an effect on a young person's success in science education?

10. **The potential factors linking SES and participation and attainment in science are complex.**
    Analysis of data from the Programme for International Student Assessment (PISA) has shown the complexity of factors all significantly related to science, mathematics and reading achievement: student characteristics (gender, 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); family background (number of books at home, parents' educational level and degree of geographical isolation of home); instruction time; and teachers' gender, educational level and years of experience.

11. **Home background and family income are related to achievement in science across most countries but it is rarely clear if the situation is different from any other subject.**
    Students from higher socioeconomic backgrounds tend to obtain higher marks and examination grades irrespective of the subjects studied, and analyses of international tests like TIMSS (Trends in International Mathematics and Science Study) have suggested that home background is a determinant of achievement in science (and numeracy and literacy) across most countries. Low family income negatively relates to students' academic performance in mathematics and science. However, it was usually not made clear in any of the literature reviewed whether the situation is the same, better or worse for the sciences compared to any other subject areas. There is nearly always a missing comparator. In addition, few studies include

prior attainment in their analyses, or in their purported explanation of SES differences.

12. Parental education and involvement in their children's education may be key influences on young people's achievement.
A review of evidence on the impact of parental education on early life suggests that key influences on a child's educational attainment in the early years include parental education and income. One explanation is 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 the focus groups studied for this report, parental influence on how pupils perceive and engage with science was cited by all pupils as having a significant impact upon them. However, only a small number of pupils stated that their parents become actively involved with their homework through discussion of topics, specific knowledge or questioning. Pupils from three schools in areas of deprivation indicated that their parents place more emphasis on English and mathematics achievement than on achievement in science.

13. Parents living in areas of deprivation are more likely to perceive SES as a barrier to achievement in science.
Parents consulted as part of this project from the more affluent areas stated that they believe social status is a barrier neither to achievement in school nor to career aspirations. The majority of parents from areas of deprivation perceived the issue differently. They felt that young people who reside in more affluent areas were far more likely to go into a scientific career than those from areas of deprivation. All parents viewed science as having high status, although this was particularly emphasised by parents from areas of deprivation.

14. Patterns of discouragement and engagement among parents may be replicated among their children's generation.
Parents from areas of deprivation perceived school science as a subject that only the most able achieved in. Many female parents had themselves either been discouraged from choosing the science subject they wanted to study at 16 or had formed an opinion that physics and chemistry were subjects for boys. A small number of pupils whose parents worked in science-related fields did state that their parents would like them to opt for science-related higher education studies. Pupils from schools in more affluent areas said that they engage more in discussion with their parents about careers and/or post-compulsory school study than do pupils from schools in areas of deprivation. The majority of pupils from the schools in the more affluent areas said that their parents expect them to attend university and enter a professional career.

15. Poor language skills can disadvantage science learners and in some cases may be associated with low SES groups.
Although mathematical and language skills are relevant contributory factors in predicting the choice of science subjects in secondary education, cohort studies suggest that these skills are themselves predicated on gender and family composition variables related to SES. In our focus groups the large majority of teachers from schools in areas of deprivation stated that language difficulties are a definite barrier that restrict clear communication between teacher and pupil, as well as placing an emphasis on pupils concentrating on English language studies above science subjects.

16. It is not clear if young people from low SES backgrounds have more negative attitudes to science.
The link between attitude and SES is unclear in the literature and cannot fully explain the pattern of participation in science and SES. The limited exploration undertaken for this project of the attitudes of pupils from schools in areas of deprivation suggested they had a less positive response to school science than their more affluent counterparts. The large majority of pupils from schools in areas of deprivation stated that school science is generally 'not relevant' to them and their daily lives. In particular, they felt that physics is 'too hard' and 'boring'.

What can schools do to improve attainment and participation in science among young people of low SES background?

17. Comprehensive school systems tend to have smaller attainment gaps between rich and poor.
International studies show that comprehensive, equitably-funded school systems tend to produce not only better outcomes overall but also smaller attainment gaps between rich and poor, and between the highest and lowest attainers. Systems with early tracking of students by ability, with high levels of fee-paying provision, with covert selection on the basis of faith or curricular specialism, and/or with differential local funding arrangements tend to have stronger links between SES and attainment than do more egalitarian ones.

18. Smaller class sizes may reduce the link between SES and attainment.
There are studies and reviews suggesting that the organisation of schooling can make some difference to reducing the link between SES and attainment, with a suggestion that decreased class size can mitigate against the effect of SES (as measured by eligibility for free or reduced cost school lunch).

19. Some parents perceive differences between schools in their support for science.
In our focus groups, parents from areas of deprivation felt that independent and/or private schools have better

quality laboratories and a smaller pupil-teacher ratio which enables teachers to devote more time to individual pupils. Parents from more affluent areas suggested that if the school has a science specialism and/or the science department demonstrates enthusiasm towards teaching and learning science, then pupils will be positively influenced by the ethos of the school and/or department.

20. Science teachers would like more freedom, particularly in relation to practical work, to engage disaffected pupils in science.
The majority of teachers participating in this project's focus groups stated that the National Curriculum and associated testing largely inhibit them from utilising teaching and learning approaches that involve exciting and creative science, particularly practicals/investigations. Teachers from schools in areas of deprivation said that they used practical sessions as an opportunity to motivate and engage those pupils who generally demonstrate disruptive behaviour and/or are switched off from science.

21. Science teachers need a range of pedagogies, good specialist knowledge and a strong bond with their pupils in order to overcome negative attitudes and/ or poor attainment.
The availability and skill of teachers are key factors in the quality of science teaching and learning. In the focus groups for this project, pupils in more affluent areas were of the opinion that science should be their teachers' 'passion' and that teachers should have strong subject knowledge. Pupils from areas of deprivation placed emphasis on teachers being 'nice' and on strong pupil-teacher relationships. These pupils were more concerned that teachers demonstrate high levels of empathy and listening skills than subject knowledge and passion for the subject. Participants in the seminar held as part of this project raised the issue of the lack of specialist science teachers – those who have a deep subject knowledge and the ability to inspire young people with it – and the way they are unevenly deployed between and within schools as a potential factor which might reinforce disadvantage in some schools, and for some classes, when studying physics and chemistry.

What conclusions and recommendations can be drawn from the work commissioned for this report?

22. Evidence for a direct causal relationship between SES and participation and attainment in science is inconclusive.
None of the studies reviewed was able, as a result of their design, to test the causal model between SES and participation and attainment in science. In spite of the proliferation of research in this area, numerous theories still abound and no conclusive evidence has been put forward as to how exactly SES impacts on students' academic achievement, and even less so on their uptake of science. Some studies have attempted to explain the relationship between SES and specific subject choice, but may have been compromised by *post hoc* rationalisation of choice once this has been revealed.

Focusing only on attainment in national tests limits the depth to which one can explore the impacts of SES on achievement in science, and ignores alternative measures of successful learning in science that come from the assessment and perceptions of teachers, parents and the pupils themselves, as well as alternative, informal environments where science learning takes place.

23. The main barrier to participation in science by young people of low SES is poor prior attainment.
Some authors suggest that schools are not very good at breaking the link between SES and attainment; yet while it may be unreasonable to ask them to break it, it is certainly reasonable to expect them not to strengthen it, and preferably to weaken it. Schools using criteria such as capability, aptitude and attainment, particularly if applied rigidly, to select students will inevitably be stratifying the student body by SES as these criteria are themselves all linked to SES.

The purpose of the G&T programme is to identify students with capability and potential regardless of their origin or current situation, whose ability may not be demonstrated best through conventional attainment tests. The results presented in this report suggest that either these students are disproportionately not in the poorest part of society or the programme is failing to identify them correctly, possibly both. Further investigation should be undertaken into the G&T programme and particularly its role in increasing opportunities in science, and perhaps other subjects, for young people of low SES.

As science is seen by many as a 'hard' choice at A-level or equivalent, it is often those who have demonstrated the most ability in the sciences who take them post-16. Whether this is the choice of the individual or a selection criterion imposed by the school or college, it means the most useful statistical predictor of participation post-16 is attainment at age 16, especially in science and mathematics. The traditional sciences, unlike psychology for example, are not taken as new subjects but as subjects in which the student must not have failed previously. Offering young people from low SES backgrounds additional financial support, while valuable in itself, may not help greatly to increase their uptake of science and mathematics post-16.

The implications of reducing or even eliminating selection on entry to an A-level in science based on prior attainment could be investigated, especially if any schools and colleges innovating in this area were identified and their practices and results explored in more detail, particularly the potential for scaling up to a larger study of open access.

While this project was limited to the traditional sciences at A-level, further work might consider other science subjects and qualifications, non-science subjects and post-compulsory qualifications taken in other part of the UK[3].

24. It is important to recognise and learn from schools and colleges that are already successful in enabling young people from low SES backgrounds to be high attainers in science.
Seminar participants were keen to note that, while attention was focused on any overall negative association between SES and science attainment and participation, there are of course instances when schools and teachers are successful in reducing the importance of this relationship. Good practice and interventions, such as out-of-classroom activities, parental involvement and after-school clubs, are too rarely evaluated and communicated beyond the school involved. Small amounts of investment might be best made in identifying these instances and enabling the practitioners involved to share their experiences more widely.

While further high-quality research in this area should be encouraged, it would also be useful to identify those schools and colleges that consistently produce numbers of young people who achieve and participate in science despite low SES. The Secondary National Strategy could be asked to begin identifying a small number of institutions whose good practices could be shared with other schools and colleges through case studies and with the support of local authorities.

Similarly, there are a number of schemes and activities operating within formal and informal education whose objectives include promoting science participation among students from underrepresented backgrounds. Organisers of and participants in these schemes could be brought together to discuss their experiences and successes in order to extract general principles and promote these more widely.

25. Innovations in science teacher pedagogy hold significant potential in engaging disaffected learners.
A promising line of research from the 1950s showed, largely via experiments, that science teaching methods can impact on students' interest and hence continued participation in science at higher levels especially for low SES students. There is a need to examine, using rigorous experimental methods, the extent to which specified teaching methods in science and mathematics can result in post-compulsory participation in science, especially for students of low SES.

3 Issues of sample size in terms of limited entry into some qualifications would need to be considered.

26. Research into young people's attitudes to science might usefully focus more on the impacts and less on the causes of these attitudes.
Most studies of attitudes to science do not look at the link between attitudes and subsequent take-up. A problem with these studies on students' attitudes towards science is the measurement of attitude itself. There is no single measure. It is not always clear whether the attitude is to science in society, scientific progress, science in education or the students' own participation in non-compulsory science. Research into young people's attitudes to science, particularly among pupils of low SES, should focus less on the causes of and differences in attitudes and more on how those attitudes relate to revealed participation and attainment in science.

27. The attitudes and experiences of parents appear fundamental to young people's motivation to achieve in science.
Parents' attitudes to science qualifications and careers are understandably shaped by their own educational experiences and occupations, as well as the world around them and their children. Parents of young people attending schools in areas of deprivation need to be given positive encouragement and more support to engage in their children's science education – from helping with homework to discussing careers – in order to overcome some of the barriers presented by the association of science with exclusivity.

Parents need greater confidence in the resources and support for science in their local school. While all the parents involved in the focus groups viewed science as having high status, this was particularly emphasised by parents from areas of deprivation, who nevertheless felt that schools from areas of more affluence are more likely to enjoy better facilities in terms of school laboratories and equipment. Also emerging as a key issue is a lack of precise and clear information about scientific careers.

It has been suggested 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 a kind of lifelong attitude to learning – a negative learner identity. While this report focused on empirical research, other research exists which has explored these issues in more detail, including social class mediation of identity, and could yield valuable insights into a complex issue.

28. Interventions targeting young people on the basis of SES may be limited if they are science-specific.
The gaps in attainment and participation between socioeconomic groups are not unique to science and therefore interventions targeted at the curriculum and/or pedagogy may be limited in their impact if targeted only on science. Indeed, the findings from the focus groups held to inform this report indicate that, while participants described some issues relating to SES as having an influence on attainment and participation, SES in itself was not seen by young people as being of importance in this regard. Moreover, it was clear that the large majority

of pupils and parents do not differentiate science from other subjects in this respect.

29. **The quality of research undertaken regarding SES and science education, and the way it is reported and communicated, could be much improved.**
As with any review, problems were encountered in identifying high quality research. The estimate presented here is that only around one third of the pieces identified was both comprehensible and based on new empirical research. The majority of even these displayed significant flaws. Care needs to be taken when modelling, via regression and related techniques; causation cannot be tested in this manner, and so mention of effects, impacts, influences and so on in reports often goes beyond what is warranted by the data.

    Every analysis covering patterns of participation makes, even by default, a number of decisions and another analyst might quite reasonably make a different set of decisions. Unless these decisions and their rationale are clearly reported there is a danger that debates apparently about issues of substance are in fact mainly about differences in analysis. If these difficulties are not acknowledged by analysts the quality of their conclusions is jeopardised. Reports should state how many models have been run, and how much the substantive findings could differ if another model had been selected for publication. In addition, all reports should explicitly state, where relevant, the order of entering variables into a multivariate model, the reason for choosing that order, and the likely impact on the substantive findings of using a different order.

    The advantages and disadvantages of any indicator of SES used in data collection and analysis should be critically examined and reported. Missing cases, values and variables (where known) should be clearly reported and their potential influence taken into account when drawing conclusions. Differences, patterns and trends need to be clear, substantive and reasonably strong (of sufficient effect size) to be of any practical importance. Analysts and researchers must discuss the level of confidence and the strength they claim for any of their conclusions.

    Even if research into this issue is improved and published in a more rigorous manner, its impact on policy makers and practitioners depends a great deal on closer and more genuine engagement with these groups.

30. **Further analysis of existing national data could give more useful information on SES and science attainment.**
Data for attainment at KS3 were not available for this project, and a more complete analysis of such data might assist in a better understanding of the changes in the relationship between SES and attainment in science through Key Stages. For example, the transition from primary to secondary education involves a change to subjects being taught in more rigid slots by different teachers often in ability groups, a situation which might be expected to increase gaps in science attainment and therefore could be a target for intervention.

    Nevertheless, there is a tendency among analysts to dredge existing data for patterns and few of the claims made about science in the research reviewed were contextualised to show that the situation was specific to science. The limited scope of this project meant that most comparisons were made between science and 'all subjects'; any further analysis should compare science to other individual subjects such as mathematics and English. In studies looking at attitudes, attainment and participation, those not taking science should be routinely included in studies as a comparison. Perhaps most importantly, ideas from in-depth, observational and modelling studies must be tested via experimental designs.

The Royal Society fully acknowledges the complexity of the issues, but encourages all those in the science education and policy communities to work together to make meaningful progress towards greater equality across socioeconomic groups.

The impact of SES on participation and attainment in science: an analysis of available data

Stephen Gorard, Beng Huat See and Emma Smith
University of Birmingham

1. Introduction

This brief report represents a response to an invitation from the Royal Society to undertake some preliminary work on the impact of young peoples' socioeconomic status (SES) on their participation and attainment in science. Its purpose is to describe and illustrate a range of existing sources of large-scale data that can be used to relate measures of SES to participation and attainment in science for students aged 14-19. The review describes some of the available sources of data for analysts concerned to investigate SES and science. It then illustrates the kinds of analyses that can be conducted with some of the most useful of these datasets, and draws some tentative conclusions about the patterning of science participation and achievement over time and between SES groups[4].

2. Sources and uses of data

The pupil-level annual schools census (PLASC) takes place in January of every school year from 2002 onwards, in England (and Wales). It extends the annual school(-level) census collected previously using many of the same variables. These include eligibility for free school meals (FSMs), ethnicity, sex, first language, whether a child is in care, whether they are identified as gifted and talented, and whether they live in a super output area of high multiple deprivation. 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 illustrative analyses below, we use FSM and multiple deprivation as proxy indicators of SES, and we use the incomplete records of gifted and talented to see to what extent there are low SES gifted and talented students not taking science. Since devolution, the records apply only to England. Each cohort consists of around 650,000 students. For Data Protection reasons, we have not been provided with information on children in care.

FSM is an indicator of a student living in a family with an income deemed to be below the poverty line (receiving family income support, for example). It applies to around 12 to 20% 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 be rare (Gorard et al. 2003). The much more substantial gap is between those eligible for and those taking the free meal. This indicator has the advantages in comparison to family occupation or 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 then this is not much of a 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. The local areas (such as wards) 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 three main problems. First, they involve adding together figures for housing, education, 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. But 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. More people with no educational qualifications live in areas where more people have no educational qualifications etc. However, these indicators can be used to flag up potentially deprived students.

Whether a student is flagged as gifted and talented is a far from rigorous procedure. Not all schools have identified any 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 a 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 determine whether this is related to SES.

The national pupil database (NPD) uses the same student identifier as PLASC and over time, 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. 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

4 A fuller report is available from s.gorard@bham.ac.uk

their points score in sciences. These are used in the illustrative analyses below. The points score is an arithmetic device based on imagining that examination grades are numeric and on an equal-interval scale. In using these, and any other existing data, we do not endorse any such questionable assumptions.

For England (and Wales), the PLASC/NPD and Edubase (database of the context and characteristics of all education providers) combination is almost certainly the best source of information on science and SES (in terms of the limited indicators available). They effectively subsume the data available from the Qualifications and Curriculum Authority (QCA) and examination providers on subject entry and qualifications, and provide a larger number of contextual variables as well. There is no single source of exam entry data (Wright 2006). Subject associations often collate some of this data. The most complete sets appear to be the Examination Board Data from the Joint Council of Qualifications since 2001, and the UK Statistics of Education, Statistical First Release. In general, the most complete data for subjects has fewest contextual variables. There are changes over time in measuring and definitions, in the timing of exams, and in the ease of separating all exam entries and those for students only of a specific age. There is also a danger of double-counting across boards of examination.

Other useful regular reports include Department for Children, School and Families (DCSF) 2007: National Curriculum Assessment, GCSE and Equivalent Attainment and Post-16 Attainment by Pupil Characteristics, in England 2006/07. This Statistical First Release (SFR) provides information showing attainment for 2006/07 broken down by pupils' characteristics, namely gender, ethnicity, eligibility for FSMs, special educational needs (SEN) and English as an additional language (EAL). The SFR will include data for Key Stage 1 and 2 National Curriculum assessments, GCSE and equivalent achievement and Post-16 achievement and is provisional. Data for Key Stage 3 National Curriculum assessments are not available and therefore will not be included.

Also via DfES (as it was at the time) there are tables showing achievement at Key Stages 1, 2, 4 and 5 by Government Office Region, IDACI, ACORN category (wealthy achievers, urban prosperity, comfortably off, moderate means and hard pressed) and Degree of Rurality of Pupil Residence. For Key stages 1 and 2, data available is % achieving Level 2 & above and Level 4 & above respectively for reading, writing, mathematics and science. Key stage 4 data includes % achieving 5A*-C, 5A*-C including mathematics and English, and Key Stage 5 data includes average point score per candidate by Government Office Region, IDACI, ACORN category and Degree of Rurality of Pupil Residence.[5]

The Higher Education Statistics Agency (in conjunction with UCAS) holds data on the HE subjects applied for and then taken by all first time undergraduates. This is contextualised by sex, ethnicity, UCAS tariff points, and parental occupation. It is perhaps the largest complete dataset to contain parental occupation. However, so many values are missing in this field that not knowing the parental occupation of a student is the single largest sub-group in the database (Gorard et al. 2007). The introduction of means-tested bursaries may lead to better information, over time, about those from the lowest income backgrounds. We present an illustrative analysis of trends over time in the SES of students applying to science and other subjects in the UK.

The Programme for International Student Assessment (PISA) is an internationally standardised assessment originated by OECD that was jointly developed by participating countries and is administered to 15-year-olds in schools every three years (2000, 2003, 2006 and now 2009). Each test involves proficiency in science (specifically scientific literacy) but in some years (2006) science, as opposed to language (2000) or mathematics (2003), is given greater prominence. PISA has 62 countries signed up to take part, and the tests are typically administered to between 4,500 and 10,000 students in each country. However, response rates vary across countries and over time. England was excluded from the 2003 analysis due to not reaching a threshold for responses. But even where countries are included the differences in response rates can far outweigh the differences in test scores. PISA 2006 provides a profile of student engagement in science which can be compared with the more usual profile of student performance in science. However, in addition to concerns about response rates there are concerns about the validity and international comparability of SES measures which are hard enough to define in one country. One of the items with the highest correlation with test scores is the (estimated) number of books in each student household. This is a better predictor of test score than parental occupation. Another concern with PISA lies in the validity of the indices constructed from individual items to create scales such as self-efficacy, general interest in science, and instrumental motivation. They are based upon

5 http://www.dfes.gov.uk/rsgateway/DB/SFR/s000759/SFR38_2007_Additional_Tables.xls

an assumption of random variation in errors in responses to each item making up the scale. The use of such constructs is widespread. Yet it can be shown that if the errors are random then the scale must be less accurate at measuring the underlying variable than a single item would be.

The ongoing Third International Mathematics and Science Study (TIMSS), run by the IEA, measures cognitive skills in mathematics and science, as well as the family background and educational settings of individual students. For more information about the design, development, implementation and analyses of TIMSS, see http://timss.bc.edu/.

The CEM Centre at Durham University runs YELLIS (and ALIS). This is a baseline assessment test for Year 10 and Year 11 students. Their value-added approach claims to provide fair comparisons of students, as it is a test of ability rather than achievement, and fluency rather than knowledge. For more on this, see http:www.yellisproject.org/RenderPage.asp?LinkID=11525000.

There is no perfect existing dataset to be used for analysing the link between SES and science at school and beyond. Differences in measures, definitions, scope and completion rates over time and place make it difficult to combine different datasets to try and overcome their limitations in isolation. The growing NPD/PLASC dataset is probably the best single source, and most of its drawbacks are inherent in research of this kind. However much care is taken in assembling the datasets, not all cases are included, not all included cases have values for all variables, and their collection depends on the actions of thousands of individuals at classroom, school and authority level. Not all cases can be matched across NPD and PLASC. The biggest drawback in design is the absence of a direct measure of parental occupation or education. However, even if a variable for parental occupation were to be included, the evidence from other official datasets is that it will contain a high proportion of missing values for a field that requires considerable judgement to code.

To decide whether a particular SES group is proportionately represented in studying science may sound like an easy task to an outsider. We simply define the SES group, define representation in science, measure the prevalence of the group in science and in the population, and divide the first by the second to see whether it is close to one. However, in practice these steps are not easy. There is no definition of SES that could be used by different people in different places at different times to mean the same thing. The categorisation of social groups by occupational class or ethnicity is a matter of judgement over which even experts disagree (Lambert 2002, Lee 2003). The categories themselves are somewhat arbitrary (Gorard 2003). A key problem in examining trends in social categories over time is that the variables collected, or the coding used for the same variables, also change so that it is often difficult to make genuine and straightforward comparisons over time or between groups. There have been moves away from classifying the occupational backgrounds of students in terms of skill or prestige. The significance of the categories themselves such as the meaning attached to being in a non-manual occupation changes with their prevalence and through historical/economic development.

Even defining the population is not easy. Does it include all young people of a certain age, or merely those who are deemed qualified for further study (i.e. those who feasibly could have continued study)? Is the base figure for A-level study those studying all A-levels, those studying anything at all, or all people of a certain age? As with all of the analytical decisions to be made, different answers to these questions will lead to very different conclusions. Is the population that for one home country of the UK, such as England, or the UK as a whole, or even the EU, where patterns of participation are very different? If domicile is used to select those in England or the UK, is it the area of residence of the student, or of one or both parents? If we exclude overseas students (on some basis), then the population census of the UK provides the most complete coverage to assess the characteristics of the relevant population. Despite it being a legal requirement, not every household takes part, not everyone is in a household and not everyone who takes part responds to the SES and ethnicity questions even when asked them. The categories used for the SES and ethnicity questions are not the same between years such as 1991 and 2001, nor are they always the same as those used in other large data sets – such as the records held by the Higher Education Statistics Agency (HESA), the Universities and Colleges Admissions Service (UCAS) database of applicants or the annual schools' census. The exam boards do not collect data on socioeconomic status. This makes it difficult to track trends over time and to use the population figures as the denominator in the final step of this analysis.

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 HESA). In fact, the unknown cases considerably outnumber all 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 per cent of first year undergraduates were unclassifiable in terms of occupational background according to HESA figures.

The high proportion of missing cases in an analysis using this 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. Some studies have attempted to overcome these limitations by using postal code data with Geographic Information Systems (GIS). However, these analyses are still limited by the incompleteness of the census. There is the added problem of the availability and accuracy of the home post codes of students. For example, only 47 per cent of Welsh-domiciled students in 2002/03 had valid postcodes and even this figure depends on some contestable assumptions about the nature of domicile. Additionally, analysts are still faced by the fact that they are using GIS so that they can associate individuals with the average background characteristics of the area in which they live. Students are thus assumed to have the same occupational background as the modal category in the area. If the area is small, then the results are more affected by patterns of missing data. If the area is large, then the modal category may not do justice to the variability of the measure. It is not clear that this approach helps at all.

So the analyst is faced with a judgement about whether there is indeed under-representation of specific social groups in science, and of whether the proportionate participation of these groups is far enough below one (1) to trigger a search for the cause. The traditional panoply of statistical analyses, such as significance tests, confidence intervals or standard errors cannot help here because these address only the sampling variation due to chance (Gorard 2006a). There is no simple answer to these analytical problems, and it is important that readers are aware of the deficiencies even in a simple consideration of whether occupational groups are proportionately represented in science. Every analysis covering patterns of participation must make, even by default, a bewildering number of decisions and every analyst might quite reasonably make a different set of decisions. Unless these analytical compromises are clearly reported there is a danger that debates about what is happening will be misinterpreted by commentators as being about issues of substance whereas they are merely about differences in analytical decisions. Just as importantly, too much emphasis may be placed on small differences between groups relative to the missing data.

3. Illustrative analyses

Using some of these sources, we present some example analyses. We have tried to make the tables below easy to read. 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 100% due to rounding.

Key Stages 1 and 2 (KS1 and KS2)

Table 1 show that there is a small negative relationship between living in an area of deprivation and the KS1 results in all three core subjects. A very similar picture appears for those attaining level 4 or above at KS2, as shown in Table 2. The differences between the results of the most and least deprived areas are relatively small (perhaps because of the threshold effect at levels 2 and 4). What is more noteworthy is that the attainment gap (calculated as the difference between two scores divided by their sum, see Gorard et al. 2001) 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%) and mathematics (14%) at KS2. This is largely due to higher scores among poorer students in science rather than lower scores among richer ones. The same is true for mathematics (7%) at KS1. Insofar as these threshold figures are useful, they suggest that SES is related to attainment from very early in schooling, but makes less of a difference to science attainment at KS1 and KS2 than in most other subjects.

Table 1 Key Stage 1 results 2007, percentage reaching level 2 or above, England, by IDACI

IDACI decile	Reading	Writing	Mathematics	Science
0 - 10% most deprived	73	68	83	80
10 - 20%	77	72	85	83
20 - 30%	79	75	87	85
30 - 40%	82	79	89	88
40 - 50%	85	81	91	90
50 - 60%	87	84	92	92
60 - 70%	89	86	93	93
70 - 80%	90	88	94	94
80 - 90%	91	89	95	95
90 - 100% least deprived	93	91	96	96

Notes: Includes pupils with valid postcodes only. Income Deprivation Affecting Children Indices for each SOA in England.

Table 2 Key Stage 2 results 2007, percentage reaching level 4 or above, England, by IDACI

IDACI decile	Eligible pupils	English	Mathematics	Science
0 - 10% most deprived	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 - each SOA in England is given a score between 1 and 32,482,1 being the most deprived.

Key Stage 4 (KS4)

Table 3 shows that there are 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 of differing backgrounds. Females do better than males, for example. However, these differences are no larger than and often much smaller than the differences for all subjects. Whatever the problem is, leading to differential attainment by social, ethnic and economic groups, it is certainly not one that is specific to science.

Insofar as it is possible to compare scores over time, given the inevitable changes in measuring, these gaps between sub-groups remain at around the same level as they did in 2001/02 when the PLASC was started (Table 4). In 2002, the achievement gap between FSM and non-FSM students in the highest point score attained in science was 17%. In 2006, the

Table 3 Mean capped points score, all students, KS4, England, 2005/06

	All subjects	Science subjects
Male	338	33
Female	378	34
White British	360	34
Chinese	455	41
Gipsy/Romany	146	14
Non-FSM	373	35
FSM	266	25
"Gifted and talented"	501	46
Not "Gifted and talented"	308	33
Overall	359	34

Source: NPD/PLASC

Note: the points scores are derived by imagining that grades can be aligned isomorphically with real numbers. The points allocated to grades vary over time. 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.

Note: the points are capped in the sense that they represent the total of the best eight scores at GCSE or GSCE equivalent (adjusted for dual or treble awards). This is used by DCSF so that the results are not unduly influenced by school and individual entry patterns. So, the overall average is just above eight C grades at GCSE.

Table 4 Mean uncapped points score, all students, KS4, England, 2001/02

	All subjects	Science subjects
Male	33	4.3
Female	37	4.4
White British	35	4.4
Non-FSM	37	4.5
FSM	25	3.2
Overall	36	4.5

Source: NPD/PLASC

Note: There are two crucial differences between the the points scores here for 2002 and those in Table 3 for 2006. These differences are in the data as held by DCFS. They are not an analytical choice. The scores are uncapped in the sense that, where students take more than eight GCSEs or equivalent all are counted in the total. A score of 8 has been allocated to an A* grade, 5 to C and 1 to G grade. Thus, the average science score is equivalent to a grade D at GCSE, as in 2006, but the overall scores are lower (above E grade on average assuming eight GCSEs taken).

achievement gap for the score in science subjects (and so not the same indicator) was still 17%. As is shown later, this 16 to 17% between FSM and non-FSM is remarkably constant both over time and across all subjects.

Using NPD/PLASC, the correlation between the multiple index of deprivation and capped points score is -0.27 for 2006. This is an effect size of only 7%, which suggests that the index of deprivation is not picking up much of the important SES variation known to stratify attainment at school. The correlation between deprivation and KS4 science points score is -0.31. In 2002, using slightly different points scores the correlation between overall points scores and deprivation was -0.34, and between science scores and deprivation it was -0.32. If these differences are considered to be meaningful over time, then the general link between attainment and SES as assessed by deprivation of area of residence has declined, but remained at the same level for science. An alternative comparison would be between science and mathematics or English, and this analysis might be worth pursuing further.

Table 5 shows the same overall patterns as Table 3. 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,

Table 5 Percentage of students achieving A* grade in a science subject, entrants, KS4, England, 2005/06

	Double-award	Physics	Chemistry	Biology	Mathematics
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
Non-FSM	3.5	1.1	1.0	1.0	3.9
FSM	0.6	0.1	0.1	0.1	0.6
"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
Overall	3.7	1.6	1.6	1.5	4.4

Source: NPD/PLASC

Note: 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 the 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.

Table 6 Achievement gap in capped points scores, FSM and non-FSM students, KS4, England, 2005/06

	Non-FSM	FSM	Gap
G&T all subjects	505	451	5.6
All students all subjects	373	266	16.7
G&T sciences	46	40	6.9
All students sciences	35	25	16.7

Source: NPD/PLASC

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. Single award science is omitted here as the numbers involved are very small, and less than 0.5% of entrants achieved an A* grade. Mathematics is included as a comparison. The results for mathematics are closer to double-award science, but generally higher for all sub-groups. 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. 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. Gorard et al. (2001) show that the attainment gap tends to be greater at the highest levels. If we can describe the difference as caused by underachievement, this underachievement is almost non-existent at low levels of attainment and almost entirely due to differences at high levels.

Ignoring missing data (around 130,000 cases have one or both FSM or G&T values missing), 7% of G&T are eligible for FSMs, which is much lower than the Key Stage 4 population figure of 13%. Of those eligible for FSMs, 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 3. Two points emerge clearly from Table 6. 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 3 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.

Table 7 Percentage of students taking science and mathematics, KS5, all entrants, England, 2005/06

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

Source: NPD/PLASC

Note: Science includes electronics, environmental science, geology and computer science. Psychology could be added to these figures.

Key Stage 5 (KS5)

Around one fifth of KS5 students (or around 17% of the age cohort) study at least one science or mathematics subject, and most of these study both mathematics and more than one science (Table 7). Since students at A-level or equivalent are generally selected on the basis of high prior attainment, by themselves and/or by their school or college, it is not surprising to find that those from low SES backgrounds are less likely to continue into science and/or mathematics at A-level than others. The link between science and SES (as measured by FSMs) is smaller than it is at GCSE.

Those taking mathematics or science in any combination have, on average, higher prior attainment scores than other students taking A-levels or equivalent (Table 8). In addition, they go on to gain considerably higher KS5 scores than other students.

The correlation between the multiple index of deprivation and total QCA points score is -0.21, an even weaker link than at KS4. While this is likely correct in being smaller than at KS4 (selective effect), an effect size of 4% is not sufficient to explain the patterning of results by SES. Whatever the index of deprivation is measuring it is not SES as traditionally conceived in the sociology of education, nor on the scale of the differences illustrated in Table 9.

Table 8 Prior and post attainment points scores, KS5, all entrants, England, 2005/06

	Total prior attainment points	Total QCA points
Science	484	844
Not science	427	663
Mathematics	487	925
Not mathematics	434	674
Science or mathematics	482	848
Neither science nor mathematics	424	648

Source: NPD/PLASC

Note: New QCA points based on A-level scores and equivalents

Table 9 Percentage gaining A grade at A-level, all KS5 entrants, England, 2005/06

	Biology	Physics	Chemistry
Male	1.5	2.0	1.9
Female	2.2	0.5	1.7
White British	1.8	1.2	1.5
Chinese	5.3	4.6	6.6
Gipsy/Romany	0	0	0
Non-FSM	2.0	1.2	1.9
FSM	0.7	0.4	0.6
"Gifted and talented"	5.4	4.1	5.5
Not "Gifted and talented"	1.6	1.0	1.5
Overall	2.0	1.2	1.9

Source: NPD/PLASC

Note: figures for human biology and single award science are too small to analyse, and less than 0.5% of candidates gained an A grade.

Higher Education (HE)

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). The greatest change over time has been the growth in number of cases whose class is not known (Tables 10 and 11). This phenomenon has been remarked before (Gorard et al. 2007). In addition, over this period of growth in the number in HE, any small changes towards a more balanced class took 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 would need to be placed against the background of changing class structure in the relevant population (whatever we decide that is).

This pattern of little change over time, but a slight increase in the proportion from lower SES groups, also applies to each of the groups of science subjects offered at university (here we focus on Biological, Physical and Mathematical Sciences – Table 12 onwards). In general, those who apply for and obtain places in science subjects but not mathematics have a higher social class profile than the general student population. Physics applicants and students tend to have a higher SES background than those studying biology or mathematics. From 1994 to 2005 the number taking physical sciences has declined while the number taking mathematics and biological sciences has increased.

Table 10 Percentage of all HE applicants by social class, UK, 1994-2001

	1994	1995	1996	1997	1998	1999	2000	2001
Professional	14	14	14	12	12	12	12	12
Intermediate	39	38	38	38	38	37	37	37
Skilled manual	17	17	16	15	15	15	15	15
Skilled non-manual	12	11	12	13	12	12	12	12
Partly skilled	8	8	8	8	8	8	8	7
Unskilled	2	2	2	2	2	2	2	2
Unknown	9	10	10	11	12	14	13	15

Source: UCAS

Note: Annual growth from 365,323 applicants in 1994 to 394,955 in 2005.

Table 11 Percentage of all HE applicants by occupational class, UK, 2002-2005

	2002	2003	2004	2005
Higher managerial	18	17	17	16
Lower managerial	25	25	25	24
Intermediate	13	12	12	12
Small employers	6	6	6	6
Lower supervisory	4	4	4	4
Semi-routine	11	11	11	11
Routine	5	5	5	5
Don’t know	19	21	20	23

Source: UCAS

Note: for the 2001 population census a new Registrar General’s scale of occupational class was used, and official figures hereafter use this different scale. ‘Don’t know’ includes never worked, long-term unemployed and unknown or invalid response.

Table 12 Percentage of Group C: Biological Sciences applicants by social class, UK, 1994-2001

	1994	1995	1996	1997	1998	1999	2000	2001
Professional	14	16	14	14	15	15	15	15
Intermediate	39	39	38	40	40	40	41	40
Skilled manual	17	16	16	15	14	14	14	15
Skilled non-manual	12	11	12	12	12	12	12	12
Partly skilled	8	8	8	8	7	7	7	7
Unskilled	2	2	2	2	2	2	2	2
Unknown	9	9	10	9	9	9	9	10

Source: UCAS
Note: Growth from 20,126 applicants in 1994 to 32,537 in 2005.

Table 13 Percentage of Group C: Biological Sciences applicants by occupational class, UK, 2002-2005

	2002	2003	2004	2005
Higher managerial	20	19	19	17
Lower managerial	27	27	28	26
Intermediate	13	13	13	12
Small employers	6	6	6	6
Lower supervisory	5	5	4	4
Semi-routine	11	11	11	11
Routine	5	5	5	5
Don't know	12	14	13	18

Source: UCAS

Table 14 Percentage of Group F: Physical Sciences applicants by social class, UK, 1994-2001

	1994	1995	1996	1997	1998	1999	2000	2001
Professional	17	17	17	17	16	17	18	17
Intermediate	40	41	41	40	41	41	41	41
Skilled manual	16	16	16	15	15	15	14	15
Skilled non-manual	11	11	11	11	11	11	11	12
Partly skilled	7	7	7	7	7	7	7	6
Unskilled	1	1	1	2	1	1	1	1
Unknown	6	6	7	7	7	7	7	8

Source: UCAS
Note: Decline from 15,841 applicants in 1994 to 13,159 in 2005.

Table 15 Percentage of Group F: Physical Sciences applicants by occupational class, UK, 2002-2005

	2002	2003	2004	2005
Higher managerial	25	24	24	22
Lower managerial	28	28	28	26
Intermediate	14	13	14	13
Small employers	6	6	6	5
Lower supervisory	5	5	5	4
Semi-routine	10	9	9	9
Routine	4	4	4	4
Don't know	9	11	10	16

Source: UCAS

Table 16 Percentage of Group G: Mathematical Sciences applicants by social class, UK, 1994-2001

	1994	1995	1996	1997	1998	1999	2000	2001
Professional	12	12	12	11	10	10	10	10
Intermediate	35	35	35	34	34	33	33	32
Skilled manual	19	19	18	18	17	18	17	18
Skilled non-manual	12	12	12	13	13	13	13	12
Partly skilled	9	9	9	8	9	9	9	8
Unskilled	2	3	2	2	3	3	3	3
Unknown	10	10	11	12	14	14	15	17

Source: UCAS
Note: Growth from 18,188 applicants in 1994 to 21,929 in 2005, with peak of 35,324 in 2001.

Table 17 Percentage of Group G: Mathematical Sciences applicants by occupational class, UK, 2002-2005

	2002	2003	2004	2005
Higher managerial	16	15	15	15
Lower managerial	21	21	21	21
Intermediate	12	12	12	11
Small employers	7	6	6	6
Lower supervisory	4	5	5	4
Semi-routine	12	12	12	13
Routine	6	6	6	6
Don't know	20	23	22	24

Source: UCAS

The pattern for acceptances is the same as for applicants, in terms of social and occupational class 1994-2005. As might be expected, the proportion of students whose background is not known declines somewhat with acceptance (either because they have more complete records or take more care to complete applications). But these few extra cases are then distributed proportionately across the social groups. As illustrated more fully by Gorard et al. (2007) the admissions process as a whole does not lead to any further stratification of the student body. The stratification is pre-existent in the applicants, and before that in the body of students with traditional HE-entry qualifications.

3. Summary

All the datasets used for this report have serious limitations. For example, PLASC/NPD is only available since 2002, contains key changes in and additions to variables over time, has many unmatched cases and so many missing values, and has no direct measure of parental occupation. In addition, data on post-16 participation and achievement excludes those not participating. Sample surveys have differential response rates over time and place, and international studies such as PISA 2006 report complex indices of doubtful validity. The most complete and consistent (in definition) indicator of SES is eligibility for free school meals though it serves only to separate those living in poverty from the rest. Therefore, all analyses presented here are for illustrative purposes only at this stage and, given these limitations, all conclusions should be considered tentative.

At Key Stages 1 and 2 the attainment gap (calculated as the difference between two scores divided by their sum) in science between the richest and poorest areas is 9%. This is substantially less than reading (12%) and writing (14%) at KS1 and English (14%) and mathematics (14%) at KS2. This is largely due to higher scores among poorer students in science rather than lower scores among richer ones. These threshold figures suggest that SES is related to attainment from very early in schooling, but makes less of a difference to science attainment at KS1 and KS2 than in most other subjects.

At Key Stage 4, the differences in attainment between social groups are no larger in science than in all subjects. These attainment gaps (proportional differences between social groups) are almost the same in 2001/2002 as 2005/2006. For example, the gap in science and in all subjects for both years is around 17%. The general link (i.e. for all subjects combined) between attainment and SES as assessed by deprivation of area of residence has declined, but remained at the same level for science. An alternative comparison would be between science and mathematics or English, and this analysis might be worth pursuing further. Overall, high grades are more common in KS4 maths and double-award science than in separate sciences.

Also at KS4, students not eligible for FSMs are disproportionately represented in the gifted and talented programme. This either means that the programme is not correctly identifying potential or there is a link between ability and poverty. If we accept that G&T captures some potential, then it is important to note that among those in G&T the link between achievement and FSM is weaker. This is true for science and all subjects (combined) at KS4.

At Key Stage 5 around 16% of students take the traditional sciences, and 9% study maths. They have higher than average prior scores and get higher than average outcomes. The entry gap at KS5 is slightly narrower than the achievement gap in science at KS4 and the link between attainment and deprivation at KS5 appears lower than at KS4.

In Higher Education, the general pattern in applications and acceptances to university is one of little change over time, but a slight increase in the proportion from lower SES groups. This pattern also applies to each of the groups of science subjects offered at university. In general, those who apply for and obtain places in science subjects but not mathematics have a higher social class profile than the general student population. Physics applicants and students tend to have a higher SES background than those studying biology or mathematics. These conclusions apply to acceptances at university as well as applications, and to all of the science subject groups. Therefore, there is stratification in science attainment and participation from Key Stage 1 to higher education.

The impact of SES on participation and attainment in science: a review of existing literature

Stephen Gorard and Beng Huat See
University of Birmingham

1. Introduction to the review

This review examines factors that might influence the participation or uptake and attainment of science subjects, especially the role of family background. We conducted electronic searches of the ERIC and Psychinfo databases looking for science participation or attainment with SES or equivalent (occupation, social class, family background, income). 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, presentations, and student theses. To these we added some of our own work and relevant pieces already known to us, yielding a total of over 1,000 pieces. We then 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. We cite 160 different pieces in the full report.

Our focus is on science participation or attainment, and SES, in the UK. However, the search yielded work of a more international nature, on participation or attainment more generally, or looking chiefly at determinants other than SES such as sex and prior education. Work was generally excluded from consideration if it did not meet two of the three search criteria upon closer examination (science, SES, UK). A comparative UK position can be gleaned from international studies written in English. However, the relevance of SES factors varies even within the UK, so that studies conducted entirely elsewhere have limited relevance. We try, where possible, to provide comparisons between science and the trajectory of other subjects. 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 work conducted in the decade 1997-2007 where feasible.

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 report the studies and the generic defects or omissions in the literature found (bearing in mind the partial nature of the search).

2. Factors influencing participation and attainment in science 14-19

In this overview synthesis we discuss associations between success in science and the SES background of students, and describe literature-based examples of interventions intended to overcome SES-based disadvantage in science. For succinctness here, we have collapsed consideration of pre- and post-16 science. The full review is available from the authors.

2.1 Family background

One of the best established findings of education research is that social class and attainment at school are linked. Students from higher SES backgrounds tend to obtain higher marks and examination grades irrespective of the subjects studied. This is true of science subjects (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 this 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).

Analyses of international tests like TIMSS have suggested that home background is a determinant of achievement in science across most countries. Students with parents of higher SES (Rothman 2003), living in homes with modern possessions (Yang 2003) and more books outperformed others (Mwetundila 2001). Expenditure on instructional supplies per student and parental volunteer hours are not significant in explaining test scores (Okpala et al. 2001), but low family income negatively related to students' academic performance in mathematics and science (Hogrebe et al. 2006). Additionally, there is some evidence that changes in SES of the school population over time are related to changes in the attainment gaps between classes (Grissmer et al. 1994, Grissmer and Flanagan 1998, Hedges and Nowell 1998, 1999, Cook and Evans 2000).

Perhaps parents from less advantaged households are less likely to be involved in the help and supervision of childrens' work and school, over and above the influence of any differences in education and income which are also important (Cotton and Wikelund 1989, Zill 1994, Wang et al. 1996, Shaver and Walls 1998). Similar findings apply to mathematics achievement (Patel 2006).

Unfortunately, some of these studies use perceptions of students' ability, rather than their actual performance, and no direct measure of SES, so education could be used as a proxy for SES here (Berends et al. 2005), and so 'parental support' might also be a proxy for SES rather than an explanation. Nor were any of the studies able, through design, to test the causal model between these relationships. Interestingly, where SES is included in studies the apparent importance of parental involvement on educational outcomes disappears (Jeynes 2005). What this shows is how difficult it is to establish causal relationships with data re-examined post hoc rather than through intervention with randomisation and generated for a specific purpose. Therefore, in spite of the proliferation of research in this area, numerous theories still abound and no conclusive evidence has been put forward as to how exactly SES impacts on students' academic achievement, and even less on their uptake of science. The main problem with all these studies is basically inconsistency in the measures used to describe family characteristics and school effects, and the fact that the practice of attributing residual variances to schools ignores these inconsistencies of measurement and sampling, the errors in measuring background using whatever schema, problems of assessing achievement, and the fact that many desirable variables such as motivation are missing.

The social class of students' families is also loosely related to the pattern of subject choice at school (Bickel and Howley 2003). Students from lower socio-economic backgrounds are less likely to study separate sciences at GCSE level (Croxford 1994, Shuttleworth and Daly 1997). Although mathematical and language skills are relevant contributory factors in predicting the choice of science subjects in secondary education (Uerz et al. 2004), cohort studies 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 (NfER 2006). Those interested in a career in science and technology, but not engineering, tended to be from higher socio-economic backgrounds. This means that participation in specialist science subjects pre-16 tends to be lower among students from manual than non-manual families, especially for physics and chemistry, even when participation grows, and sometimes in spite of curriculum change (Croxford 1997). Lyons (2004) found that students who made different decisions about studying physical science in US high school reported similar experiences and conceptions of science. It was not these that led them to make the choice. Rather it was family influence.

Parents are both a source of information and a major influence on students choosing courses at school. Thus, the occupational and educational status of parents could be a factor in any relationship between SES and subject choice (Sadker and Sadker 1994). In the US, mothers with no formal employment seem to encourage their children to pursue non-technical (non-science) majors, while working mothers with higher occupational status seem to encourage study of technical majors (Kalmijm 1994, Khazzoom 1997).

There are other patterns among those who participate in physical sciences at A-level and beyond (Osborne et al. 2003). There have been reported differences in attitude towards science between ethnic groups, with Asians favouring medicine-related degrees, engineering or mathematics compared to their white peers, while Afro-Caribbean students prefer degrees in social sciences (Taylor 1993, Modood 1993). A pattern has been observed in the US (Xie and Goyette 2003). A suggested explanation has been the influence of parents (Woodrow 1996), but these relatively small differences could equally well be explained by the prevalence of necessary prior qualifications among these groups.

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 (Gorard and Rees 2002, Gorard 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). Those who 'failed' at school often come to see post-school learning of all kinds as irrelevant to their needs and capacities (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'. Perhaps family poverty, lack of role models, and a sense of 'not for us', coupled with poor experiences of initial schooling can act to create a kind of lifelong attitude to learning – a negative learner identity. Of course, these influences on post-16 participation are not specifically about science anyway, and in part the SES stratification post-16 in science simply reflects the backgrounds of those who stay on in school or college.

Some studies have attempted to explain the relationship between SES and specific subject choice – perhaps believing the link to be stronger than it is. For the most part, these are little more than speculations. Participation in science by more higher SES groups may reflect parental encouragement, a academic school environment and social selection (Eggleston 1977). Students from lower SES backgrounds may suffer actual and material deprivation as well as lack of parental advice and support, which may discourage them from taking up science (Shuttleworth and Daly 1997).

However, there is always a danger of post hoc rationalisation of choice once it has been revealed and an equivalent danger of unrealistic choice beforehand. This is one of the unavoidable dangers of the reliance on self-report in UK education research.

2.2 Prior attainment

The relatively minor role for SES, once other factors are accounted for, needs to be emphasised. In an earlier review by Osborne et al. (2003), most studies reported no substantial relationship between science uptake and social class. Given the restrictions on choice imposed by the 14-16 National Curriculum, the fact that prior attainment predicts both later participation and subsequent attainment, that SES is one of several related variables loosely patterning participation, and that there are clear differences between school uptake of different subjects which are unrelated to SES, SES does not seem that important as a factor in pre-16 subject choice regarding science, especially if prior attainment is taken into account in any analysis

O'Connor et al. (1999) found that prior attainment (especially in mathematics) 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 (Mwetundila 2001, Uerz et al. 2004). The low uptake in sciences, especially physical sciences and particularly 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). 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), and there is some evidence that science and mathematics have been harder to get a high grade in A-level than other subjects, other than modern languages (Fitz-Gibbon 1999, Coe 2008). Therefore, 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 may be less (Kahneman and Tversky 2000). 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 mathematics. 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, which is in turn linked to high attainment at each previous Key Stage, and so to some extent to social class background.

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 higher status occupational family backgrounds, perhaps the underlying explanatory variable is talent (as defined by Rawls 1971). If talent – a combination of ability/aptitude and willingness to work hard – is inherited directly from parents as well as nurtured by an educated, well-resourced home environment then this could explain the overall pattern. 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 talent. In a review of evidence on the impact of parental education on early-life, Feinstein et al. (2004) showed that key influences on a child's educational attainment in its early years include parental education and income. One explanation for this pattern relies on an assumption of the inheritability of 'talent'. If parents are talented (in educational attainment terms) 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. Another explanation would be that the income and education of parents affects 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 of explanations is almost impossible on the basis of the kinds of data available to researchers.

If very young children (aged four and five) are given new mathematical problems 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 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 assist the development of basic mathematical competence in most children. Those from high SES families simply appear better at solving problems from a young age. A review by Wallace (2005) also found a lower ability to solve the kinds of problems that appear in intelligence tests among children from lower SES families. Gottfredson (2004) claims that variation in general intelligence is a 'fundamental cause' of inequalities between and within social classes. However, her claim is only weakly supported by her correlational findings, and measuring intelligence is subject to a variety of systematic errors. Results suggest that the development of cognitive skills is highly sensitive to variations in environmental factors, and there is no evidence that differences in cognitive performance are due largely to genetic differences (Layzer 1974). Fischer et al. (1996) found that social factors, such as family size, structure of family and geographical residence predicted future success better than IQ, but the study did not consider hereditary influences. Turkheimer et al. (2003) demonstrate that the proportions of IQ variance attributable to genes and environment vary with SES in a non-linear fashion. The models suggest that in impoverished families, 60% of the variance in IQ 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.

So, the suggested explanation for the lower 'ability', as tested, of lower SES children is that it is part genetic and a large part the result of certain environmental components that appear more often in poverty – including perhaps poor early diet. If true, then early welfare and educational interventions might be effective in reducing the difference. After controlling for SES, there is some evidence that even minimal increase in parent involvement has a positive impact on preschoolers' early development and mastery of basic skills (Marcon 1999). Adoption studies have indicated an effect of postnatal environment on the IQ of children born to low-SES backgrounds and adopted by high-SES parents, and vice versa (Capron and Duyme 1989).

2.3 Attitudes to science

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 mathematics (NFER 2006). In addition to future utility (Khoury and Voss 1985), the students' perceived aptitude for a subject and, of course, enjoyment are the most commonly cited reasons for choosing a subject to study. Students' interest in science generally decreases as they progress from primary to secondary schools (Schoon et al. 2007). Murphy and Begg (2001) suggest possible reasons for this change in attitude. These include lack of experimental work as part of the intensive repetitive preparation for national tests at Key Stage 2 (Campbell 2001, Ponchaud 2001, Bricheno 2000); curriculum content which has no relevance to the children's lives (Jidesjö and Oscarsson 2005); and shortcomings in teachers' knowledge of science in the upper years, leading to an overemphasis of acquisition of purported knowledge (OFSTED 1995). Students, thus, erroneously see science as the acquisition of facts, meaning that the compulsory teaching of science by 'inadequate' teachers and pencil and paper tests could actually be counter-productive.

However, the link between attitude and SES is unclear and cannot explain the pattern of participation in science and SES. In fact, most studies of attitudes to science do not even look at the link between attitudes and take-up. Those that do either find no link or the opposite pattern to the one that would help explain the situation. For example, Breakwell and Beardsell (1992) found that class was negatively associated with attitude towards science - children from lower social class having more positive attitudes. Positive attitudes towards science, however, did not translate to uptake in science. This may be due to school policy of encouraging more able students to study science as it is often perceived as a more difficult subject, but it certainly casts some doubt on the value of 'attitudes' as predictors of science take-up.

Despite Osborne and Collins (2000) sounding the caution that modern curricula for science, with an emphasis on recall and copying, may result in some students rejecting science because it is not challenging enough, sciences, particularly the physical sciences, are commonly seen as difficult relative to other school subjects. This is part of the reason given for not choosing them after Key Stage 3 (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 attitudes to science 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). Physics and chemistry as separate subjects are more likely to be taken by academically able students, especially middle-class males from independent schools (Lightbody and Durndell 1996). Combined, dual, single and general science, on the other hand, has been studied more by lower-attaining students, girls, and those from working-class backgrounds (Cheng et al. 1995). Again, these patterns are likely to be due to a combination of individual and family choices, school-imposed choice criteria and guidance, and the availability of relevant expertise in specific schools. For example, according to Jovanic and King (1998), one of the major factors in girls' antipathy towards sciences is their perception that they are better at, and so more likely to succeed in, other subjects. The results of an analysis of PISA 2003 data (Schulz 2005) confirmed previous studies which 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.

Catsambis (1995) shows that eighth-grade female students do not lag behind their male classmates in science achievements tests, grades, and course enrolments. Actually, some female students have higher probabilities of enrolling in high-ability classes than males. However, female students have less positive attitudes toward science, participate in fewer relevant extracurricular activities, and aspire less often to science careers than males. Mwetundila (2001) also found that boys in Australia have more positive attitudes towards science than the girls, and suggested that these attitudes may subsequently influence their approaches to science learning. Studies on primary school children, however, show that girls tended to have more positive attitudes towards science than boys although there are differences in their favoured topics. Girls preferred topics in life sciences while boys preferred physical sciences (Murphy and Beggs 2001).

The causal model is unclear here. 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 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. 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).

A meta-analysis of research suggests that there is only a moderate correlation between attitude towards science and achievement (Weinburgh 1995), while measures used in the TIMSS study (Beaton et al. 1996) found a consistent relationship between attitude and achievement. However, such a relationship would be more convincing if the attainment and the attitude were measured on separate occasions. Oliver and Simpson (1988) used a longitudinal study, and found a strong relationship between attitude towards science, motivation to achieve and self-concept of own ability - and students' achievement in science.

2.4 School-level factors

Some studies claim that there is a school mix effect on achievement. For example, Pong (1997) reports that attending a 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 mathematics and reading achievement. Perhaps schools with high concentrations of students from lower SES occupational backgrounds, which might be associated with 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. Yang (2003) found an indirect relationship in OECD countries between attainment in mathematics and science, average levels of family possessions, and average school mathematics and science scores for the school.

Analysis of PISA data (Fuchs and Wobmann 2004) showed that student characteristics (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), family background (number of books at home, parents' educational level and degree of geographical isolation of home), instruction time, teachers' sex, educational level and years of experience are all significantly related to mathematics, science and reading achievement. Wobmann (2003) examined the effects of family background, resources and institutions on mathematics and science performance using an international database of more than 260,000 students from 39 countries which includes extensive background information at the student, teacher, school and system level. At the student-level, international differences in student performance were largely related to institutional factors rather than differences in resources. Among the many institutional factors which combine to yield positive effects on student performance are centralised exams and control mechanisms, school autonomy in personnel and process decisions, individual teacher influence over teaching methods, limits to teacher unions' influence on curriculum scope, scrutiny of students' achievement and competition from private schools.

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). Schools with low levels of students living in poverty (as defined by FSM) tend to have higher entry rates for German. Other than this, once the individual characteristics of students are accounted for, the variation in subject take-up between schools cannot be explained. This residual variation could, of course, represent unmeasured qualities of the teachers and local practice. Thus, SES is only one of a linked batch of individual characteristics that help predict uptake of science at GCSE level, and even in combination these variables account for only part of the pattern. Perhaps students who were not expected to perform well in GCSE, often clustered in specific schools in the Shuttleworth and Daly (1997) study, are discouraged from taking up separate sciences. Few studies include prior attainment in their analysis, or in their purported explanation of SES differences.

A promising line of research from the 1950s has shown, largely via experiments, that science teaching methods can impact on students' interest and hence continued participation in science at higher levels especially for low SES students (Boeck 1953, Bloom 1954, Lucow 1954, Obourn 1956, Smith and Washton 1957). These studies in the 1950s were consistent in their findings that those students who were identified as gifted and talented in science had encouragement from parents and science teachers (Bull 1955, MacCurdy 1954).

Although international reviews and systematic reviews have not shown conclusively the influence of single-sex schools on educational attainment (Daly and Shuttleworth 1997, Airnes 2001), there is evidence to suggest that students in single-sex schools are less likely to hold stereotypical views about science subjects compared to students in co-educational schools (Gallagher et al. 1997). In a very small study, Airnes (2001) found no difference to either boys or girls from single-sex classes in co-educational schools. There are studies and reviews suggesting that the organisation of schooling can make some difference in reducing the link between SES and attainment. Miller-Whitehead (2002) illustrates that reducing class size can mitigate against the effect of SES (as measured by eligibility for free or reduced school lunch). Her data show that many lower SES schools were actually able to achieve at or above the levels of some high SES schools. In a comparison of within-school variance in 14 year-old achievement attributable to family background between US, England and

Sweden, it was found that this was similar in each country (Burstein et al. 1980).

The extent to which family SES advantage plays out in the structure of interpersonal allocations of rewards 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 (Burstein et al. 1980, 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). Also in Finland, the influence of family SES on test performance in scientific, mathematical and reading literacy is noticeably lower than in Germany. In fact, this is a finding that has been replicated in meta-level consideration of a number of different international studies (Haahr et al. 2005). Systems with early tracking of students by ability, with high levels of fee-paying provision, with covert selection on the basis of faith or curricular specialism, or with differential local funding arrangements, tend to have stronger links between SES and attainment than egalitarian ones. Furthermore, good teaching can make a difference (Osborne et al. 2003).

The proportions of students taking science subjects vary between schools, even controlling for the profile of students (Smyth and Hannan 2006). School structures at both lower and upper secondary levels are found to play a role in shaping the choices made by students regarding science. If admissions tutors at HE prefer single subject GCSEs in science compared to dual award and the former is more common in selective and independent schools, then this could be a lever towards social polarisation.

None of the speculation explains or even considers why science as opposed to languages or humanities should be specifically affected by schools in this way. There are common issues involved in the choice of a range of subjects including science (Wright 2006). Many of the recurring issues raised, such as a restrictive curriculum and assessment regime dominated by content rather than process, and narrow teaching methods, are also faced by subjects which generally attract less concern (e.g. English). Some authors suggest 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 idea of a school mix effect (suggesting that attending a school or lesson with high attaining students has an impact on attainment) is a widely disputed notion with others proposing that the apparent impact of individual characteristics aggregated at higher levels is more likely to be due to measurement and modelling error (Gorard 2006b).

2.5 Sex differences

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 lower rate of participation post-16 than males, particularly in 'hard' sciences, and to some extent pre-16 as well. As with SES, it is slightly easier to note the pattern or disproportionality but somewhat harder to find convincing research evidence of the causes.

The gap has been attributed to teachers' expectations, the types of career aspirations for girls and lack of female role models. NfER (2006) found that boys are 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. But this is a tautology not an explanation. One large Dutch study found that the choice of science and mathematics 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 higher mathematics and science self-concepts and a background of high school advanced science and mathematics courses. 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 the declining number of girls taking post-16 physics, Murphy and Whitelegg (2006) concluded that girls' perceptions about their own competence in mathematics 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. 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 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. Lamb (1997) attributed the differential participation between boys and girls to the views of mathematics that they reported developing in their junior years. Boys, for example, developed positive views of mathematics in their junior years, which gave them the confidence to choose academic mathematics courses later. In contrast, many girls did not develop such positive attitudes and were more likely to select non-university mathematics options. 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 university math options.

A large-scale study of uptake of science at A-levels (Gallagher et al. 1997) indicates that the number of A-level science subjects taken by girls was higher in 1995 than in 1985, while that for boys had dropped. The gap had narrowed. They suggest that this was due to the girls' improved expectations of employment prospects and perceptions of wider labour-market opportunities for women, rather than changes in attitudes to the curriculum itself. Even though girls are taking more A-level sciences, sexed differences in subject choices still exist in that the proportion of boys taking physics and further mathematics as well as computer studies and design and technology is higher than for girls. Girls are still over-represented among those studying home economics and biology. This study, however, has several problems, first of which is the researchers' definition of science subjects. Interestingly they include home economics/food science technology as a science subject whereas fields of study such as psychology, business studies, statistics and economics are classified as arts subjects. Secondly, only grammar schools were included in the study. Results might be different if the secondary modern schools were included. Thirdly, the proportion of girls in selective schools increased from 51% in 1985 to 55% in 1995, while that for boys has dropped correspondingly. Furthermore, the focus group interviews were conducted with girls only.

The findings of two British cohort studies (Schoon et al. 2007) suggest that there is a persisting sex imbalance both in terms of aspirations and occupational attainment. Interest in and attachment to a science-related career are formed early in life, often by the end of primary education. School experiences, in particular, appear crucial in attracting young people to a career in science. The study states some implications for policies aimed at improving the uptake of science at secondary level. One way of encouraging more students to take up science post-16 is to make school experiences more relevant and engaging for young people. Shuttleworth and Daly (1997) used survey data on individual/family background and school characteristics and science uptake at GCSE in Northern Ireland to suggest that sex and religious differences in uptake of 'hard' science could be the result of hard-to-pin down elements such as ethos, individual choice and school provision. Their study involves a series of multi-level logistic regression models. They included important variables such as prior attainment which might further explain differences in uptake of 'hard' science.

To a considerable extent, changes in the science curriculum and pedagogy combined with socio-economic developments have been associated with a decline in the sex gap for participation in sciences. Why is there not such as clear position for SES? Perhaps 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 multinomial and non-biological, definition than sex. Unlike sex and science the problem of SES crosses the whole curriculum. It is not specifically a science problem.

3. Quality of research

As with any review, we encountered problems in identifying high quality research. 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 about it appearing in the paper. Of the remainder, much published research writing presents no empirical evidence. A further substantial proportion does 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 empirical research. The majority of these displayed major flaws – such as making causal claims without an intervention or equivalent, making comparative claims without a suitable comparator, or the exclusion from research of those not participating in science even in research about non-participation in science. There is little clear sense, even in the UK pieces, of the pattern that the literature is attempting to explain. It is, therefore, difficult to judge the worth of an attempted explanation since we are not sure what it should be an explanation of. Care needs to be taken when modelling, via regression and related techniques. 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. Readers must be very clear that this process is very different to any kind of rigorous test. The models are sensitive to the precise order of entering the explanatory variables.

The most common generic defect in research reports is the link between the evidence presented and the conclusions drawn from it. Our experience suggests that this is no worse than in other areas of education research. Few of the claims made about science were contextualised to show that the situation was specific to science. There is little scepticism about attitudes, preferences and choice. Where studies do not have revealed choices as well as attitudes or preferences they cannot say how accurate or influential the latter are. Where choices are revealed there is a danger that attitudes or preferences become a tautology. It is not sometimes clear when students are asked about science whether their response is about the school subject or the current international endeavour or the history of the enlightenment. Such attitude work does not seem a fruitful area for further investigation. Those not taking science should be routinely included in studies as a comparison. Perhaps most importantly, ideas from in-depth, observational and modelling studies must be tested via experimental designs, as the most ethical way forward for research seeking to make causal claims (Gorard and Cook 2007).

4. Summary and recommendations

The research reviewed showed that there is a clear link between SES and attainment and participation in science (as with all subjects). It is not at all clear from the literature that there is a strong patterning of science participation and achievement by SES once other variables are accounted for, nor is it clear that the situation for science is worse than for other subjects, nor worsening over time.

While the best predictor of both aspects of performance in science education is prior attainment, it is likely that parental interest and involvement form part of the explanation of gaps between different SES groups. There may also be a school (or teacher) effect on attainment and subject choice; in general, mixed non-selective school systems are better at breaking the link between SES and attainment in science and other subjects. Early experiences of school and family appear to create a learner identity or subjective opportunity structure that creates a post-16 barrier for some. Overcoming other barriers such as cost may be necessary but not sufficient to encourage participation. Science is seen as a relatively difficult subject post-16 and so simple human capital theory would predict low uptake.

'Science' in education refers primarily to the traditional natural sciences based on physics, chemistry and biology, and combinations of these such as dual award science, in the 14-19 curriculum. It is these that give most concern to commentators, particularly in terms of post-14 participation. However, the review also considers subjects such as mathematics, psychology, and sports science that are not usually central to the debate but which have elements of science involved at A-level. In fact, there is a general increase in elements of science and technology in a wide range of subjects (Bell 2001).

The definitions of a science subject differ between studies and vary over time and place. In addition, a focus on attainment and participation as measures of performance in science education ignore other more meaningful but less measurable outcomes of science learning, such as enjoyment.

Minor differences in the assumptions underlying an analysis can, quite correctly, lead to very different conclusions using the same dataset (see Gorard et al. 2007, Gorard 2008a). Sometimes this is the unavoidable result of the researcher re-using existing data collected for another purpose and so having to use proxy measures for SES. This highlights another almost unavoidable problem for most datasets – missing variables and cases. In some studies such as birth cohort studies, 50% or more of cases were missing data, and there is no real way of assessing the impact of missing variables since we may not even be aware of them. What this means is that analysts must be very cautious in drawing attention to patterns and trends.

This review leads to some recommendations for research. Improvements could be made in terms of empirical methodology and transparent reporting. Missing cases, values, and variables (where known) should be clearly reported and their potential influence taken into account. Differences, patterns and trends have to be clear to be of any practical importance. Analyses of population, incomplete or non-random cases should never use or report significance (standard errors, confidence intervals, p-values etc.). All reports should specify how many models have been run, and how much the substantive findings could differ if another model had been selected for publication. All reports should explicitly state the order of entering variables into a model, the reason for choosing that order, and the likely impact on the substantive findings of using a different order. One possible standard method of entry would be in lifecourse order so that each variable can only 'explain' variance remaining after previous life stages.

Until its purpose and utility has been clearly argued, work on attitudes to science should be reined in to allow more work on the determinants of revealed choice and attainment. However, much of the field is working towards a trial. The research literature suggests that reducing the relevance of prior attainment in science to future study, and/or reducing the element of compulsion in pre-16 science study, could give more opportunities to some students of low SES. Trials exploring these ideas need to be conducted before we can proceed to 'engineering' the results of research into usable products for policy and practice.

Current perceptions of the impact of SES on science participation and attainment: a focus group investigation of pupils, teachers and parents

Stuart Bevins, Eleanor Brodie and Merisa Thompson
Sheffield Hallam University

This paper presents key findings from a qualitative study into perceptions of the potential impact of socioeconomic status (SES) on young people's participation and achievement in school science and beyond. The data reported derive from a series of focus groups conducted with pupils, parents and science teachers in South Yorkshire, the North West, Midlands and London. The importance of investigating this issue has emerged from a number of existing studies that acknowledge inequity in participation, achievement and/or interest in the subject of science at school (YCS 2004, Jenkins 2005, Osborne and Collins 2000). Moreover, the apparent lack of suitably qualified individuals choosing science-based careers is of increasing concern (Roberts 2002). This, together with shortages in science teacher recruitment and retention (Smithers and Robinson 2000), places science and innovation within the UK in a precarious situation. If the UK is going to compete effectively within global markets, interventions will have to be designed and implemented that will tackle key issues that are affecting participation and achievement in school science, post-compulsory school science and careers.

1. The sample

Eight schools were invited to take part in the study based on the socioeconomic make-up of their catchment areas to provide a cross-section. The schools were spread across four regions of England—South Yorkshire, the North West, Midlands and London with two schools selected in each area—one representing an area of social deprivation and one of social affluence. Areas of deprivation and more affluent areas were defined using descriptions of the school areas from the Office of Standards in Education (OfSTED) reports for participating schools. None of the eight participating schools were selective and as a result the socio-economic make-up of the school reflected that of the surrounding area.

The participating pupils were selected based on their socio-economic circumstances to generate a representative cross-section of the school as a whole. It was felt that due to the teachers' knowledge of both the school and the socio-economic make-up of the catchment area they were best placed to select the participating pupils. Therefore, individual pupils from each school were selected by teachers to provide a representative sample of gender, ability and ethnicity.

A total of 43 pupils from Years 8 and 9 were identified to participate. It was decided that pupils within this age range would be appropriate participants as they are beginning to consider factors that impact on their study and career choices and would have a relatively current and fresh insight into influencing factors as opposed to, for example, pupils studying A-levels who have already selected their study and career paths. However, a larger scale study would benefit from the perceptions of a wider range of pupils. Ten pupils were from minority ethnic groups, while 22 were boys and 21 girls.

Parents were invited by the participating science teachers to take part in the focus groups. A total of 24 parents participated with 6 from minority ethnic groups, and 19 female and 5 male.

Teachers represented all three main science specialisms and included Heads of department, Heads of year and classroom teachers. A total of 24 participated with 13 being male and 11 female.

2. Research methods

Grounded theory (Glaser and Strauss 1967) was used to underpin the study and to provide a way of gathering, analysing and organising data. Grounded theory offers an approach to constructing abstract theoretical descriptions and explanations of social processes that are rooted within the data. Theory is developed inductively from a corpus of data rather than deductively from a grand theory which then attempts to support a hypothesis or preconceived notions through data. Grounded theory is concerned with understandings of the world which use categories drawn from participants in the research themselves, with a focus on making implicit belief systems explicit.

The primary objective of grounded theory, then, is to explain a phenomenon by identifying the key elements of that phenomenon, and then categorize the relationships of those elements to the context and process of the research. This is to say, that the aim is to go from the general to the specific while considering that the emergent theory should account for a phenomenon that is relevant to the research participants.

Constructing a grounded theory requires a number of steps within the research process:

- simultaneous involvement in data collection and analysis;
- constructing analytic codes and thematic categories from the data and not from preconceived hypotheses;
- constant comparison of data;
- identifying samples for theory construction and not for representativeness.

Within the reported study simultaneous involvement in data collection and analysis required the research team to engage in systematic and rigorous data analysis alongside data collection. This enabled a constant comparison of data sets throughout the study and the development and modification of analytic codes and categories as the study progressed. The primary intention of the research was to obtain an understanding of how science and science education is viewed by pupils, parents and teachers from different socioeconomic backgrounds. Therefore, the data presented are not intended to be generalised across a larger population, rather to provide an understanding of how the participating groups perceive science, science education and participation and achievement.

Two researchers attended each focus group, where possible, and discussions were tape recorded. Coding of researcher notes and taped discussions consisted of two main phases: 1) an initial phase in which each segment of data was highlighted with a theme or name followed by 2) a focused phase that involved the most significant and/or frequent codes to synthesize the data (Charmaz 2006). These initial coding phases assisted the development of thematic categories at a later stage. Constant comparison of data (Glaser and Strauss 1967) enabled the establishment of analytic distinctions and, therefore, the researchers were able to highlight similarities and differences within the data.

Where possible, teacher, parent and pupil groups were engaged separately in an attempt to manage group size and to focus discussion within the context of their roles as teachers, parents and pupils. Interview schedules (Appendix 3) were developed and used as prompts to encourage open but structured discussion. Each group engaged in discussion with researchers for approximately 60 minutes.

3. Key findings

3.1 Perceptions of science

All participants perceived science to be an important factor to the maintenance of healthy global economies and social well being. They stated that science underpins technological advances and that scientific and technological innovation is central to the way our world operates and functions. However, the majority of parents stated that they have little interest in science unless it has personal relevance. While they recognise that science and technology have significant influence on the way they live they see science as '*something that somebody else does*':

I don't normally watch things on TV about science or technology. If there's something on the news about hospital superbugs or food I will listen because it's relevant to me. But I'm not interested in the Russians going to the moon and stuff like that (Parent – Low SES)

3.2 School science

While parents' experiences of school science varied, a general trend emerged from the data that suggested parents from areas of deprivation perceived school science as a subject that only the most able achieved in. Female parents, in particular, related that they were often either discouraged from choosing the science subject they had wanted to study at O-level or had formed an opinion that physics and chemistry were subjects for boys:

Actually, I wanted to do a chemistry O-level but was told that I couldn't because the option was full. There was one girl doing chemistry in my year and she was very clever. I had to do biology (Parent – Low SES)

This resonates with findings from a study into parents' views on the school science curriculum (Osborne and Collins 2000) which also showed that a lack of opportunities to combine arts and science subjects at O-level was a factor.

The large majority of pupils from schools in more affluent areas indicated that they find school science interesting and that generally they understand the science they are taught and its relevance to the world around them. They emphasised that practical/investigation sessions are particularly enjoyable and that they are less likely to gain a full appreciation of concepts and/or topics which rely solely on written activity or teacher instruction:

Yes, I enjoy science lessons, particularly the practical bits, I really enjoy them. I don't take it in (topic) as much when we have to write or listen to the teacher for a long time (Pupil – High SES)

While a similar perception was reported by pupils from schools in areas of deprivation, regarding practical/investigation sessions and a dislike of written activity, there was a less positive response to school science. The large majority of these pupils suggested that school science is generally '*not relevant*' to them and their daily lives. In particular they felt that physics is '*too hard*' and '*boring*'. Although the pupils were not prompted to discuss the sciences separately they compared physics to biology stating that biology relates to things all around them which are, quite often, tangible and relate to daily lives:

Physics is way too hard and boring. I just can't see why we do most of the stuff we do. At least in biology you can see where it might affect you, like going to the hospital and stuff like the environment (Pupil – Low SES)

Although not differentiated by gender, this emergent theme from pupils' responses from areas of deprivation is consistent with findings from Osbourne and Collins (2000) who reported a general antipathy towards physics and chemistry by pupils.

The majority of participating teachers stated that the National Curriculum and testing largely inhibit them from utilising teaching and learning approaches which involve exciting and creative science, particularly practicals/investigations. They felt that this can be a specific problem for those pupils who have the potential for achieving highly in science but '*switch off*' if not engaged in stimulating activity, as well as for those pupils who demonstrate poor behaviour or little interest generally in science:

It's frustrating not being able to do enough, the syllabus always comes first…when we do practicals their (pupils') behaviour is totally different, you can see they enjoy it. You end up giving merits to kids you wouldn't expect to (Teacher – Low SES)

In contrast, a small number of teachers working in schools from affluent areas did not express great concern over the National Curriculum and practical/investigation sessions. These teachers stated that being able to trust the pupils' behaviour in practical sessions allows them to engage much more in this type of approach:

Trust is the key. If you can trust the pupils in the class to behave responsibly we can do as many practical activities as we want, and we do a lot here. But you need to be able to trust them (pupils) for health and safety reasons if nothing else (Teacher – High SES)

It is interesting to note here that teachers from schools in areas of deprivation expressed a view of utilising practical sessions as an opportunity to motivate and engage those pupils who generally demonstrate disruptive behaviour and/or are switched off from science:

Teachers here have to plan their lessons to a much higher degree than in most schools because you can't afford not to, you couldn't get away with just handing out text books and saying turn to page 37; they need short tasks to do, then move on and keep them busy (Teacher - Low SES)

A key issue that emerged whilst talking to teachers was that they felt the rote learning required for national tests, especially SATs, restrained learning in science and presented a barrier to learning for some pupils with lower academic ability. In particular, two of the schools in areas of deprivation felt that a move towards inclusion of practical examinations was needed:

Literacy is a real problem when it comes to attainment. They can come in and tell you 50 million things about something, but when it comes to the SATs questions … they can't access it, they can't understand what the question is asking (Teacher – Low SES)

I think if there were other ways for pupils being assessed, like role play and practicals, then the lower kids would be able to access that. There's more than one way to show understanding (Teacher – Low SES)

Teachers, particularly from London schools and areas of deprivation, stated that circumstances such as poor science teacher retention and a lack of support staff has the strongest impact on learning science.

Participating pupils and parents from both areas of affluence and deprivation felt that learning science depends heavily on good teaching and teaching styles. Pupils from more affluent areas placed an emphasis on creativity and making the topic interesting and, while the use of practical/investigation sessions was again mentioned, group discussion and being given autonomy and responsibility to research a topic were also suggested. They felt that science should be their teachers' '*passion*' and that teachers should have strong subject knowledge. These pupils also highlighted the importance of effective pupil-teacher relationships and that the teacher should demonstrate a willingness to listen to pupils' views:

We did a research project over summer and I got really interested in finding information from the Internet and library and then organising the information into a report (Pupil – High SES)

If you don't like the teacher it can be hard to like the subject because they are teaching it and you can't separate the personality from the subject. But if you get on with them it can motivate you more (Pupil – High SES)

Pupils from areas of social and economic deprivation placed emphasis on teachers being '*nice*' and on strong pupil-teacher relationships. These pupils were more concerned that teachers demonstrate high levels of empathy and listening skills than subject knowledge and passion for the subject. However, the pupils did state that making science interesting is very important and can help to develop good pupil-teacher relationships which in turn encourages pupils to work hard:

Teachers need to be nice and listen when you have a problem (Pupil – Low SES)

It's (science) got to be interesting or you won't learn anything and you might not like the teacher if it's boring. If they (teachers) make it interesting you'll probably work harder (Pupil – Low SES)

Parents echoed these views and stated further that the type of school is an influencing factor. Parents from areas of deprivation felt that independent and/or private schools have better quality laboratories and a smaller pupil per teacher ratio which enables teachers to devote more time to individual pupils. Parents from more affluent areas suggested that if the school has a science specialism and/or the science department demonstrates enthusiasm towards teaching and learning science then pupils will be influenced by the ethos of the school and/or department:

Posh schools have better equipment and not as many kids in the class. It's bound to make a difference (Parent- Low SES)

It depends on the school I think; if it's a specialist science school or if the science department is enthusiastic about sciences then it will rub off on the kids (Parent – High SES)

While pupils and parents were asked whether the type of school was an influencing factor, they were not prompted to discuss specifically teachers and teaching. However, they placed a clear importance on the role of teachers and teaching approaches that is consistent with existing work on effective classroom teaching (Cooper and McIntyre 1996).

3.3 Ethnicity, gender and social status

Only a small minority of pupils from schools in areas of deprivation perceived ethnicity and/or gender as having an effect on studying science. They suggested that some of their peers found studying science particularly difficult due to a limited knowledge of the English language:

My friend is from Poland and she really struggles in science cause she can't speak English very well yet … but I think she will be ok when she learns the language (Pupil – Low SES)

None of the remaining pupils from schools in either type of area saw ethnicity and/or gender as being contributory factors in either learning science or in the way science may be perceived generally. Moreover, there was a strong consensus among the participating pupils that science is a subject which is common to everyone, similar to mathematics and different from languages and history, which depend upon geographical location for specific contexts:

Science is the same all over the world no matter where you are. But history depends on where you come from as to what's important … languages depend on what country you're from too (Pupil – Low SES)

Parents' perceptions were largely consistent with those of the pupils regarding ethnicity and/or gender. All parents said that they believe ethnicity and/or gender has no impact on perceptions of science or achievement in school science. They suggested that engagement with science in any manifestation is due to individual preference and not culturally, ethnically or gender based:

It really doesn't matter where you come from, it's about individual interests (Parent – Low SES)

However, it should be noted that parents were uncomfortable discussing the issue, and suggested that they did not have adequate understanding and knowledge to discuss the issues in depth.

A number of existing studies (Jenkins 2005, Osborne and Collins 2000) have provided evidence to suggest that there are differences in the way girls' and boys' interests and achievements manifest themselves in separate science subjects. The study reported here cannot claim any resonance with these existing studies but recognises that the issue of gender was not explored to the same extent as some previous studies.

Teachers from schools in more affluent areas did not perceive ethnicity and social status as significant factors influencing pupils' engagement with science. Two teachers did state that pupils with weak English may be constrained somewhat, but said that it would not affect their interest and motivation to achieve in science. However, the large majority of teachers from schools in areas of deprivation stated that language is a definite barrier that restricts clear communication between teacher and pupil, as well as placing an emphasis on pupils concentrating on English language studies above science subjects:

Language is definitely a barrier, it can make it so difficult to explain even simple concepts. It's clearly hard for the kids and they obviously have to concentrate more in English…and I know that their parents expect that because some of the kids are going home and teaching their parents English (Teacher – Low SES)

However, one school from an area of deprivation found ethnicity to be a conduit to science learning and interest in the pursuit of science-related careers. Unfortunately no parents were available to attend a focus group at this school:

I think that we're in an Asian school matters a lot because there is an increasing drive from parents for children to be doctors or dentists. The parents deem science to be an important subject (Teacher – Low SES)

Parents from more affluent areas stated that they believe social status is not a barrier to achievement in school and career aspirations through all subjects. They suggested that a young person who has a genuine interest in science may progress through school science and post-compulsory study and obtain a scientific career through hard work and dedication which is not dependent upon social status. They described current school and higher education systems as affording opportunities for anyone who is prepared to commit to learning:

Even with the burden of student loans, if someone really wants a career in science or any other field they can achieve it with hard work and commitment. It shouldn't matter what your background is or where you come from (Parent – High SES)

However, the majority of parents from areas of deprivation perceived the issue differently. They suggested that young people who reside in more affluent areas are far more likely to go into a scientific career than those from areas of deprivation. They stated that young people are influenced by their surroundings and what they see and experience within those surroundings. Accordingly, these parents felt they would not normally aspire to scientific careers even if they had an intrinsic interest in the subject:

They see what their friends are doing and their parents and that's what they relate to. I don't know any scientists who came from a housing estate, do you? (Parent – High SES)

This view of parents from areas of deprivation suggests that they perceive science as being of high status which resonates with the view of parents reported by Osborne and Collins (2000) who suggested that their experience of school science was as '*recipients of a received and revered body of high status knowledge, where only the keenest and most able were encouraged to study it after age 14*' (p. 85). However, it should be noted that Osborne and Collins do not specify different social class as a criteria within their sampling.

3.4 Parental influence

Parental influence on how pupils perceive and engage with science was cited by all pupils as having a significant impact upon them. In general, parents are viewed as supportive and demonstrate strong encouragement to achieve. However, only a small number of pupils stated that their parents become actively involved with their homework through discussion of topics, specific knowledge or questioning. It is important to note that the majority of pupils who raised this issue have parents who work in science-related or engineering-related careers. Most of the remaining pupils stated that parents generally display strong encouragement towards educational achievement and that no specific emphasis is placed upon science:

They just want me to do well and try to encourage me to work hard all the time not just in science (Pupil – High SES)

Interestingly, pupils from three schools in areas of deprivation indicated that their parents place more emphasis on English and mathematics achievement:

They (parents) are more interested in how I do in mathematics and English I think … they are always asking about mathematics and English but not science so much (Pupil – Low SES)

During focus groups with pupils it emerged that those from schools in more affluent areas engage more in discussion with their parents about careers and/or post-compulsory school study than pupils from schools in areas of deprivation. The majority of the pupils in affluent areas suggested that their parents expect them to attend university and enter a professional career. Most pupils pointed out that their parents do not emphasise science-related study and careers as a preferred option for their children, although a small number whose parents work in science-related fields did state that their parents would like them to opt for science-related higher education studies:

Dad would like me to go into science in some way. He's a doctor but he doesn't say I have to go into medicine he just says that doing science can be good. I would like to do forensics (Pupil - High SES)

This is in contrast to the perceptions of pupils from schools in areas of deprivation. They suggested that their parents would welcome the idea of them attending university but do not expect it. They also added that their parents rarely engage them in discussion about post-compulsory school study and/or career options. When probed further, they described their parents' expectations as wanting them to work hard and achieve as highly as possible but not seeing university education or a professional career as probable outcomes and that going to university should not be viewed by their children as the ultimate goal. None of the pupils from areas of deprivation stated that their parents specifically encourage science as a preferred option for potential careers:

We don't really talk about it (study and careers) but I don't think they (parents) expect me to go to university, but they do want me to get something that I enjoy doing (Pupil – Low SES)

My Mum says that going to university isn't the be all and end all (Pupil – Low SES)

Perceptions of studying science after the age of 16 differed between parents. However, in the main, parents from more affluent areas expect their children to attend university, although not necessarily engaging in science-based study. On the other hand, most parents from areas of deprivation did not expect their children to attend university. Moreover, they felt that while higher education may benefit their children it is not the 'Holy Grail' of educational achievement:

If he (pupil) wanted to go to university and thought he could do well that would be fine, but it isn't everything and doesn't mean he won't get a good job and do well (Parent – Low SES)

Teachers' perceptions of parents' expectations of their children reinforced pupils' views. The general feeling was that the large majority of parents are supportive of their children and want them to achieve as highly as possible across all subjects but not specifically science.

3.5 Science careers information

Pupils from two schools in more affluent areas complained of a lack of careers information available at school and a general confusion over which subjects to choose for GCSE and A-levels as they are confused as to the specific requirements for particular careers. They explained that this especially relates to science since a clear definition of specific scientific careers does not exist. This was supported by the majority of parents who expressed strong views on careers information, particularly concerning science. They felt that very little support and information is provided for young people and, indeed, for parents in order to develop an informed discussion with their children. Parents from areas of affluence and deprivation agreed that science is not clearly defined in terms of specialist knowledge and skills needed for particular fields of work and that this may confuse young people when thinking about potential study and careers:

I don't think there's enough information for them (young people) to help them decide what they want to do, definitely in science too. I think it's hard for them to know which science they need and what they should specialise in for a particular field of work. There are lots of jobs that involve science and a mix of sciences. This needs to be made clear to them (young people) so that they, and we (parents), can discuss what interests them (Parent – High SES)

Teachers from two schools supported pupils' and parents' concerns regarding a lack of appropriate careers information in science. They explained that they do not have suitable knowledge of the wide range of science-based careers on offer and that expert advice is needed for pupils on a regular basis:

I think I should be giving the kids more information but I haven't got the type of expert knowledge required. I can talk a bit, in lessons, about certain careers that may be linked to the topic of the time but they need much more and on a regular basis (Teacher – Low SES)

4. Conclusions

The sensitive nature of the topic under investigation cannot be underestimated when drawing conclusions from the data. Participating parents, in particular, were reluctant to discuss issues regarding ethnicity and aspects of SES. Therefore, any further study designs or interventions that may be considered would need to integrate measures to avoid trampling on participants' sensitivities. In addition, the relatively small sample and nature of the study prevents firm generalisations. That said, the study has produced findings which not only suggest the need for further investigation but also indicate that there are some aspects of SES that participants felt do impact on engagement and achievement in science.

All parents viewed science as having high status, although this was particularly emphasised by parents from areas of deprivation who perceived individuals who enter science-based professions as living in, and having attended schools in, more affluent areas. These parents also felt that schools from areas of more affluence are more likely to enjoy better facilities in terms of school laboratories, equipment and pupil-teacher ratio. While the great majority of parents were reluctant to discuss ethnicity and whether or not this is a factor, the issue of poor English language emerged and was reinforced by teachers and pupils.

However, while these aspects suggest some impact of SES upon participation and achievement in science, overall the findings indicate that SES is not perceived by these participants as having a major impact upon the participation and achievement in compulsory science education and beyond by young people. Moreover, it is clear that the majority of pupils and parents do not differentiate science from other subjects. Since both pupils and parents perceive science as important, the indication is that they view science education as an element of a pupil's all-round development and not as a subject to be treated separately from, certainly, English and mathematics.

Emerging clearly as a key issue is a lack of precise and clear information about scientific careers. Although not voiced by all of the participants, discussions about this issue highlighted strong discontent from those pupils, parents and teachers that did express an opinion. A UK national careers coordinator has been appointed and would do well to open up a lengthy and in-depth dialogue with pupils, parents and teachers in order to develop potential interventions that are appropriately based on recipients' views.

References

Aikenhead, G. (1995) Cultural assimilation in science classroom: border crossings and other solutions. Unpublished paper

Airnes, J. (2001) Students' perceptions of gender segregation in biology. *SCRE Newsletter No. 69*, Winter 2001

Beaton, A., Martin, M., Mullis, I., Gonzalez, J., Smith, T. and Kelley, D. (1996) *Science Achievement in the Middle School Years: IEA's Third International Mathematics and Science Study.* Chestnut Hill, MA: Boston College

Becker, G. (1975) Human Capital: *A Theoretical and Empirical Analysis*. Chicago: University of Chicago Press

Bell, J. (2001) Patterns of subject uptake and examination entry 1984-1997. *Educational Studies*, 27, 2, 201-19

Beller, A. and Chung, S. (1992) Family structure and educational attainment of children: effects of remarriage. *Journal of Population Economics*, 5, 309-320

Berends, M., Lucas, S., Sullivan, T. and Briggs, R. (2005) *Examining Gaps in Mathematics Achievement among Racial-ethnic Groups*, 1972-1992. Santa Monica, Calif.: RAND Corporation, MR-255

Bickel, R. and Howley, C. (2003) *Elementary Math Achievement for Rural Development: Effects of Contextual Factors Intrinsic to the Modern World. Working Paper.* Report: WP-15

Birnie, J. (1999) Physical geography at the transition to higher education: the effect of prior learning. *Journal of Geography in Higher Education*, 23, 1, 49-62

Bloom, S. (1954) The search for science talent. *Science Education*, 38, 232-236

Boeck, C. (1953) Teaching chemistry for scientific method and attitude development. *Science Education*, 37, 2, 81-84

Breakwell, G. and Beardsell, S. (1992) Gender, parental and peer influences upon science attitudes and activities. *Public Understanding of Science*, 1, 2, 183-197

Bricheno, P. (2000) *Science attitude changes on transition*. Paper presentation at the ASE annual conference, Leeds

Brown, C. (2005) Equity of literacy-based math performance assessments for English language learners. *Bilingual Research Journal*, 29, 2, 337-363

Bull, G. (1955) The activities and backgrounds of students with dominant science interests. Doctoral thesis. Columbia: University of Missouri, 366 pp. Abstract: *Dissertation Abstracts* 15: 61, No. 1, 1955

Burchardt, R., Le Grand, J. and Piachaud, D. (1999) Social exclusion in Britain 1991-1995. *Social Policy and Administration*, 33, 3, 227-244

Burstein, L., Fischer, K.B. and Miller, M.D. (1980) The multilevel effects of background on science achievement: a cross-national comparison. *Sociology of Education*, 53, 4, 215-225

Callender, C. (2003) *Attitudes to Debt: School Leavers and Further Education Students' Attitudes to Debt and their Impact on Participation in Higher Education*, London: Universities UK

Campbell, B. (2001) Children's perceptions of science education at primary and secondary school, in Behrendt, H. and Dahncke, H. et al. (eds.) (2001) *Research in science education – past, present and future*. London. Kluwer Academic, pp. 125-130

Capron, C. and Duyme, M. (1989) Assessment of effects of socioeconomic status on IQ in a full cross-fostering study. *Nature*, August 17, 552-553

Catsambis, S. (1995) Gender, race, ethnicity, and science education in the middle grades. *Journal of Research in Science Teaching*, 32, 3, 243-257

Chapman, B. and Ryan, C. (2002) Income contingent financing of student Higher Education charges: assessing the Australian innovation. *Welsh Journal of Education*, 11, 64-81

Charmaz, K. (2006) *Constructing Grounded Theory*. London: Sage

Cheng, Y., Payne, J. and Witherspoon, S. (1995) *Science and Mathematics in Full-time Education after 16. England and Wales, Youth Cohort Study*. London: Department of Education and Employment

Coe, R. J. (2008) Common examinee methods, in *Techniques for Monitoring the Comparability of Examination Standards*. Newton, P., Baird, J-A., Goldstein, H., Patrick, H. and Tymms, P. London: QCA. 331-368

Cook, M. and Evans, W. (2000) Families or schools? Explaining the convergence in White and Black academic performance. *Journal of Labour Economics*, 18, 4, 729-754

Cooper, P. & McIntyre, D. (1996) Effective Teaching and Learning: Teachers and Students' Perspectives. Buckingham: Open University Press

Cotton, K. and Wikelund, K. (1989) *Parent Involvement in Education*. School Improvement Research Series (SIRS). Office of Educational Research and Improvement (OERI), US

Crawley, F. and Black, C. (1992) Causal modelling of secondary science students' intentions to enrol in physics. *Journal of Research in Science Teaching*, 29, 6, 585-599

Croxford, L. (1994) Equal opportunities in the secondary school curriculum in Scotland, 1977-1991. *British Educational Research Journal*, 20, 4, 371-391

Croxford, L. (1997) Participation in science subjects: the effects of the Scottish Curriculum Framework. *Research Papers in Education*, 12, 1, 60-89

Darcy, J. (1994) Gender issues in public examinations, in Trew, K. et al. (eds) *Girls and Women in Education*. Leicester: British Psychology Society

Davies, P., Telhaj, S., Hutton, D., Adnett, N. and Coe, R. (2004) The myth of the bog standard secondary school: a school level analysis of students' choice of optional subjects. Paper prepared for BERA, 2004, Manchester

Dearden, L., Emmerson, C., Frayne, C. and Meghir, C. (2005) *Education Subsidies and School Drop-out Rates*, IFS Working Paper W05/11

Dearden, L., McGranahan, L. and Sianesi, B. (2004) *The Role of Credit Constraints in Educational Choices: evidence from NCDS and BCS70*, London School of Economics and Political Science, Centre for the Economics of Education, Discussion Paper No. 48

Dearing, R. (1997) *Higher Education in the Learning Society*. Report of the Committee under the Chairmanship of Sir Ron Dearing, London, Stationery Office

Denholm, J. and Macleod, D. (2003) *Prospects for Growth in Further Education*, Wellington: Learning and Skills Research Centre

Department for Trade and Industry (1998) *Our Competitive Future: Building the Knowledge Driven Economy*, White Paper December 1998, London, Stationery Office

Department for Education and Skills (DfES) (2004) *Youth Cohort Study (Wave 12, sweep 1)*

Department for Education and Skills (DfES) (2007) *Gender and Education: The Evidence on Students in England*. Nottingham: DfES

Dhillon, J. (2004) An exploration of adult learners' perspectives of using learndirect centres as sites of learning, *Research in Post-Compulsory Education*, 9, 1, 147-158

Domovic, V. and Godler, Z. (2005) Educational systems' efficiency evaluation on the basis of student performance: comparison Finland-Germany. *Drustvena Istrazivanja*, 14, 3, 439-458

Education and Employment Committee (2001) *Higher Education Access*, Fourth Report, HC 124, London: House of Commons

Eggleston, J. (1977) *The Sociology of the School Curriculum*. London: Routledge and Kegan Paul

Erebus International (2005) *Review of the Recent Literature on Socio-economic Status and Learning*, NSW Department of Education and Training

Ethington, C.A. (1988) Differences among women intending to major in quantitative fields of study. *Journal of Educational Research*, 81, 6, 354-359

European Group for Research on Equity in Educational Systems (2005) Equity in European educational systems: a set of indicators, *European Educational Research Journal*, 4, 2, 1-151

Feinstein, L., Duckworth, K. and Sabates, R. (2004) *A model of Inter-generational Effects of Parental Education*, Research Brief RCB01-04, Nottingham: DfES

Fischer, C., Hout, M., Jankowski, M., Lucas, S., Swidler, A. and Vos, K. (1996) *Inequality by Design: Cracking the Bell Curve Myth*. Princeton, NJ: Princeton University Press

Fitz-Gibbon, C., (1999) Long-term consequences of curriculum choices with particular reference to mathematics and science. *School Effectiveness and School Improvement*, 10, 2, 217-252

Forsyth, A. and Furlong, A. (2003) *Socio-economic Disadvantage and Access to Higher Education*. Bristol: Policy Press

Fryer, R. (1997) *Learning for the Twenty-First Century*, London: Department of Education and Employment

Fuchs, T. and Wobmann, L. (2004) What accounts for international differences in student performance? A re-examination using PISA. *Empirical Economics*, 32, 2-3, 433-464

Fullarton, S., Walker, M., Ainley, J. and Hillman, K. (2003) Patterns of participation in year 12. *Commonwealth Department of Education, Science and Training (DEST) Research Report 33*

Gallagher, T., McEwen, A. and Knipe, D. (1997) Science education policy: a survey of the participation of sixth-form students on science and other subjects over a 10-year period, 1985-1995. *Research Papers in Education*, 12, 2, 121-42

Ginsburg, H. and Pappas, S. (2004) SES, ethnic, and gender differences in young children's informal addition and subtraction: a clinical interview investigation. *Journal of Applied Developmental Psychology*, 25, 2, 171-192

Glaser, B. G. and Strauss, A. L. (1967) *The Discovery of Grounded Theory*. Chicago: Aldine

Glover, D., Law, S. and Youngman, A. (2002) Graduateness and employability: student perceptions of the personal outcomes of university education. *Research in Post-Compulsory Education*, 7, 3, 293-306

Gorard, S. (1997) Initial Educational Trajectories, Patterns of participation in adult education and training, Working paper 8, Cardiff: School of Education

Gorard, S. (2000) E*ducation and Social Justice*, Cardiff: University of Wales Press

Gorard, S. (2004) The international dimension: what can we learn from the PISA study? pp.26-32 in Claire, H. (Ed.) *Gender in education 3-19: A fresh approach*, London: Association of Teachers and Lecturers

Gorard, S. (2005) Where shall we widen it? Higher Education and the age participation rate in Wales. *Higher Education Quarterly*, 59, 1, 3-18

Gorard, S. (2006a) Towards a judgement-based statistical analysis. *British Journal of Sociology of Education*, 27, 1, 67-80

Gorard, S. (2006b) Is there a school mix effect? *Educational Review*, 58, 1, 87-94

Gorard, S. (2006c) Value-added is of little value. *Journal of Educational Policy*, 21, 2, 233-241

Gorard, S. (2008a) Research impact is not always a good thing: a re-consideration of rates of 'social mobility' in Britain. *British Journal of Sociology of Education*, 29, 3 (May)

Gorard, S. (2008b) The value-added of primary schools: what is it really measuring? *Educational Review*, 60, 2

Gorard, S. and Cook, T. (2007) Where does good evidence come from? *International Journal of Research and Method in Education*, 30, 3, 307-323

Gorard, S. and Rees, G. (2002) *Creating a learning society?* Bristol: Policy Press

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

Gorard, S. and Smith, E. (2006) Beyond the 'learning society': what have we learnt from widening participation research? *International Journal of Lifelong Education*, 25, 5

Gorard, S. and Taylor, C. (2001) *Student funding and hardship in Wales: a statistical summary*. Report to the National Assembly Investigation Group on Student Hardship, Cardiff: National Assembly for Wales

Gorard, S., Rees, G. and Fevre, R. (1999a) Patterns of participation in lifelong learning: do families make a difference? *British Educational Research Journal*, 25, 4, 517-532

Gorard, S., Salisbury, J. and Rees, G. (1999b) Reappraising the apparent underachievement of boys at school. *Gender and Education*, 11, 4, 441-454

Gorard, S., Rees, G. and Salisbury, J. (2001) The differential attainment of boys and girls at school: investigating the patterns and their determinants. *British Educational Research Journal*, 27, 2, 125-139

Gorard, S., Selwyn, N. and Madden, L. (2003) Logged on to learning? Assessing the impact of technology on participation in lifelong learning. *International Journal of Lifelong Education*, 22, 3, 281-296

Gorard, S., Taylor, C. and Fitz, J. (2003) *Schools, Markets and Choice Policies*. London: RoutledgeFalmer

Gorard, S., See, B. H., Smith, E. and White, P. (2006) *Teacher Supply: The Key Issues*. London: Continuum

Gorard, S. with Adnett, N., May, H., Slack, K., Smith, E. and Thomas, L. (2007) *Overcoming Barriers to HE*, Stoke-on-Trent: Trentham Books

Gottfredson, L. (2004) Intelligence: is it the epidemiologists' elusive 'fundamental cause' of social class differences in health? Electronic version. *Journal of Personality and Social Psychology*, 86, 174-199

Grissmer, D., Kirby, S., Berends, M. and Williamson, S. (1994) *Student Achievement and the Changing American Family*. Santa Monica, Calif.: RAND Corporation, MR-488

Grissmer, D. and Flanagan, A. (1998) E*xploring Rapid Score Gains in Texas and North Carolina*, commissioned paper, Washington, D.C.: National Education Goals Panel, 1998

Haahr, J. with Nielsen, T., Hansen, E. and Jakobsen, S. (2005) *Explaining Student Performance: Evidence from the International PISA, TIMSS and PIRLS surveys*, Danish Technological Institute, www.danishtechnology.dk, accessed August 2005

Halsey, A., Heath, A. and Ridge, J. (1980) *Origins and Destinations: Family, Class, and Education in Modern Britain*. Oxford: Clarendon

Hand, A., Gambles, J. and Cooper, E. (1994) Individual Commitment to Learning. *Individuals' Decision-making about Lifelong Learning*. Employment Department

Harrison, R. (1993) Disaffection and access, in Calder J. (Ed.) *Disaffection and Diversity. Overcoming Barriers to Adult Learning*, London: Falmer

Harvard, N. (1996) Student attitudes to studying A-level sciences. *Public Understanding of Science*, 5, 4, 321-330

Hedges, L. and Nowell, A. (1998) Black-White test score convergence since 1965, in Jencks, C. and Phillips, M. (eds) *The Black-White Test Score Gap*. Washington D.C.: The Brookings Institution Press, pp. 149-182

Hendley, D., Parkinson, J., Stables, A. and Tanner, H. (1995) Gender differences in student attitudes to the National Curriculum Foundation Subjects of English, mathematics, science and technology in Key Stage 3 in South Wales. *Educational Studies*, 21, 1, 85-97

Herrnstein, R. and Murray, C. (1994) *The Bell Curve*. New York: Simon and Schuster

Higher Education Funding Council for England (2005) *Young Participation in Higher Education*. Bristol: Higher Education Funding Council for England

Hogrebe, M. C., Kyei-Blankson, L. and Zou, L. (2006) Using GIS to examine science and mathematics attainment. *Report for the Centre for Inquiry in Science Teaching and Learning (CISTL)*

Hoyles, C., Newman, K. and Noss, R. (2001) Changing patterns of transition from school to university mathematics. International Journal of Mathematical Education in Science and Technology, 32, 6, 829-45

Hramiak, A. (2001) Widening participation and ethnic minority women, Annual SCUTREA Conference proceedings

Hudson, C. (2005) Widening Participation in Higher Education Art and Design: Part 2 – Questionnaire Report. Winchester: Council for Higher Education in Art and Design

Jenkins, E. W. (2005) Important but not for me: students' attitudes towards secondary school science in education. Research in Science & Technological Education, 23, 1, 41-57

Jeynes, W. (2005) The effects of parental involvement on the academic achievement of African American youth. *Journal of Negro Education*, 74, 3, 260-274

Jidesjö, A. and Oscarsson, M. (2004) Students' attitudes to science and technology: First results from the ROSE project in Sweden. Paper presented at the XI IOSTE (International Organization for Science and Technology Education) symposium: *Science and Technology Education for a Diverse World*, Lublin, Poland. www.ils.uio.no/english/rose/network/countires/sweden/swe-jidesjoe-ioste2004.pdf

Jones, P. and Elias, P. (2005) *Science, Engineering and Technoloy and the UK's Ethnic Minority Population*, a report for the Royal Society

Jovanic, J. and King, S. (1998) Boys and girls in the performance-based science classroom: who's doing the performing? *American Educational Research Journal*, 35, 3, 477-496

Kahneman, D. and Tversky, A. (eds.) (2000) *Choices, Values and Frames*. Cambridge: Cambridge University Press

Kalmijn, M. (1994) Mother's occupational status and children's schooling. *American Sociological Review*, 59, 257-276

Kennedy, H. (1997) *Learning Works: Widening Participation in Further Education. Coventry*: Further Education Funding Council

Khazzoom, A. (1997) The impact of mothers' occupations on children's occupational destinations. *Research in Stratification and Mobility*, 15, 57-89

Khoury, G. A. and Voss, B. E. (1985) Factors influencing high school students' science enrollments patterns: academic abilities, parental influences, and attitudes towards science. *Annual meeting of the National Association for Research in Science Teaching*

Lamb, S. (1997) Gender differences in mathematics participation: an Australian perspective. *Educational Studies*, 23, 1, 105-125

Lambert, P. (2002) Handling occupational information. *Building Research Capacity*, 4, 9-12

Layzer, D. (1974) Heritability analyses of IQ scores: science or numerology? *Science*, 183, 131, 1259-1266

Lee, C. (2003) Why we need to re-think race and ethnicity in educational research. *Educational Researcher*, 32, 5, 3-5

Lemke, J. (2001) Articulating communities: socio-cultural perspectives on science education. *Journal of Research in Science Teaching*, 38, 296-316

Lightbody, P. and Durndell, A. (1996) Gendered career choice: is sex stereotyping the cause or the consequence? *Educational Studies*, 22, 133-146

Lord, P. and Johnson, A. (2005) *Students' Experiences and Perspectives of the National Curriculum and Assessment: Fifth Update of the Research Review*. London: Qualifications and Curriculum Authority

Loury, L. (1995) Letter to the editor, *Commentary*, 100, 2

Lucow, W. (1954) Estimating components of variation in an experimental study of learning. *Journal of Experimental Education*, 22, 265-271

Lyons, T. (2004) Choosing physical science courses: the importance of cultural and social capital in the enrolment decisions of high achieving students. Paper presented at the International Organisation for Science and Technology Education IOSTE XI Symposium, Lublin, Poland, 25-30

MacCurdy, R. (1954) *Characteristics of Superior Science Students and some Factors that have led to their Development*. Doctoral thesis. Boston: Boston University

Maguire, M., Maguire, S. and Felstead, A. (1993) *Factors Influencing Individual Commitment to Lifelong Learning*, Research Series No.20, Sheffield: Employment Department

Marcon, R. (1999) *Impact of Parent Involvement on Children's Development and Academic Performance*: A Three-Cohort Study. Paper presented at the Meeting of the Southeastern Psychological Association (Savannah, GA, March 1999)

Marks, G. (2007) Are father's or mother's socioeconomic characteristics more important influences on student performance? Recent international evidence. *Social Indicators Research*, 85, 2, 293-309

Metcalf, H. (2005) Paying for university: the impact of increasing costs on student employment, debt and satisfaction. *National Institute Economic Review*, 191, January, 106-117

Miller-Whitehead, M. (2002) *Class Size and Student Science Achievement: Not as Easy as It Sounds*. Report: ED470676

Modood, T. (1993) The number of ethnic minority students in higher education: some ground for optimism. *Oxford Review of Education*, 19,167-182

Murphy, C. and Beggs, J. (2001) Students' attitudes, perceptions and understanding of primary science: comparisons between Northern Irish and English schools. Paper presented at the BERA conference, University of Leeds, September 13-15

Murphy, P. and Whitelegg, E. (2006) Girls and physics: continuing barriers to 'belonging'. *Curriculum Journal*, 17, 3, 281-305

Mwetundila, P. (2001) *Gender and other Student Level Factors influencing the Science Achievement of 13-14 year old Australian*. MA (Ed) Thesis, Flinders University of South Australia

Nash, R. (2005) Cognitive habitus and collective intelligence. *Journal of Education Policy*, 20, 1, 3-21

National Audit Office (2002) *Widening Participation in Higher Education in England*. London: The Stationery Office

NfER (2006) *Factors Influencing Year 9 Career Choices*. Report for The Engineering and Technology Board, Slough: NFER

O'Hare, W. (1996) A new look at poverty in America. *Population Bulletin*, 51, 1-46

Obourn, E. (1956) The role of assumptions in ninth-grade General Science. *Science Education*, 40, 2, 87-91

O'Connor, S., Miranda, K. and Beasley, T. (1999) The linkages among the home environment and academic self-concepts on achievement of intact and nonintact family structures of American high school students. Paper presented at the Annual Meeting of the American Educational Research Association, Montreal, April 23

OFSTED (1995) Science: *A Review of Inspection Findings 1993/94*. London: HMSO

Okpala, C., Okpala, A. and Smith, F. (2001) Parental involvement, instructional expenditures, family socioeconomic attributes, and student achievement. *Journal of Educational Research*, 95, 2, 110-115

Oliver, J. and Simpson, R. (1988) Influences of attitude toward science, achievement motivation and science self-concept on achievement on science: a longitudinal study. *Science Education*, 72, 2, 143-155

Osborne, J. and Collins, S. (2000) *Students' and Parents' Views of the School Science Curriculum*. London: King's College London

Osborne, J., Simon, S. and Collins, S. (2003) Attitudes towards science: a review of the literature and its implication. *International Journal of Science Education*, 25, 9, 1049-1079

Patel, N. (2006) Perceptions of student ability: effects on parent involvement in middle school. Doctoral thesis. *Dissertation Abstracts International, A:* The *Humanities and Social Sciences*, 67, 03

Payne, J. (1998) *Routes at Sixteen*: *Trends and Choices in the Nineties*. London: DfES Research brief No 55

Peng, S. and Jaffe, J. (1979) Women who enter male-dominated fields of study in higher education. *American Educational Research Journal*, 16, 3, 285-293

Ponchaud, B. (2001) *Primary science: Where next?* Paper presented at the ASE conference, Leeds

Pong, S. (1997) The school compositional effect of single parenthood on 10th-grade achievement. *Sociology of Education*, 71, 1, 23-42

Pustjens, H., Van de gaer, E., Van Damme, J. and Onghena, P. (2004) Effect of secondary schools on academic choices and on success in higher education. *School Effectiveness and School Improvement*, 15, 3/4, 281-311

QCA (2004) *Mathematics 2003-04 Annual Report on Curriculum and Assessment*. London: QCA

Rawls, J. (1971) *A Theory of Justice*. Oxford: Oxford University Press

Roberts, G. (2002) *SET for Success: The Supply of People with Science, Technology, Engineering and Mathematics Skills*. HM Treasury

Robinson, P. (1997) *Literacy, Numeracy and Economic Performance*. London: Centre for Economic Performance, London School of Economics and Political Science

Rothman, S. (2003) *The changing influence of socioeconomic status on student achievement: recent evidence from Australia*. Paper presented at the annual meeting of the American Education Research Association. Chicago, April

Sadker, M. and Sadker, D. (1994) *Failing at Fairness*, New York: Scribner

Schoon, I., Ross, A. and Martin, P. (2007) Science related careers: aspirations and outcomes in two British cohort studies. *Equal Opportunities International*, 26, 2, 129-143

Schulz, W. (2005) Mathematics Self-Efficacy and Student Expectations: Results from PISA 2003. *Paper prepared for the Annual Meeting of the American Educational Research Association*, Montreal, Apr 11-15

Selwyn, N., Gorard, S. and Furlong, J. (2006) *Adult Learning in the Digital Age*, London: Routledge

Shaver, A. and Walls, R. (1998) Effect of parent involvement on student reading and mathematics achievement. *Journal of Research and Development in Education*, 31, 2, 90-97

Shuttleworth, I. and Daly, P. (1997) Inequalities in the uptake of science at GCSE: evidence from Northern Ireland. *Research Papers in Education*, 12, 2, 143-156

Simpson, J. C. (2003) Mom matters: maternal influence on the choice of academic major – 1. *Sex Roles: A Journal of Research*, May

Smith, H. and Washton, N. S. (1957) The natural sciences and mathematics. *Review of Educational Research*, 27, 4, 343-355

Smithers, A. and Robinson, P. (2000) *Coping with Teacher Shortages*. Centre for Education and Employment Research, Liverpool University, for the National Union of Teachers

Smyth, E. and Hannan, C. (2006) School effects and subject choice: the uptake of scientific subjects in Ireland. *School Effectiveness and School Improvement*, 17, 3, 303-327

Taylor, C. and Gorard, S. (2005) *Participation in Higher Education: Wales. Report for Independent Study into Devolution of the Student Support System: The Rees Review*. Cardiff: National Assembly for Wales

Taylor, P. (1993) Minority ethnic groups and gender access in higher education. *New Community*, 19, 425-440

Tinklin, T., Croxford, L., Ducklin, A. and Frame, B. (2003) Inclusion: a gender perspective. *Policy Futures in Education*, 1, 4, 640-652

Turkheimer, E., Haley, A., Waldron, M., D'Onofrio, B. and Gottesman I. (2003) Socioeconomic status modifies heritability of IQ of young children. *Psychological Science*, 14, 6, 623-628

Uerz, D., Dekkers, H. and Beguin, A. (2004) Mathematics and language skills and the choice of science subjects in secondary education. *Educational Research and Evaluation*, 10, 2, 163-182

Ulrich, N. (2004) *Mature Students: Access to and Experience of HE Part-time Foreign Language Degrees*. Aston University

van Langen, A., Rekers, M. and Dekkers, H. (2006) Sex-related differences in the determinants and process of science and mathematics choice in pre-university education. *International Journal of Science Education*, 28, 1, 71-94

Walford, G. (2004) No discrimination on the basis of irrelevant qualifications. *Cambridge Journal of Education*, 34, 3, 353-361

Wallace, C. (2005) *Science Paper: Socioeconomic Status and Intelligence*. Creighton University. www.icherney.com/Teaching/Courses/Intelligence/Science%20Papers/Erin_Wallace.doc

Wang, J., Wildman, L. and Calhoun, G. (1996) The relationship between parental influences and student achievement in seventh grade mathematics. *School Science and Mathematics*, 96, 8, 395-400

Weinburgh, M. (1995) Gender differences in student attitudes toward science: a meta-analysis of the literature from 1970 to 1991. *Journal of Research in Science Teaching*, 32, 4, 387-397

Wilson, W. (1987) *The Truly Disadvantaged*. Chicago: Chicago University Press

Wobmann, L. (2003) Schooling resources, educational institutions and student performance: the international evidence. *Oxford Bulletin of Economics and Statistics*, 65, 2, 117-170

Woodrow, D. (1996) Cultural inclinations towards studying science and mathematics. *New Community*, 22, 23-38

Wright, S. (2006) *The Health of Subjects: Evidence from Examinations Entries*. The Nuffield Review of 14-19 Education and Training. Research Report 5

Xie, Y. and Goyette, K. (2003) Social mobility and the educational choices of Asian Americans. *Social Science Research*, 32, 3, 467-498

Yang, Y. (2003) Dimensions of socio-economic status and their relationship to mathematics and science achievement at individual and collective levels. *Scandinavian Journal of Educational Research*, 47, 1, 21-41

Zill, N. (1994) Understanding why children in stepfamilies have more learning and behaviour problems than children in nuclear families. In Booth, A. and Dunn, J. eds. *Stepfamilies: Who Benefits? Who Does Not?*, 97-106. Hillsdale, NJ: Erlbaum

Appendices

Appendix 1 – List of seminar attendees

Presenters

Professor Stephen Gorard, School of Education, University of Birmingham

Dr Stuart Bevins, Centre for Science Education, Sheffield Hallam University

Eleanor Brodie, Centre for Science Education, Sheffield Hallam University

Merisa Thompson, Centre for Science Education, Sheffield Hallam University

Attendees

Ms Gillian Beeley, Lancashire Education Business Partnership

Professor Jo Boaler, Sussex Institute, University of Sussex

Ms Audrey Brown CBE, Chief Statistician, DCSF

Ms Debra Dance, STEM Curriculum Leader, DCSF

Professor Jim Donnelly, School of Education, University of Leeds

Dr Pat Drake, School of Education, University of Sussex

Dr Lee Elliot Major, Sutton Trust

Ms Angela Hall, Nuffield Curriculum Centre

Professor Edgar Jenkins, School of Education, University of Leeds

Mr Geoffrey Kent, School of Education, University of Sussex

Ms Magdalini Kolokitha, London Knowledge Lab

Professor Patricia Murphy, Department of Education, The Open University

Ms Alison Redmore, East of England Science Learning Centre

Dr Jim Ryder, School of Education, University of Leeds

Dr Tony Sewell, Generating Genius

Mr Birendra Singh, Barking and Dagenham LA

Dr Emma Smith, School of Education, University of Birmingham

Mr Nigel Thomas, Gatsby Charitable Foundation

Mr Anthony Tomei, Nuffield Foundation

Royal Society

Professor Michael Reiss, Education Director

Ms Ginny Page, Education Senior Manager

Ms Geraldine Treacher, Education Policy Officer

Appendix 2 – Council review group

Professor Kay Davies CBE FRS, Dr Lee's Professor of Anatomy, Honorary Director, MRC Functional Genetics Unit, Associate Head, Department of Physiology Anatomy and Genetics, University of Oxford

Mr Mike Januszewski, Head of Science, Thomas Hardye School

Professor Mary Ratcliffe, Head of School of Education, University of Southampton

Professor Martin Taylor FRS (Chair), Physical Secretary and Vice President, The Royal Society

Appendix 3 – Interview schedules for focus groups

Parent Interview Schedule: Items/prompts

Context

1. What is your attitude towards science?
   Does it interest you? Do you view it as important?
2. How do you view science and do you see any connections/relevance to your world?
3. How do you currently understand the worlds of school and school science?
4. How did you find studying science when you were at school?
5. Do you think your social background influences how you or your children think about science and science education?
6. How do you feel ethnicity and/or culture affects how one thinks about science?

Specific

7. How do you think science impacts on your children?
8. How do you determine what is appropriate support/influence to exert upon your children and what isn't?
9. Do you interact with your children regarding their school studies?
10. What about science? Is your engagement with your children to a lesser or greater extent when compared with other subjects?
11. Do you think that the type of school your child goes to has a (strong) influence on their views/perceptions? In relation to science?
12. Has your own experience of education influenced your attitudes to what you want for your child?

Teacher Interview Schedule: Items/prompts

1. Can you describe how you perceive science teaching currently?
2. How well do you think the pupils here interact with your lessons?
3. Would you say pupils at this school enjoy science?
4. Do you think teaching science at a wealthy grammar/poor comprehensive school would be much different to your current experience? Please explain any differences.
5. Do you think that there is a certain type of pupil that aspires towards science more than others? Please explain.
6. Do you think that ethnicity has an impact on a pupils' participation and attainment in school science? If so, why do you think this is?
7. Do you think that the social background of pupils has an affect on pupils' participation and attainment in school science? If so, why do you think this is?
8. What do you think the key issues are that inhibit or enhance the teaching and learning of science at your school?
9. Do you have much contact with parents?
10. Do you think that more contact with parents would enhance pupils' learning or willingness to learn?

Pupil Interview Schedule: Items/prompts

1. Do you enjoy science at school? Why/why not?
2. Do you find science at school interesting? Why/why not?
3. Do you think science is an important subject?
   Why/why not?
   How do you feel your teachers/family/peers/wider community affect this?
4. Do you think it is important to do well in science?
   Why/Why not?
   How do you feel your teachers/family/peers/wider community affect this?
5. Do you feel that it is easy or difficult to succeed in science? Why/Why not?
   How do you feel your teachers/family/peers/wider community affect this?
6. Do you think it is important to work hard in science?
   Why/Why not?
   How do you feel your teachers/family/peers/wider community affect this?
7. Who encourages you to work hard in science school work?
   Teachers/family members/peers/wider community?
8. What are the expectations of your teachers/family/peers/community?
9. Do you feel that there are any barriers to succeeding at school? Science/general? Where do you come across them? Teachers/School, Family/Ethnicity/Cultural Background, Peers/Wider Community?
10. What changes in your life would have the biggest impact on your attitude towards science and your willingness to work hard?

The Royal Society
Education
6–9 Carlton House Terrace
London SW1Y 5AG
tel +44 (0)20 7451 2500
fax +44 (0)20 7451 2692
email education@royalsociety.org
web royalsociety.org

The Royal Society is a Fellowship of more than 1300 outstanding individuals from all areas of science, mathematics, engineering and medicine, who form a global scientific network of the highest calibre. The Fellowship is supported by over 100 permanent staff with responsibility for the day-to-day management of the Society and its activities. The Society encourages public debate on key issues involving science, engineering and medicine, and the use of high quality scientific advice in policy-making. We are committed to delivering the best independent expert advice, drawing upon the experience of the Society's Fellows and Foreign Members, the wider scientific community and relevant stakeholders.

As we prepare for our 350th anniversary in 2010, we are working to achieve five strategic priorities:

- Invest in future scientific leaders and in innovation
- Influence policymaking with the best scientific advice
- Invigorate science and mathematics education
- Increase access to the best science internationally
- Inspire an interest in the joy, wonder and excitement of scientific discovery

ISBN: 978-0-85403-699-8
Issued: June 2008 RS1258

Founded in 1660, the Royal Society is the independent scientific academy of the UK, dedicated to promoting excellence in science

Registered Charity No 207043