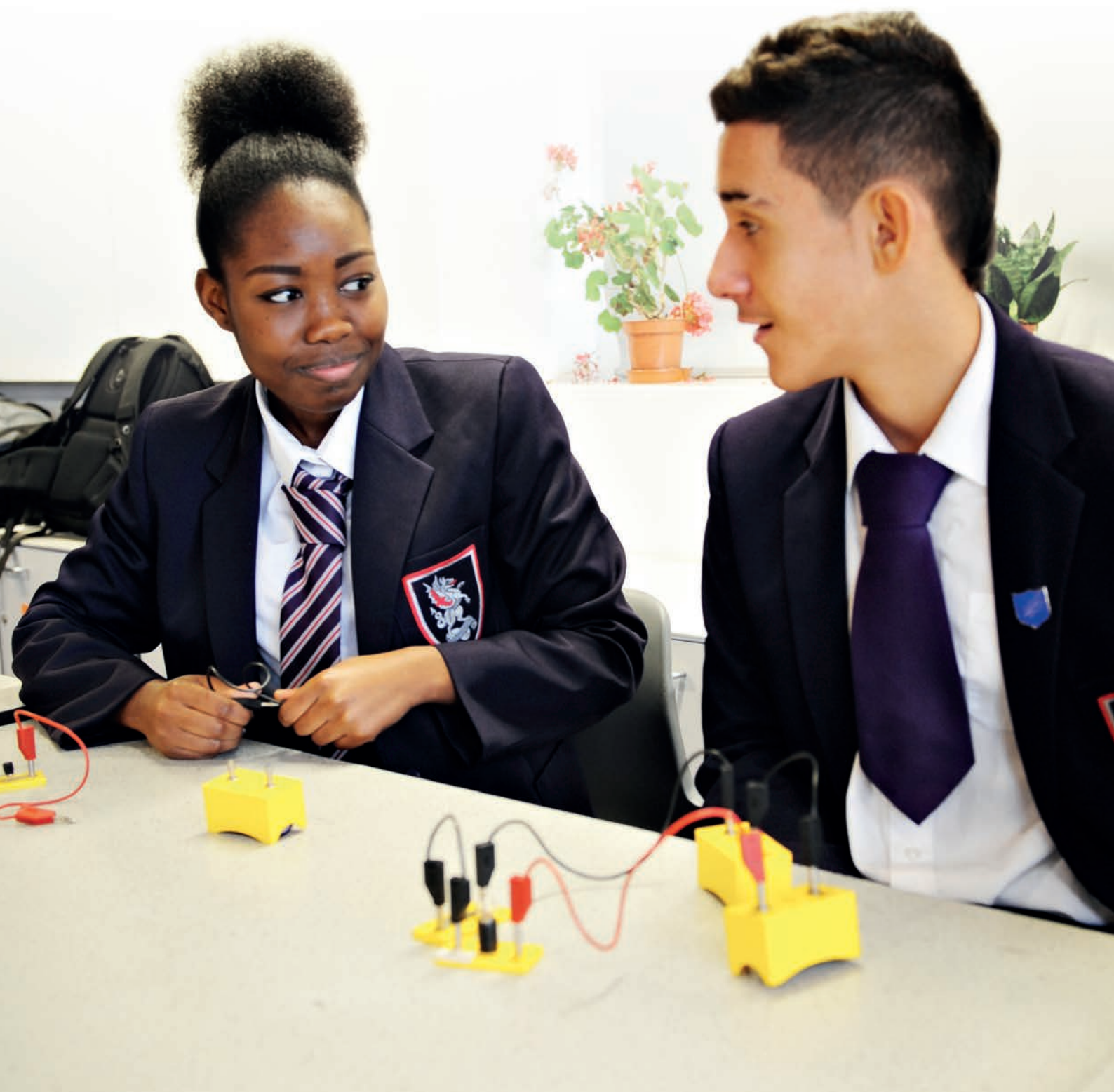# Raising Aspirations in Physics

A review of research into barriers to STEM participation for students from disadvantaged backgrounds

IOP Institute of Physics

The Institute of Physics is a leading scientific society. We are a charitable organisation with a worldwide membership of more than 50,000, working together to advance physics education, research and application. We engage with policymakers and the general public to develop awareness and understanding of the value of physics and, through IOP Publishing, we are world leaders in professional scientific communications.

In September 2013, we launched our first fundraising campaign. Our campaign, Opportunity Physics, offers you the chance to support the work that we do.

Visit us at **www.iop.org/fundraising**.

Contents

1

Introduction

Three major demographic factors are correlated with the likelihood of a young person choosing a physics course beyond the compulsory phase of education:

- Gender: girls are much less likely to take physics than boys.
- Socioeconomic status (SES): children from more disadvantaged families are less likely to take physics.
- Ethnicity: people from certain ethnic backgrounds are more (e.g. Chinese and Indian) or less (e.g. white-British and Afro-Caribbean) likely to take physics.

The Institute of Physics aims to actively promote physics to all, regardless of their background. To date, most of the emphasis of its work has been on gender and, to a lesser extent, ethnic minorities[1]. For the work on gender, an important first step was a literature review (Murphy and Whitelegg, 2006), which provided the evidence base for subsequent projects and reports.

This review aims to perform a similar task for the issue of socioeconomic status; it sets out to determine what previous research and surveys reveal in relation to the barriers preventing young people from lower socioeconomic groups choosing science, technology, engineering and mathematics (STEM) subjects. Of those subjects, physics has the largest disadvantage gap, with high achievers from disadvantaged backgrounds (as measured by free school meals) much less likely to enter physics A-level and less likely to gain top grades than their contemporaries from more privileged backgrounds, but with similar achievement at GCSE (Department for Education, 2011b).

As well as a discussion of the evidence, there is also a set of recommendations aimed at policymakers, practitioners in secondary schools and organisations that provide support for schools, as well as researchers who are interested in the topic. The issues are deep-rooted and any solutions will require concerted action from policymakers, education providers and employers.

The overriding message from the evidence is that poverty affects educational outcomes in myriad ways. This makes it difficult to counter them all with remedial measures. The evidence points to deep-rooted social differences, indicating that it would be most effective to address the underlying issue of economic inequality, rather than attempting to combat inequality of opportunity piecemeal across many independent issues. While this is a political statement, all of the major political parties agree on the need to broaden the range of social backgrounds of people entering the professions (Milburn, 2012), which, for physics, means increasing the range for those progressing to A-level.

Despite the deep-seated nature of the issue, there are a number of measures that can and should be taken to increase the number of students from lower SES backgrounds entering STEM subjects and some of these are presented in section 2.

Recommendations

There is no easy solution to increasing the number of students from disadvantaged backgrounds taking physics. The Joseph Rowntree Foundation states that a lack of robustness and evaluation, and questionable assumptions about low aspirations in poorer children and parents has led to a proliferation of interventions with unknown effectiveness in enabling disadvantaged children to realise their ambitions (Carter-Wall and Whitfield, 2012).

The recommendations below are based on the best evidence from the review and indicate the approaches that are most likely to make an impact. Each area is discussed in more detail, with full references, in the main body of the report.

2.1. Raise attainment with effective in-school measures

Physics (and many other STEM) courses at A-level and beyond require a high level of previous attainment. Prior attainment in science and mathematics is the strongest indicator of whether or not a student will go on to study physics. As prior attainment is strongly linked to SES, students from lower SES backgrounds are at a disadvantage when it comes to taking physics post-16.

The evidence shows that a number of measures may be effective. Schools should implement evidence-based strategies that improve attainment, such as:

- Use feedback from students effectively.
- Provide targeted homework (at secondary school).
- Engage pupils with the issues surrounding SES and their own learning.
- Instigate peer-learning programmes for pupils to help increase attainment, build self-confidence and give students opportunities to develop presentation skills.
- Recruit specialist physics teachers where possible.
- Provide training to improve teaching, which can help to break the cycle of poor attainment in schools in deprived areas. Interventions such as the Stimulating Physics Network (SPN)[2] have been shown to be effective.
- Avoid setting; if that is not possible, take into account that prior attainment may be heavily dependent on social background.
- Select students for Gifted and Talented programmes based on potential and interest rather than solely on past attainment.

2.2. Develop home–school partnerships

Involving parents with school and their child's education can help to increase a child's attainment and aspirations. Developing a successful programme of parental engagement takes time and trust between all parties concerned.

Schools should:

- Consult the whole school community to create and implement a meaningful "Home School Agreement", which can be recognised on all sides.
- Integrate parental engagement into a whole-school approach, rather than as a "bolt-on" activity.
- Provide well structured programmes (e.g. homework clubs) with high-level support to reduce drop-out rates.
- Train all school staff about the best ways to engage parents with their child's education and give teachers adequate time to undertake this work.
- Provide advice on how parents can help their children with homework and generally improve educational achievement.

2: Recommendations

Working with parents:
- Recognise parental needs and have the improvement of pupils' learning as a clear goal.
- Use flexible models of working in partnership in different contexts and maintain a genuine two-way exchange.
- Tap into parents' needs and interests by creating comfortable environments and involve other members of the community.

2.3. Provide appropriate advice on routes through education

Many students and families from disadvantaged backgrounds are not aware of the range of careers that exist in STEM areas and, equally important, in areas where STEM skills offer a significant advantage. Consequently, subject choices are made without proper information as to where they might lead and the economic consequences of particular choices are not made visible. The evidence indicates that it is not sufficient simply to offer examples of STEM jobs; such an approach is unlikely to succeed and may be counter-productive.

Schools should:
- Integrate awareness of skills development into mainstream teaching; students should realise that STEM skills are applicable across a wide range of careers.
- Ensure careers advice and guidance: starts early enough (before year 9) to be effective; is bespoke to the student and their current aspirations; concentrates on the next stage of choice; and includes parents.
- Implement a proactive approach in matching work placements with pupils.
- Provide information on how to access higher education and which subjects are desired by universities.

2.4. Increase science capital

Science capital[3] refers to having science-related qualifications, understanding, knowledge (about science and "how it works"), interest and social contacts (e.g. knowing someone who works in a science-related job). Students from under-represented groups will have few role models, people who are "like them", visible in STEM careers. Parents who have not been to university themselves may not be familiar with the routes into higher education and may not see this as an option for their children. For such children, inspiration and information from other adults, including teachers, can be important and influential. Girls especially are more likely to take a subject post-16 if they think the teacher is interested in their education as an individual, yet conversely girls are much less likely to think this is true compared with boys.

Schools should:
- Raise the overall profile of science in school. This requires support from senior leadership and the science department as a whole. Any strategies need to be embedded and should foster a general culture among adults in the school and the surrounding community of being positive about physics and STEM.
- Endeavour to build long-term relationships between pupils and role models (who could be ex-pupils) with a similar background in terms of geography and SES. One-off visits are much less likely to be effective than establishing a successful STEM club.
- Make sure all teachers are aware of the influence they can have on children's future careers, that they are informed about current entry routes to different careers and they do not discourage pupils from pursuing STEM careers based on their personal opinions and stereotypes.
- Explore socio-scientific issues in lessons: this has a positive effect on encouraging young people (especially females) to choose post-compulsory STEM education.

Professional bodies, employers and other organisations should:

- Assist schools in running events by providing resources, including staff, that can engage parents and pupils about different careers routes.
- Provide and support appropriate role models with similar social backgrounds so students can see and get to know people "like them" in STEM roles.
- Assist schools in implementing long-term programmes to highlight the many careers and opportunities available in and from science.
- Use media in a positive way to provide examples of different career paths and to counteract stereotypical images of scientists.

2.5. Improve awareness of further and higher education

There appears to be a number of barriers that make it difficult for students from low SES backgrounds to study STEM subjects at university. Some of these may be practical, such as the costs involved with moving away from home and tuition fees. Others are linked to a lack of information or aspiration.

Further and higher education providers should:

- Provide schools with information about the appropriate subjects and courses to study at school that are required to apply for their HE STEM courses.
- Provide information about bursaries and other financial help available at their institution.
- Be aware of the impact of partner-school agreements especially if certain STEM courses (e.g. physics) are not offered widely in the region.
- Ensure there is a collaborative outreach/ambassador approach across the different STEM-related departments within the university so best practice can be shared.
- Provide opportunities for families to increase their science capital.

3

The importance of science, technology, engineering and maths (STEM)

There are many reasons to try to increase the uptake of STEM subjects at A-level. Many employers have difficulty recruiting staff with appropriate STEM skills and/or expect difficulty meeting the need for STEM skills in the next three years (CBI, 2012). Young people themselves need the skills and aspirations essential for building the UK's economy and to allow them to participate in an increasingly scientific and technological society (Finegold, Stagg and Hutchinson, 2011). Projections of future employment suggest there will be even more of a demand for STEM-qualified workers, along with significant political pressure to reduce migration levels.

It is often pupils from less-privileged backgrounds who have most to gain by pursuing STEM qualifications, but they are also the least likely to know how to access different types of qualifications, higher education and the appropriate routes to different careers (Gorard and Bevins, 2008). Analysing the demographics of physics graduates shows them to be overwhelmingly white (87%), male (79%) and from higher socioeconomic groups (80%[4]) (Institute of Physics, 2006) (Institute of Physics, 2012a). Recent figures indicate that almost all pupils (>95%) who gain an A-level in physics are accepted onto university courses (Institute of Physics, 2012b). This suggests that students from lower SES backgrounds are not applying to do physics in the first place, rather than being prevented by the admissions procedures at universities (Gorard and Bevins, 2008).

3.1. STEM subjects at A-level
A-levels are generally seen as the main route into higher education, although other routes are possible. University degree courses usually ask for a combination of specific A-level courses and grades. A significant number of schools are not entering any candidates in A-level physics and mathematics, so they do not have the appropriate combinations of subjects to enter a number of STEM degree courses. The lack of STEM graduates has established a self-perpetuating cycle with too few scientists and mathematicians being produced to help inspire and educate the next generations (The Royal Society, 2011).

As well as being important subjects in their own right, physics and mathematics underpin most of engineering and the other sciences. However, between 2005 and 2009, the most popular A-level subjects were social sciences (~30% of all A-level entries) and arts (~25%), followed by the core sciences (~15%). Over a similar period, only 28% of students took any core science at A-level (The Royal Society, 2008). Within the core sciences of chemistry, biology and physics, physics is the least popular subject (see figure 1). In 2007, only 3.6% of the 17 year olds in England took physics (Bennet, Hampden-Thompson and Lubben, 2011). This compares with 7.1% taking biological sciences and 5.3% taking chemistry. However, when employers or universities are asked, physics is rated as one the most highly sought after subjects at A-level (The Russell Group, 2012). A similar pattern is also seen at university level where biological sciences remain popular, while chemistry and physics degree courses do not attract as many students (Stagg, Laird and Taylor, 2003) (McWhinnie, 2012).

In recent years, entries to all STEM A-levels have risen, although, in the case of physics, they are still below the levels achieved in the 1980s.

Figure 1: Numbers of science A-level entries over the last three decades
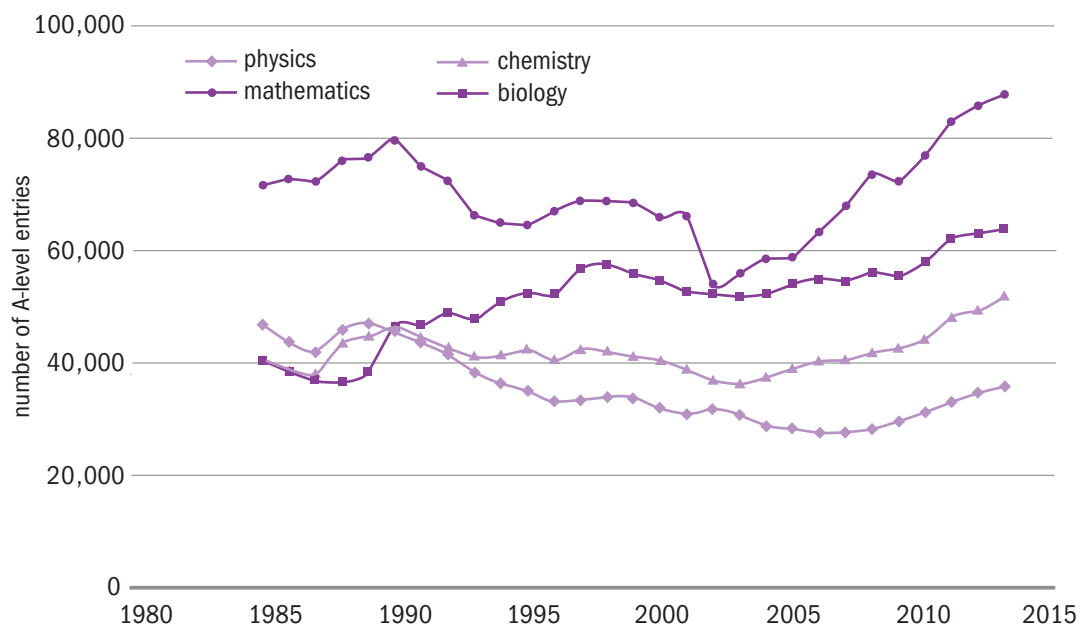
Data from the Joint Council for Qualifications (JCQ)

4

Factors influencing school success in STEM

Many factors influence participation and achievement in STEM subjects at school (see table 1). Some of these are intrinsic to the child, such as ethnicity, gender and SES, while others, such as basic literacy and prior attainment (the most important factor) may often be contingent on the intrinsic factors. For example, low levels of literacy and numeracy will often be correlated with low SES (Crawford, Macmillan and Vignoles, 2014). However, different factors can have different impacts when combined. American children living in poverty for some part of their childhood are much more likely to drop out of high school compared with students who have never lived in poverty. Additionally, children who are poor at reading when they enter high school are also more likely to drop out. For those children who cannot read well and live in poverty, this has a "double whammy" effect in terms of their risk of dropping out of school (Hernandez, 2011).

The Campaign for Science and Engineering in the UK (CaSE) (CaSE, 2008) found that simply belonging to a group that is under-represented is a disadvantage in itself and belonging to more than one can be a double disadvantage, for example coming from a lower SES background and belonging to certain ethnic backgrounds (Department for Business, Innovation and Skills, 2011a). In the UK, SES appears to have little impact on the GCSE performance of children from Chinese origins, but white British and black Caribbean boys eligible for free school meals (FSMs) perform poorly (HM Government, 2011). It is possible that this difference stems from cultural attitudes: white western students believe that success in mathematics comes from being naturally gifted, whereas students from China and other Asian cultures relate success in these subjects to hard work (Stigler and Hiebert, 1999).

Inevitably, underrepresentation in school leads to shortages of individuals at higher levels to act as role models or to provide support networks. This lack of suitable role models is discussed in more detail in section 6.6 (p28), but research carried out at the Institute of Education suggests that identification with "key elders" is an important factor in influencing youngsters to read physics at university (Rodd, Reiss and Mujtaba, 2007).

Table 1: Factors influencing entry into STEM subjects at school

Prior attainment	Basic literacy, numeracy and investigative skills
GCSE and A-level choices (or equivalent)	Ethnicity
Perception of science and engineering	Socioeconomic status (SES)
Aspirations of individual students	Gender

Effects of socioeconomic status on education

Socioeconomic status (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 FSMs or an indicator of deprivation in the local area. These are explored in more detail below.

- The Index of Multiple Deprivation (IMD) uses 38 separate indicators organised within seven domains[5]. These are weighted and combined to calculate the IMD, which is an overall measure of deprivation experienced by people living in a specific area (of approximately 1500 people). As the scale is continuous and relative, there is not a definitive cut off at which we can say an area is deprived. A common use of IMD is to focus on the most deprived 10%. This can be misleading as some areas may have a mixture of households with varying levels of SES, yet the whole area will be labelled with one measure.
- Income Deprivation Affecting Children Index (IDACI) is a ranking based on the percentage of children living in low-income households. Again, this is based on geographical area (of around 1500 households), so is not reliable on the level of a single child.
- Free school meals (FSMs), which are available to students whose families have a low income (<£16k roughly) or are in receipt of certain benefits. Nationally, approximately 18% (Department for Education, 2013a) of pupils are eligible; however, this is likely to be an underestimate of those eligible as many do not claim, possibly due to the stigma associated with being "labelled" FSM (Kounali *et al.* 2008) (Rock, 2012). The take up of FSMs declines as pupils

progress through the education system, probably for the same reason.

- The "Pupil Premium" is additional funding introduced in April 2011 to support disadvantaged pupils. It is allocated to schools for every pupil who: has been registered for FSMs at any point in the last six years; has been "looked after" continuously for more than six months; or is a child of service personnel. Using this as a measure is therefore more inclusive than a current year's FSM data alone.

These measures are actually indications of income deprivation, rather than SES, but are widely used as an indicator for SES and educational disadvantage.

In Britain, parental income has a stronger influence on a child's future income than in Canada, Germany or Sweden (HM Government, 2011) and schools in the UK are among the most socially segregated (OECD, 2012) (Coughlan, 2012). Children growing up in poorer families emerge from school with substantially lower levels of educational attainment (Goodman and Gregg, 2010), which is a major contributing factor to patterns of social mobility and poverty. A study of schools in East London (Hamnett, Ramsden and Butler, 2007) found that the SES of students accounted for more variation in school performance than ethnicity. In addition, the proportion of pupils from a given social background played some role in boosting or diminishing the overall school performance and therefore influenced the performance of an individual pupil regardless of their background.

There is clearly a lack of social mobility in the UK; in a recently published social mobility strategy the government acknowledged there is still "a long way to go" (HM Government, 2011). Only 7% of the UK population attend independent (fee-paying) schools, but the

[5] The seven domains used in the IMD are: Income, Employment, Health, Education, Skills and training, Housing and services, Crime and Living environment

privately educated account for more than half of the top level of most professions, including 70% of high court judges, 54% of top journalists and 54% of chief executive officers of FTSE 100 companies (HM Government, 2011).

Children living in a household with lower SES are less likely to do well at school or go to university. In 2010, the Sutton Trust reported that, at the 25 most academically selective universities in England, only 2% of the student intake was made up of FSM pupils (nationally 16% of secondary school pupils are eligible for FSMs), compared with 72.2% of other state school pupils, and just over a quarter of the intake (25.8%) was from independent schools (The Sutton Trust 2010). These participation gaps mainly reflect differences in prior attainment: independent school pupils are three and a half times more likely than FSM pupils to attain five GCSEs with grades A*–C including English and mathematics. Pupils who do well in physics and mathematics at the age of 16 are more likely to go on to study physics at A-level and therefore have

the option to study physics at university. A large group of children are therefore being precluded from a physics career simply by being born into a poorer family (The Sutton Trust, 2010) (Gill and Bell, 2011) (Crawford, Macmillan and Vignoles, 2014).

The Royal Society (The Royal Society, 2008) acknowledges the link between SES and attainment differences in GCSE and A-level results in science and mathematics, but suggests that if students from low SES backgrounds do achieve good grades at GCSE, then they are just as likely as other students to go on to take those subjects at A-level (Bennet, Hampden-Thompson and Lubben, 2011). However, other research shows that pupils from lower SES backgrounds are being lost from the pathways into STEM careers at all stages, from primary school through to attainment at GCSE and subject choices post-16 (Gorard and See, 2009) (Department for Education, 2011b). Consequently, support needs to be provided for these young people at all stages of their education.

> " No-one should be prevented from fulfilling their potential by the circumstances of their birth. What ought to count is how hard you work and the skills and talents you possess, not the school you went to or the jobs your parents did.
> **HM Government, April 2011**

Barriers to attainment facing pupils from lower socioeconomic backgrounds

There are a number of important points in a child's education that can influence their attainment through school (Goodman and Gregg, 2010). These include:

- Early years: the richness of the early home-learning environment.
- Primary school: maternal aspirations for higher education, how far parents and children believe their own actions can affect their lives, and children's behavioural problems.
- Secondary school: pupil's and parents' expectations for higher education, access to material resources and engagement in anti-social behaviour.
- Across childhood: parents' own cognitive abilities.

This section looks at some of these potential barriers to attainment in more detail.

6.1. The impact of socioeconomic status in education

6.1.1. The attainment gap

The gap in attainment between the poorest and richest children grows particularly rapidly during the primary school years. By age 11, only around three-quarters of children from the poorest families reach the government's expected level at Key Stage (KS) 2, compared with 97% of children from the richest. Most tellingly, by age seven, poor children who do well in the early years fall behind relative even to low-ability children from better-off backgrounds (Goodman and Gregg, 2010) (see figure 2).

Pupils who are eligible for FSMs perform considerably less well in STEM subjects than those who are not eligible and this difference is even more marked in KS3 than in KS2

Figure 2: Children from poorer families who have shown early signs of high ability tend to fall back relative to more advantaged peers who have not performed as well

Source: HM Government 2011

(The Royal Society, 2010). By the time young people take their GCSEs, the gap between rich and poor is very large. For example, only 21% of the poorest quintile manage to gain five good GCSEs (grades A*–C, including English and maths), compared with 75% of the top quintile (Goodman and Gregg, 2010). It is also interesting to note that attainment in general decreases as pupils progress through school (The Royal Society, 2010) and many young people fail to understand the link between attainment and good employment (Hutchinson and Parker, 2009). Providing information at an early age about the grades needed for certain careers/courses could be useful. For example, some students may take GCSE exams early and be content with a grade C, not realising this may prevent them achieving their aspirations (Menzies, 2013). Poor language skills can also disadvantage

science learners and in some cases may be associated with low SES groups (Gorard and Bevins, 2008).

Because prior attainment is strongly associated with SES, schools may reinforce the attainment gap by selecting and streaming pupils based on prior attainment. This link between prior attainment and SES should be considered when pupils are selected for Gifted and Talented (G&T) or similar programmes. Such programmes should identify students with capability and potential whose ability may not be demonstrated through conventional tests (Gorard and Bevins, 2008).

6.1.2. Improving attainment and uptake of STEM subjects in school

The pupil premium was introduced in April 2011 as a cash boost to support disadvantaged pupils in schools. As there is

Adapted from Higgins, Kokotsaki and Coe 2011

Figure 3: Strategies from The Sutton Trust Toolkit for improving attainment in schools

Strategy	Summary	Pros	Cons
Effective feedback	Information given to learner and/or teacher about learner's performance relative to the learning goals, which then refocuses actions to achieve the goal. Feedback needs to include what is right, be specific and encourage their self-esteem.	Very high impact for low cost.	The method has not been used to a great extent in science so far. Feedback can have negative effects so it is important to know limitations.
Homework	Tasks given to pupils to be completed outside of class. Pupils benefit from feedback on homework and effective integration with teaching in lessons.	Appears to be an effective way of improving students' attainment at secondary school. Moderate impact.	Pupils must complete the homework for it to be effective.
Metacognitive and self-regulation strategies	These teaching approaches make learners' thinking about learning more explicit in the classroom. Usually more effective in small groups where discussion is possible.	High levels of impact including low-achieving pupils, low cost.	It may require CPD for teachers. Most studies have focused on English or maths.
Peer tutoring/peer-assisted learning strategies	Learners work in pairs or small groups to provide teaching support.	Gives benefits for both parties especially in cross-age tutoring. High impact for low cost.	Studies have focused on maths and reading. Needs coordination and some staff training.
Parental involvement	Actively involve parents in supporting their child's learning.	Moderate impact for moderate cost.	Developing effective parental involvement is challenging.

no direct link between spending on schools and outcomes for pupils, The Sutton Trust developed a toolkit (Higgins, Kokotsaki and Coe, 2011) to summarise the evidence on the best ways to improve learning and attainment, to help schools spend their pupil premium allowance effectively. The main strategies that might be useful for raising aspirations in physics are summarised in figure 3. The toolkit also reports that homework at primary school, smaller classes and uniforms are among the least effective ways of boosting school performance.

However, simply improving attainment may not raise students' aspirations for what further learning may accomplish for them (Higgins, Kokotsaki and Coe, 2011). So any strategy aimed at raising attainment must be implemented alongside strategies for raising aspirations. The Joseph Rowntree Foundation recommends further development of programmes to improve mentoring and raise self-confidence (Carter-Wall and Whitfield, 2012). For example, a peer-learning programme in schools could help to increase attainment, build self-confidence and give students opportunities to develop presentation skills.

6.1.3. STEM subjects at GCSE
At GCSE level, biology, physics and chemistry as separate subjects are more likely to be taken by academically able students, especially middle-class males from independent schools. Combined, dual, single and general science courses, on the other hand, are studied more frequently 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 (Gorard and Bevins, 2008).

Students who take separate sciences at GCSE (triple science) are about three times more likely to take physics at A-level relative to those who took double award science (The Royal Society, 2008). The number of students taking triple science has been increasing over the last few years[6], and in 2010 the CBI recommended that the top 40% of 14 year olds should automatically be opted in to separate science GCSEs, to try to increase the numbers[7]. In 2008, the science curriculum reform introduced an entitlement for highly attaining students to study three separate sciences at GCSE. A five-year study investigated the outcomes of this reform. The researchers found that the percentage of students taking triple science had increased, although girls were still under-represented (and are over-represented in dual science) at the time of the report, and although there had been a small increase in the number of FSM pupils taking triple science, they were still grossly under-represented. Furthermore, FSM pupils were still under-represented even if prior attainment was controlled for (Homer, Ryder and Donnelly, 2013).

Data from The Royal Society (The Royal Society, 2008) suggest that SES does not affect progression from those achieving good science GCSEs to physics A-level. They claim the same is true for maths and chemistry. However, more recently, the Department for Education looked at data from the National Pupil Database (NPD) in England and found that FSM pupils who had achieved an A or A* at GCSE were just as likely to take A-level mathematics, but were less likely to achieve a grade A or B (63%) compared with non-FSM high achievers (70%). There was a similar pattern in biology, chemistry and physics. Physics had the largest disadvantage gaps with FSM high achievers less likely to enter physics A-level and less likely to gain top grades (Department for Education, 2011b).

6.1.4. Choosing to study STEM subjects post-16
The most useful indicator of whether a child will take STEM subjects post-16 is attainment at 16. To progress in the traditional sciences, students must not have "failed" previously, in contrast to "new" subjects such as psychology, which are not taken before A-level. The concept of failure is relative; many schools insist on a minimum grade

[6] www.nationalstemcentre.org.uk/news/2010-gcse-results--triple-science-continues-to-grow, www.russellgroup.ac.uk/russell-group-latest-news/137-2011/4980-growing-stem-gcse-takeup-welcome-but-language-decline-of-deep-concern/ both accessed 16/03/12

[7] www.cbi.org.uk/media-centre/press-releases/2010/08/cbi-reacts-to-gcse-results/ accessed 03/07/14

B at GCSE for progression to mathematics and physics A-level. Pupils that score highly in mathematics are more likely to want to do physics at A-level, and those with lower mathematics scores tend to do biology. As prior attainment in both science and mathematics is linked to SES, it is not surprising to find that those from low SES backgrounds are less likely to take STEM subjects, and in particular physics at A-level, than other students (Gorard and Bevins, 2008) (Stagg, Laird and Taylor, 2003). An NPD study found that once prior attainment was controlled for, SES did not have much impact on choosing to study science post-16 (Homer, Ryder and Banner, 2013b).

In contrast to the recommendation that more pupils should take separate sciences, a report for the AstraZeneca Science Teaching Trust found that schools with a high level of STEM uptake post-16 tend to have a diverse pre-16 curriculum, such that it offers a range of choices for pupils with differing aptitudes for science, including applied science and triple science (Bennet, Hampden-Thompson and Lubben, 2011).

The Royal Society (The Royal Society, 2011) recommends that to increase the "pool" of potential STEM undergraduates there should be more:

- Specialist STEM teachers and continuous training.
- Understanding of school structures and curricula and how they can impact on STEM learning.
- Careers information, guidance and advice available to the post-16 cohort that allow progression to STEM HE.

The Royal Society (Gorard and Bevins, 2008) suggests a study of how reducing or even eliminating selection on entry to an A-level in science based on prior attainment

might benefit young people from low SES backgrounds. However, simply lowering the entry strategy does not result in higher uptake of chemistry and physics at A-level; rather it promotes the converse (Bennet, Hampden-Thompson and Lubben, 2011). So this approach may only be useful in certain situations and additional support may needed to help these students succeed.

6.1.5. Teaching quality

There appears to be a cycle of poorer teaching of disadvantaged students resulting in poorer grades and a widening of the SES attainment gap. Ofsted has shown that being taught by specialist teachers improves student motivation and performance. However, schools in socially disadvantaged areas are the least likely to have specialist science and mathematics teachers (CaSE, 2008) (Moor *et al.* 2006) (Gorard and Bevins, 2008) and are less likely to offer triple science at GCSE due to a lack of specialist teachers (The Royal Society, 2008). If this cycle could be broken, it could have a significant impact for pupils from disadvantaged backgrounds. According to The Sutton Trust, having a very effective teacher compared with a poorly performing teacher could boost a disadvantaged pupil's learning by a whole year (The Sutton Trust, 2011).

Effective 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 (Gorard and Bevins, 2008). Even quite subtle differences within classroom cultures can profoundly shape the extent to which particular pupils (e.g. girls and minority ethnic pupils) feel that they are able to "identify" with science (e.g. to see themselves as a "science person"), irrespective of academic ability and the science curriculum (Archer, Osborne and DeWitt, 2012b) (IRIS, 2012).

A survey of more than 5000, year 8 students (Wilson and Mant, 2011) found that pupils

> **"** Engagement with science could be improved by raising the profile of science education within the overall school curriculum and highlighting the relevance and applicability to everyday life.
> **The Wellcome Trust**

who engage with their science lessons highlighted the following characteristics as being important in their lessons:

- Teachers who are clear explainers.
- Thinking and problem solving.
- Discussion.
- Fewer teacher-led demos and more practical work by pupils themselves.
- Contextualised science.

Another study (NfER, 2011a) recommends that engagement with science could be improved by raising the profile of science education within the overall school curriculum, and highlighting the relevance and applicability to everyday life. Teachers need up-to-date examples and applications to make science appear more relevant to pupils. They also recommended improved advice on the benefits of science education for future progression pathways.

However, teachers draw attention to the National Curriculum and associated testing that inhibit them from using teaching and learning approaches that involve exciting and creative science, particularly practical work and investigations. Science teachers would like more freedom, particularly in relation to practical work, to engage disaffected pupils in science. Teachers from schools in areas of high deprivation see practical sessions as a good opportunity to motivate and engage those pupils who generally demonstrate disruptive behaviour and/or are switched off from science (Gorard and Bevins, 2008). The current system puts the focus on performance goals rather than learning goals, which is directly at odds with building relationships with students. If students feel their grades are more important than their learning they are more likely to disengage with subjects they perceive as "hard" (pers. comm. K Bloom, National Science Learning Centre) (Institution of Mechanical Engineers, 2010).

6.2. Home life

Analysis of a cohort of children born in 2000 finds that even at the start of school (age 4–5), children from low- to middle-income families are five months behind children from higher-income families in terms of vocabulary skills and have more problems with behaviour (Waldfogel and Washbrook, 2011). Simply being raised in a lower SES environment means a student is less likely to perform well in school in mathematics and science (Gorard and Bevins, 2008). Low income and a lower level of parental education are potential key factors and are especially important in the early years. Children from poor backgrounds also face much less advantageous "early childhood caring environments" than children from better-off families, including features such as low birth weight and not being breastfed. Reading to young children and implementing regular bedtimes and mealtimes also form part of a child's learning environment and differences are seen between children from different SES backgrounds (Goodman and Gregg, 2010) (Department for Education, 2012).

However, it is more important what parents do with their children and not who they are; for example, parental interest in their child's education and involvement in their child's reading can overcome the influence of low SES on attainment (Department for Education, 2012). A child with all three of the following:
1) A good early years home-learning environment
2) A good-quality pre-school
3) An effective primary school

is more likely to have improved cognitive and social outcomes compared with children who have experienced two or fewer of these experiences (Department for Education, 2012). Despite a wealth of evidence suggesting how important the early years are in creating a child's future, the UK annual expenditure per pre-primary pupil is less than the OECD average (OECD, 2012), although, since September 2013, two year olds from lower-income households are eligible for some free early education. The Department for Education hopes this will improve the attainment of some of the most disadvantaged children[8].

[8] **www.gov.uk/free-early-education**

Enrichment of children by their families is known as cultural capital (initially proposed by the sociologist Bourdieu). It means that whatever formal education is given to children, it will never have equal impact, as different children come to school with different levels of cultural capital. For example, a child with more cultural capital might have the confidence to ask a question in a lesson, whereas another might sit there thinking that they are just not clever enough to understand and not ask for clarification. School offers pupils the opportunity to invest in their cultural capital but they may be inhibited by their desire to "belong" in their own social group (Reay, David and Ball, 2001) (Cochrane, 2007).

Families in poverty, struggling to meet the basic needs of food, housing and utilities, simply cannot afford the costs of educational opportunities outside of school, such as music lessons, sports clubs, family outings and holidays. As a result, poorer children often miss out on the developmental benefits these experiences can provide (Teacher Support Network, 2010) (Hutton, 2012). The ASPIRES project interviewed 12–13-year-olds and found that a third of them were inspired by out-of-school activities when thinking about future careers, but less-privileged students were much less likely to cite this as an influence on their aspirations (Archer, 2013a).

" The majority of families can be said to lack science capital and these are disproportionately likely to be from working-class backgrounds.
The ASPIRES project

The ASPIRES project defines families that see science as an important part of their lives as having high amounts of science capital (L Archer, J DeWitt and J Osborne et al. 2012) (Willis, 2011). These families seem to be few and far between – about 15% in their study were classified as benefiting from substantial knowledge and interest in science, and were in a position to promote it to their children – and were from predominantly white or South Asian middle-class backgrounds. It follows that the majority of families lack science capital, particularly those with working-class backgrounds.

It is not a simple matter to redress this lack of science capital. A study of minority, ethnic groups with low SES in London (Dawson, 2012) found these groups to have limited experience of engagement with science and little or no direct experience of informal science learning. They had negative attitudes towards science and informal science learning developed from their own school experiences and experiences of science in their daily lives. Even after an accompanied visit to a science museum/centre, participants felt uncomfortable with exhibits and the facilitation styles of staff. They noted they were unlikely to visit again due to a number of reasons, including: cost, their language skills, a broad lack of interest in science, the lack of appealing food and competing priorities for their time.

More positively, the California Science Centre in Los Angeles was found to have a strong impact on the understanding, attitudes and behaviours to STEM of low-income and minority visitors. This science centre has free admission and the residents that visit generally represent the diversity of the population (Falk and Needham, 2011). Another US study (Dabney et al. 2012) of university students also highlighted out-of-school science activities as being influential in their decision to study STEM subjects at university. In the UK, the large national science museums are free, but most other dedicated science centres have an admission charge, although they are charitable organisations. Generally people in the UK from minority ethnic backgrounds, low SES groups and rural areas are less likely to take advantage of informal science learning opportunities such as science centres, nature centres and aquaria (Dawson, 2012). A MORI survey suggests that most people in the UK that visit museums have a higher SES (Martin, 2003). Out-of-school influences, including science centres, are mentioned as being inspirational by students studying

STEM at university, especially males (IRIS, 2012) (Dabney *et al.* 2012), although there is little evidence for a causal link between such activities and increased STEM participation post-16. It is likely that youngsters from lower SES backgrounds are missing out on potentially inspiring experiences.

6.2.1. Parental opinions and aspirations

Family background is an important influence on a child's attainment at school (Gorard and Bevins, 2008). A parent's interest in their child's education is a significant predictor of a child's attainment in education (especially for girls) and this effect is not due to increasing their self-esteem (Flouri, 2006). Parents are much more likely to read to their children and encourage them to continue in education beyond 16 if their own parents did the same for them. The passing of these traits across generations helps to explain the persistent disadvantage that children from poor backgrounds face in their educational attainment (Goodman and Gregg, 2010) (Hutchinson and Parker, 2009).

Parental aspirations for their children differ according to their SES. Considering children age nine, 81% of the richest mothers hope their child will go to university compared with 37% of the poorest mothers (Goodman and Gregg 2010). Parental perceptions of their child's ability in secondary school are often based on their child's own estimation (Hutchinson and Parker, 2009), possibly leading to a lack of aspiration. In addition, some schools seem to be better than others at turning positive parental attitudes to science into higher student aspirations, although it is not clear what these schools are doing differently (Willis, 2011).

Parents are an important source of information on course and careers choice, and the advice they give is likely to be based on their own experience and knowledge (Gorard and Bevins, 2008). In the case of STEM subjects, parental attitudes are likely to be passed on to their children (Willis, 2011). Mothers who had a bad experience of science at school are more likely to think their children

will not do well in science and that chemistry and physics are boys' subjects (Gorard and Bevins, 2008). Parents with negative attitudes towards STEM are unlikely to encourage their child to pursue a STEM career or even to choose STEM subjects at school.

Differences in attitudes and behaviours during primary school account for around 12% of the total attainment gap between the poorest and richest children at age 11. This increases to 40% when prior attainment is not controlled for. It follows that actions aimed at changing mothers' and children's attitudes and behaviours during primary schooling could be effective in reducing the growth in the rich–poor gap that takes place over this period.

There are several factors that can contribute to GCSE success for students from low SES backgrounds:

- Parental expectations that their child will go on to higher education.
- Shared family meals and outings.
- Relatively infrequent family quarrels.
- Parents devoting material resources towards education, including private tuition and computer and internet access (Goodman and Gregg, 2010).

The vast majority of parents do care about their children and want the best for them. In choosing schools, parents are generally discerning, knowledgeable and realistic about what is best for their children. They have a strong preference for local schools and want good teaching, good behaviour and a broad curriculum that develops pupils intellectually, socially and emotionally. Other skills such as self-esteem, respect for others and politeness are also seen as important (Miller and Wood, 2012). It is important to bear in mind that what looks like "parental disengagement" may be the result of a high level of commitment to their child's education, which is not matched by their capacity to provide effective support or by the ability of schools to work effectively with parents (Carter-Wall and Whitfield, 2012).

6.3. Parental engagement with schools

As discussed above (see section 6.2.1), although parents want the best for their children, frequently they are not well placed to help with either schoolwork or to advise on a career path. Greater involvement of parents with school and their child's education can increase both attainment and aspirations. The more engaged parents are in the education of their children the more likely their children are to succeed. Parental engagement is strongly linked to SES, as well as a parent's own experience of education. Parents from poorer backgrounds, or those who have not been successful in education, may lack the practical knowledge that enables them to support their children. Parents at a comprehensive school in Newcastle said they felt powerless to support their children in their studies in science because of their own lack of knowledge and very limited understanding of contemporary issues in science (Bond and Harbinson, 2010). In a US study, 81% of teachers thought parents did not know how to talk to their teens about their schoolwork (Ramirez, 1999).

> " What looks like 'parental disengagement' may be the result of a high level of commitment to their child's education, which is not matched by the capacity to provide effective support or by the ability of schools to work effectively with parents.
> **Joseph Rowntree Foundation**

Teachers and parents agree that more should be done for families that have a disordered home environment, which can affect a child's behaviour at school. Parents with a negative attitude towards education may have been affected by negative experiences in their own upbringing and existing structures do not address these issues adequately. There is also agreement that home-school communications need to improve (Teacher Support Network, 2010). Where parents and teachers work together to improve learning, the gains in achievement are significant (Harris and Goodall, 2007).

However, not all attempts succeed in gaining a sufficient degree of engagement (Higgins, Kokotsaki and Coe, 2011). It is very difficult and time-consuming to build an effective home-school relationship, but schools that do build positive relationships with parents and embrace diversity in the community show a sustained school improvement in terms of student achievement. Such measures seem especially effective in primary schools (Goodall *et al.* 2011).

Researchers from the University of Warwick argue that asking parents to support activities in school is less effective than offering them support for learning at home (Harris and Goodall, 2007). The design of a project to engage parents needs to be carefully planned with clear objectives. Approaches need to be sensitive to local settings and provide opportunities for intergenerational working on areas of common interest between young people and their parents. Activities outside the school setting can be useful, especially if there is scepticism about formal schooling and a history of low attainment in the community (Kintrea, St Clair and Houston, 2011).

Material barriers to parental engagement include cost, time and transport. These can be reduced by measures such as car-pools, involving children in the activities and taking account of parental work schedules (Goodall *et al.* 2011). Other potential barriers that need to be considered include parental disability, non-resident parents, other carers such as grandparents, and parents for whom English is a second language.

Schools that offer bespoke support to parents are more likely to engage them in their child's learning (Harris and Goodall, 2007). Activities such as out-of-hours' clubs, parenting classes, extended schools and outreach work can lead to improvements in completion of homework, learning behaviours and improved attendance (Goodall *et al.* 2011).

6.3.1. Areas of parental intervention
The charity Family Lives proposes several suggestions for communicating with parents.

Parents want information about issues such as teaching quality, behaviour, bullying, and pupil progress and wellbeing. They suggest that schools should provide termly reports via post, e-mail or secure webpages to help parents support their children's progress. Schools should consider "safe" ways of sharing views of parents and pupils within the school community. More information about how SEN is supported should also be made available (Miller and Wood, 2012).

The Joseph Rowntree Foundation (Carter-Wall and Whitfield, 2012) breaks down parental engagement into four broad areas of intervention that have been shown to increase attainment:
1) Improving at-home parenting.
2) Involving parents in school.
3) Engaging parents in their children's learning and in their own learning.
4) Aligning school-home expectations.

Training in parenting skills makes interventions more effective, but needs to be carefully designed with a supportive, non-judgemental attitude (Goodall *et al.* 2011). Family literacy and numeracy programmes can have a positive impact on the most disadvantaged families, including the academic outcomes of their children. The benefits have been shown to last beyond the duration of the intervention.

Methods of communication are also important, 62% of parents who responded to a Parentlineplus survey said they had felt patronised, side-lined or ignored when trying to deal with an issue in their child's school. The equivalent teacher survey found that 64% of teachers had been subjected to verbal or physical abuse from a pupil's parent (Teacher Support Network, 2010).

In the Achievement for All (AfA) project, structured conversations between teachers and parents are used as a method to build a relationship and engage parents in their children's education. The structured conversations needed to be collaborative and involve a two-way exchange of information, ideas, aspirations and concern in order to be successful (Humphrey and Squires, 2011). There is the potential to use these types of parental meetings to replace traditional "parents' evenings". These conversations are undoubtedly easier to implement in primary schools, which are generally smaller and pupils have one main key worker; secondary schools are much larger and pupils have a different teacher for each subject.

6.4. Attitudes towards STEM careers and scientists

A 2010 survey (European Commission, 2010) showed that most Europeans are interested in science and technology and feel informed about new developments, but they are not actively involved in public issues around science and technology. The public has a positive view of scientists but does not understand what they do and they think governments should do a better job of encouraging young people and women to be involved with science. This generally positive attitude towards science where it is seen as interesting, but ultimately something that other people do, is also reflected in the UK. Interviews with 10–14 year olds showed that there is a popular view that scientists and people who are good at science are "clever" or "specialist" leading to the idea that science is "not for me" (DeWitt, Archer and Osborne, 2013).

The majority of children aged between 10 and 13 find science at school interesting, have parents who think science is important, think scientists do important work and enjoy science activities at school. However, even at this age, very few aspire to be a scientist (Archer, 2013a) (NfER, 2011a) (Whitelegg, Holliman *et al.* 2008b) (Bennet, Hampden-Thompson and Lubben, 2011) (Archer, Osborne and DeWitt, 2012b) (L Archer, J DeWitt *et al.* 2010) (Willis, 2011). Additionally only a small number of children who do want to do science cite their science classes as a career inspiration (Archer, 2013a).

There are some 10-year-olds who have positive views towards science and high science aspirations, but come from families

with low science capital. These children are perhaps most at risk of losing their interest in science as their families do not have the mechanisms to support their interests (Willis, 2011) (L Archer, J DeWitt and J Osborne *et al.* 2012). In the ASPIRES project, only a small minority of pupils at age 10 were not at all interested in science, but these were all white girls from low SES backgrounds (Willis, 2011). It is not clear if young people from low SES backgrounds have more negative attitudes towards STEM or just have lower aspirations, but young people from more deprived areas do not see science as relevant to them or their daily lives (Gorard and Bevins, 2008) (Dawson, 2012).

Stereotypes about science and scientists influence the attitudes of young people (especially girls) and how they see themselves in the context of STEM. A study by the Open University looked at children's television programmes for STEM content. They found that programmes showed a bias towards men or male characters, with more than 70% of STEM content being voiced by males (Whitelegg, Holliman *et al.* 2008b). Scientists are often thought of as being brilliant but eccentric, with crazy hair, and being white, male, old and middle class. This makes it hard for many youngsters, especially girls, to identify with science and see themselves as a scientist in the future (Archer, DeWitt *et al.* 2010). A "draw a scientist" activity with school children (Whitelegg, Hollimann *et al.* 2008a) found that strong stereotypes exist, with the majority of students drawing male scientists. Other research shows that children and their parents hold quite complex views of science and scientists. Most are able to see beyond the scientist stereotype but are only able to recognise a small number of "famous" scientists, who are overwhelmingly white men (Archer, Osborne and DeWitt, 2012b).

Parents also worry about their daughters being in a male-dominated environment associated with many science careers (Archer, 2013a). Using media in a positive way to provide examples of STEM identities and applications and to counter the stereotypical images of scientists in the media is one of the recommendations of the IRIS project (IRIS, 2012).

Most youngsters see science qualifications as leading to a limited range of careers, i.e. scientist, science teacher or doctor (Archer, 2013a). Long-term programmes that highlight both the breadth of careers available in science and the relevance it has in many other careers could help change this attitude (Archer, Osborne and DeWitt, 2012b). Evaluation of STEMNET's services suggested that using STEM ambassadors and running a STEM club after school can increase engagement, interest and knowledge in STEM subjects as well as increasing awareness of STEM careers options (NfER, 2011b).

The early years of secondary education (age 11–13) are likely to be particularly crucial in shaping attitudes. Attitudes to science and school science, when compared with mathematics and English, decline most noticeably during this time (The Royal Society, 2008). Students enter secondary schooling with an equal liking of biology and physics, but over the course of their studies they become less positive about physics relative to biology (Baram-Tsabari and Yarden, 2005) (Spall *et al.* 2004). More than 70% of year 6 and year 8 pupils agree that they learn interesting things in science classes and only 19% say they find science difficult (Archer, 2013a). So, at least at the beginning of secondary school, students enjoy science classes as much as in primary school (up to age 11). The decline in positive attitudes starts as pupils progress through secondary school. Negative attitudes towards education may be exacerbated in poorer children by a lack of confidence in their own ability to succeed in a system organised around a middle-class ethos that they do not relate to (Carter-Wall and Whitfield, 2012).

Studies of pupils aged 14–16 in Birmingham showed that although more than half enjoyed science, only 10% thought it was their favourite subject, with biology as the most popular science (Stagg, Laird and Taylor, 2003). Physics, in particular, is perceived by school

pupils as a hard subject (Archer, Osborne and DeWitt, 2012b) (Gorard and Bevins, 2008) (Stagg, Laird and Taylor, 2003); and as having more content with harder exams (NfER, 2011a). Students also think you need to be "naturally interested" to do well at science (L Archer, J DeWitt *et al.* 2010). Teachers often share these views and think students would be more likely to get higher grades in other subjects (Stagg, Laird and Taylor, 2003).

Science is not regarded as a glamorous career by many students. This view applies across a variety of educational backgrounds and ethnicities, while popular notions of the type of individual who becomes a scientist also lead to negative perceptions about the subject (Bond and Harbinson, 2010). The IRIS project (IRIS, 2012) found that teaching about socio-scientific issues within schools has a positive effect on encouraging young people to choose post-compulsory STEM education, especially female students.

6.4.1. Careers advice and guidance in schools
From September 2012, all schools were required to provide careers information advice and guidance (IAG) for year 9–11 pupils (approximate age 14–16) and from September 2013 this was expanded to cover pupils in years 8–13 (approximate age 13–18). Among other things, schools must provide independent face-to-face careers guidance and provide other careers activities for young people. However, "it is for schools to decide the careers guidance provision to be made available based on the needs of pupils and the opportunities available. Schools should meet the costs of provision from their overall budgets"[9] (Department for Education, 2013b).

In 2011, Ofsted found careers advice in KS3 to be generally weak, making it difficult for young people to make informed choices about careers and educational routes. The girls surveyed did not understand how choices made at school could influence their future career progression and pay (Ofsted, 2011). A more recent and larger survey found that careers advice and guidance (even under the statutory duty to provide it)

was not good enough in the majority of the schools surveyed. Only 12 out of 60 schools surveyed ensured students received sufficient information to consider a wide breath of career possibilities (Ofsted, 2013). Ofsted found schools did not have sufficient skills in-house nor had purchased expertise externally and that students did not receive a broad base of information to increase awareness of the range of careers available. Schools successful at giving effective careers advice had made the duty a high strategic priority at top levels (leaders and governors). With the compulsory education age rising to 18 in 2015, it is now even more important that young people are aware of the different learning routes and qualifications available to them – including diplomas, apprenticeships and Foundation Learning, as well as GCSEs and A-levels[10]. There are also other studies showing that students do not get good advice about applying for university courses or careers advice from their schools, particularly in the state sector (Reay, David and Ball, 2001).

Very few pupils cite schools' careers resources as influencing their career aspirations (Archer, 2013a). This may be due to the lack of effective careers guidance in many schools or the students' reluctance to engage with the advice that is available. Furthermore, the advice that does exist concentrates on the A-level route and subsequent university entry, ignoring the range of more vocational courses that most students are unaware of (Archer, 2013a) (Henshaw, 2013) (Ofsted, 2013). A study of 13-year-olds (year 9) showed they had all thought about what they would like to do in the future and their aspirations clearly came from a shared experience with a family member or close family friend. Schools need to provide advice and guidance earlier than age 13 to help pupils make the right choices at this age. However, the form of this advice needs to be credible and relevant for young people with a wide range of interests (Cochrane, 2007) to overcome the other factors that discourage young people from having aspirations in STEM careers.

[9] www.education.gov.uk/aboutdfe/statutory/g00205755/statutory-careers-guidance-for-young-people accessed 11/09/13

[10] www.teachingtimes.com/articles/iag-strategy-question-answer.htm accessed 11/09/13

6.4.2. STEM careers advice in schools

STEM graduates on average have higher starting salaries, and higher earnings and higher lifetime income than non-STEM graduates (The Russell Group, 2009) (London Economics, 2007) (Department for Business Innovation & Skills, 2011a). Yet many young people are unaware of the higher earning potential and rewarding careers that STEM skills can unlock.

Currently, careers in and from science are not commonly perceived as "for all", which discourages many children from developing science aspirations (Archer, Osborne and DeWitt, 2012b). Only 34% of year 9 pupils thought it would be good to have a job as a scientist despite 84% thinking it is important for this country to have well qualified scientists (Bennet, Hampden-Thompson and Lubben, 2011). Students find it difficult to make direct links between the science they learn at school and applying it to everyday situations (NfER, 2011a). As aspirations are influenced by social background, science needs to be seen as an attractive career option by a broader range of pupils (Archer, Osborne and DeWitt, 2012b).

It is suggested that schools where students have high STEM aspirations and positive attitudes have:

- Appointed a STEM coordinator (Finegold, Stagg and Hutchinson, 2011).
- Targeted career advice from informed science teachers (Bennet, Hampden-Thompson and Lubben, 2011) (Sutcliffe, 2011).
- Provided a range of opportunities to see science in the workplace such as visits to industry and universities, participation in science week, careers days and a high level of pupil involvement (Bennet, Hampden-Thompson and Lubben, 2011) (Sutcliffe, 2011).
- A proactive approach in matching work placements with pupils (Bennet, Hampden-Thompson and Lubben, 2011).

> " 22% of girls surveyed say they cannot afford to study beyond the age of 18, up from 8% in 2010.
> **Girlguiding UK survey, 2011**

Ofsted (Ofsted, 2013) recommends that: the government should provide clear, explicit guidance to schools about planning, securing and monitoring careers guidance; employers and employer networks should provide schools with more information about local job options and local skills shortages; and schools should develop a clear strategy for careers guidance utilising the necessary external expertise and promote a wider range of progression routes.

6.4.3. Choosing subjects and courses at school

The academic choices a young person makes throughout their education should be viewed as a continuous process rather than a single event that is made at a specific point in time (IRIS, 2012).

At the age of 13–14, students have choices about the GCSE (or equivalent) courses they will study. However, there are a number of constraints that an individual will face that can have an impact on their choices. For example, any given school will offer a limited number of courses and low achievers will be directed towards vocational-type courses and high achievers in the opposite direction. The identification of low achievement with aptitude for vocational routes is a perverse consequence of the educational system that tends to strengthen social differences. Families with higher levels of cultural capital will influence their children to choose qualifications in more academic subjects. Schools, however, are anxious to maintain their position in the league tables, a consideration that often determines which students are directed to which courses.

All of these factors mean pupils from higher SES backgrounds tend to be in a more privileged position in their ability to access courses (Cochrane, 2007). An Australian study reached similar conclusions, stating that decisions about taking physical science courses were associated with the resources of cultural and social capital within their families rather than their science lessons at school, which the students found irrelevant,

uninteresting and difficult (Lyons, 2006). 56% of girls surveyed by Girlguiding UK felt they didn't get enough advice about choosing the right GCSEs and A-levels at school (The Guide Association, 2011).

Independent schools are more successful at sending pupils onto higher education courses at top universities. Part of the reason for this success seems to be a focus on quality over quantity in subject choices at A-level. The most successful schools, with highly able pupils, target their examination entries more effectively than others (O'Leary and Kendall, 2011). However, this is not the whole story, as comparing the types of schools with the best progression rates shows that selective state (grammar) schools still have more entrants to the top 30 universities compared with the best non-selective state (comprehensive) schools, even though their results are similar. Even schools of the same type and similar results can vary widely in the number of successful applications to top universities. The authors of this Sutton Trust report suggest that these outcomes cannot be explained by ability but may be influenced by parental backgrounds, geography, curriculum (especially post-16), and careers information and advice provided in the different schools.

6.4.4. Careers advice from other sources

The most common source of information about careers is a student's family, followed by friends and then teachers. Parents with lower SES will not have had the same access to educational and career opportunities as their more affluent counterparts (Craven, 2003) (Archer, 2013a). They may not be aware of the full range of possibilities nor understand the various routes that lead to post-compulsory education (Carter-Wall and Whitfield, 2012).

6.5. Aspirations of students

At the age of 14, expectations for higher education among parents and children are generally high across the board (Goodman and Gregg, 2010). A youngster's aspirations may be influenced by social class, gender, ethnicity, culture and history or simply by where they live. White, young, working-class people are among the least aspirational. They value traditional, skilled, "blue collar" occupations even though these types of jobs are now scarce (Kintrea, St Clair and Houston, 2011) (Archer, DeWitt and Wong, 2013b). These attitudes all contribute towards a perception of higher education being "inaccessible" either due to geography or elitism (Evans, 2009). There is a "collapse" in expectations regarding university between the ages of 14 and 16, particularly among children from the poorest backgrounds (Goodman and Gregg, 2010).

A survey of more than 11,000 13–18-year-olds recorded the career aspirations of youngsters against a list of 69 potential occupations (Mann *et al.* 2013). These were then mapped to the predicted demand for labour across 25 occupational areas in the UK from 2010 to 2020. In line with other studies, they found that career aspirations of young people change over time and become more realistic. They also found that most youngsters wanted jobs in a narrow range of occupations. Importantly in terms of job prospects, analysis of the data showed that the career aspirations of teenagers have nothing in common with the projected demand for labour in the UK from 2010 to 2020. The danger is that many young people will gain the qualifications and work experience relevant for jobs for which there are relatively few opportunities (e.g. only 1 in 10 youngsters interested in culture, sport and media careers are likely to be successful in these areas) and are not suited to the jobs that are available. The most popular occupational preference for 13–14 year olds was actor/actress (5.6%), for 15–16 and 17–18-year-olds it was teacher/lecturer (4.4% and 6.7%, respectively), both perhaps reflecting a lack of knowledge and realism about the job market.

6.5.1. Gender stereotypes and career aspirations

Young people's opinions and attitudes towards gender influence their educational choices and in turn their career choices. Some groups have more stereotypical views than others;

for example, those working at lower levels of achievement in mathematics and English (Hutchinson and Parker, 2009). A survey by Girlguiding UK found that career aspirations often conform to gender stereotypes, with hairdresser or beautician as top career choices for girls; few girls consider a career in science or engineering. When asked, most girls said that hairdressing is what girls are interested in and that STEM is too hard or complicated (The Guide Association, 2011). At the age of 12/13, girls are more likely to aspire to an arts-based career and boys are more interested in careers in engineering (Archer, 2013a).

> **"** Explicit discussion about under-representation of women in science was positively linked to a physics identity for females.
> **Hazari et al. 2010**

The Girlguiding survey in 2011 also reported that about 10% of girls planned to leave education at the age of 16. Reasons included were: this is what they wanted (47%); they didn't enjoy studying (44%); and they didn't need to study further 33%. 16% said they could not afford to study or needed a paid job, an increase from 11% in 2010. For those who said they wanted to leave at age 18, reasons given were similar to those who wanted to leave at age 16, i.e. they wanted to (40%) or this is what they needed for their job (38%). For some, though, this was something that their school (16%) or their parents (11%) expected. 22% said they could not afford to study beyond the age of 18, up from 8% in 2010 (The Guide Association, 2011). A survey carried out by Ofsted found that although girls were open to the idea of pursuing careers that challenged gender stereotypes this did not necessarily translate into practice. Course and career choices taken by girls were predominantly stereotypical (Ofsted, 2011).

6.5.2. Socioeconomic status and career aspirations

In Australia, students from lower SES backgrounds are roughly half as likely to go on to higher education compared with those from medium or higher SES backgrounds. A survey of more than 7000 students found that although attitudes towards secondary school were similar in many ways, their aspirations and intentions regarding higher education were strongly influenced by SES, gender and geographical location. SES was the biggest factor influencing the perceptions of value and attainability of higher education. Despite a high proportion (90%) of Australian students reporting that they would like to attend tertiary education, students from higher SES backgrounds were confident they could get there (nearly 70% thought they would), whereas for students from medium and lower SES backgrounds only 50% and 42%, respectively, felt the same (James, 2002).

Australian students from lower SES backgrounds believed that vocational courses are more useful than university courses, had less confidence that their parents wanted them to go to university and had a stronger interest in earning an income as soon as they left school. These students were also less confident that their academic results and subject choices would be good enough to get in to interesting courses (James, 2002). Similarly, Australian indigenous students, who are traditionally from low SES backgrounds, wanted to leave school earlier and had lower expectations of going to university. They were also less likely to know what they wanted to do after school and had therefore not chosen subjects appropriate to their aspirations (Craven, 2003).

More recent studies in the UK challenge the view that young people from poorer backgrounds have low aspirations. The Joseph Rowntree Foundation (Kintrea, St Clair and Houston, 2011) found that young people do want to go to university, and have professional and managerial jobs. It is the knowledge of the pathways through education and employment that is limited, rather than the young people's aspirations. The period between the ages of 13 and 15 seems to be the critical time at which aspirations to university entrance disappear. Although many ideal occupations at the age of 13 were related to sport or

celebrity, these were modified by the age of 15 to more realistic career aspirations (Kintrea, St Clair and Houston, 2011).

The ASPIRES project also found that young people generally had high aspirations to professional, managerial and technical careers (Archer, 2013a). Top aspirations at age 10–11 were: sports related (16%), performing arts (13%), teacher (10%), doctor (8%) and vet (6%). Two years later, top aspirations were: performing arts (20%), doctor (10%), business (9%), sports related (9%) and teacher (6%). The majority of the pupils wanted to be affluent and famous. Social class has an effect, with more pupils from advantaged backgrounds aspiring to be a doctor (45%) or scientist (23%), compared with 22% and 9%, respectively, for disadvantaged students.

It is worth noting that what might look like "low aspirations" may often be high aspirations eroded by negative experience (Carter-Wall and Whitfield, 2012). In the North East of England, young people feel uncertain about their future employment opportunities and this may limit their aspirations. Women, in particular, often opt for low-skilled jobs that meet immediate needs, rather than making long-term career choices (Hutchinson and Parker, 2009). The Joseph Rowntree Foundation (Menzies, 2013) suggests that more effort is needed to assist young people achieve their aspirations. Such actions will be most effective when schools and parents collaborate in helping children achieve the best outcomes. On balance it appears that there is less need to change young people's aspirations, but more to provide appropriate support and advice on how to channel their studies and subject choices to avoid closing off routes to achieving them.

6.5.3 Choosing to study STEM

There is a strong relationship between intention to participate and patterns of participation, so if students intend to study physics post-16 they generally will (Mujtaba and Reiss, 2011). Both girls and boys that aspire to do science post-16 are either high academic achievers who are confident enough to be labelled as "not cool" within their peer group, or they tend to actively promote their "cool" behaviours such as being in a sports team or being interested in fashion (DeWitt, Archer and Osborne, 2013). This may not always be the case; for example, in some ethnic minority groups from low SES communities, science subjects are highly regarded (IOP, 2014).

Girls and boys tend to have different reasons for studying STEM subjects. Girls cite interest or enjoyment of a subject as important and are more likely to want to "make a difference". Boys are more likely to give aptitude for a subject as a reason for studying it and enjoy games, toys and clubs focused on hard sciences (Newman, Bangpan and Tripney, 2009) (Nelson, 2011) (IRIS, 2012). A study in London showed that motivation of working-class girls to enter university was linked to higher earning power, but more so they could support their family rather than themselves. This seems to be in contrast to the earning motivations of young working-class men who would use their incomes to support their future families rather than their existing families (Evans, 2009).

Girls who have aspirations to study science post-16 tend to be high academic achievers in general and describe themselves as "not girly", although a smaller number "balance" their science interest with a more "girly" identity, e.g. being fashionable, sociable and sporty (Archer, 2013a). In her book *Delusions of Gender* (Fine, 2011), Cordelia Fine discusses research by Emily Pronin (Pronin, Steele and Ross, 2004) and suggests that women who do succeed in male-dominated environments turn their back on more "female" characteristics such as wearing makeup and being visibly emotional. Archer *et al.* (L Archer, J DeWitt and J Osborne *et al.* 2013c) suggest that the popular perception of scientists is completely opposed to the image that young girls identify as desirable and feminine. Consequently, scientific careers are unthinkable for many of them, especially those from working-class backgrounds.

6.6: Key elders and role models

In contrast, most boys who aspire to do science post-16 are not "geeks" and also have interests in fashion and sports. A smaller number of boys are high achievers and are "not cool". This latter group tend to be from upper-middle-class families, and are confident and self-assured (Archer, 2013a).

The more science capital a family has the more likely their child is to aspire to a science-related career and/or plan to study science post-16 (Archer, 2013a). The authors think these families with science capital make science careers more "obvious" and desirable by making science something "we" do. They recommend programmes for increasing science capital among working-class families as a route to raising awareness and accessibility of STEM careers.

A European study (IRIS, 2012) proposed that the role of identity is crucial in educational choice: a student must be able to see him/herself as a "STEM person" in order to choose STEM courses post-16. In America, researchers defined a "physics identity" in secondary (high) school students as: having an interest in physics; being recognised by others as being a good physics student; and having the belief in their abilities to perform and understand physics. They found that having a physics identity was linked with a desire to have a fulfilling career, but was negatively linked with a desire for personal or family time, or a desire to work with other people. The research also found that explicit discussion about under-representation of women in science was positively linked to a physics identity for females, whereas having female guest speakers and discussion of women scientists did not have an effect (Hazari *et al.* 2010).

> " Students from socially advantaged backgrounds are more likely than their less advantaged counterparts to know someone in their family, or close social circle working in the job that they aspire to.
> **Archer, 2013a**

6.6. Key elders and role models

The presence of a key elder (relative, family friend or teacher) seems to be vitally important in fostering an interest in physics in young people; it emerged as a principle influence for physics undergraduates (Rodd, Reiss and Mujtaba, 2007). Their relationship with this person was much more important in influencing them to study physics post-16 and at university than one-off outreach interventions in schools. We have seen in previous sections that young people tend to form their career aspirations based on their social circles and what they see in their local communities. If pupils from lower SES backgrounds have not had that "key elder" to ignite the initial spark, because no-one in their family has studied science, they are less likely to see physics as a plausible subject. In addition, if pupils lack self-esteem they are less likely to choose physics post-16, seeing it as too difficult.

In a survey by the Chartered Institute of Public Relations (CIPR Education & Skills Group, 2012), students rated their parents as the strongest influence in deciding which educational establishment (at secondary school, FE and HE levels) to go to. In the absence of a family member who might initiate an interest in higher education or in studying STEM subjects, teachers become the "key elder" who can influence a young person to continue studying physics. In families where there was no previous aspiration to apply for an elite university, an effective teacher and attending a Sutton Trust summer school were found to have a positive influence on helping working-class students attend elite universities (Reay, Crozier and Clayton, 2009).

There are several studies suggesting that the impact a teacher has on a pupil seems to be linked to the student's gender and socioeconomic background. Pupils in more affluent areas thought their teachers should be passionate about science and have strong subject knowledge. Pupils from areas of deprivation placed emphasis on teachers being "nice" and on strong pupil-teacher relationships (Gorard and Bevins, 2008).

Boys were more likely than girls to think that teachers encouraged them to continue with physics post-16 and that those teachers were more likely to be interested in them as a person (Mujtaba and Reiss, 2011). Head teachers had a greater influence over male students than female (they were least important for females). Unsurprisingly, in general, individual class teachers were more influential than head teachers on HE choices but were more than five times as influential for female students (CIPR Education & Skills Group, 2012) (Hill, 2010a). This suggests that, when girls do form a good relationship with an inspiring subject teacher, they are very likely to continue with that subject. This is particularly true for physics.

Focus groups showed that girls tended to find the GCSE physics curriculum dry and uninteresting (Hill, 2010a). Most state secondary schools have fewer physics specialists than other science subjects, so students are less likely to be enthused in physics than other sciences. A study in America found that despite accounting for classroom experiences, academic progress and family support, when rating their teachers, boys rated their female science teachers significantly lower than their male teachers. Girls only under-rated their female teachers if they taught physics (Potvin *et al.* 2009). This negative bias is important in the context of encouraging more women to go on to study science and to become physics teachers. However, other research has found that the quality of the teacher is much more important than the gender of the teacher (Carrington, Tymms, Merrell *et al.* 2008) and (Francis, Skelton, Carrington, Hutchings, Read and Hall, 2008).

A recent study in the US found that the gender inequality in physics uptake in high school was related to the number of women in STEM in the local community. As expected, across their whole sample, females were less likely than males to take physics at high school. In agreement with other studies, they also noted that students with higher attainment levels and higher levels of parental education were significantly more likely to take physics. However, in schools serving communities where there were more women employed in STEM-related occupations, there was less of a gender gap in the uptake in high school physics and in some cases it disappeared. This did not alter the likelihood of boys choosing to take physics (Riegle-Crumb and Moore, 2013). This suggests that the high number of women working in STEM meant that many more families had science capital.

6.7. Applying for higher education

Demand for university graduates remains strong in the UK, with employment of graduates increasing slightly (by 0.1%) between 2008 and 2010, while employment among non-graduates decreased by 3.3% over the same period (OECD, 2012). People with degrees are more likely to be employed, more likely to return to employment after being out of work and are likely to earn between 20 and 25% more than their equivalents with two or more A-levels: the so-called "graduate premium". The financial benefit of completing a degree is greatest for men from families with lower levels of income (London Economics, 2007).

> Schools appear to differ considerably in the levels of aspiration they engender in their pupils and in the quality of preparation for selection for higher education.
> **The Sutton Trust (O'Leary and Kendall, 2011)**

Although there has been an increase in the numbers of people entering university and gaining degrees, the class divide remains strong. One possible reason may be that an increase in the number of graduates overall means more jobs require a degree as a minimum requirement. Students from lower SES backgrounds are more likely to enter the "new" universities rather than prestigious older institutions, potentially leading to working-class graduates (especially women) accepting lower-paid jobs (Evans, 2009).

Entry to the most prestigious universities

is dominated by independent schools and selective state schools (O'Leary and Kendall, 2011). Independent school pupils are more than twice as likely as pupils in comprehensive schools to be accepted into one of the 30 most highly selective universities: on average, 48.2% of independent school applicants in England were accepted by these universities, compared with 18.0% of applicants from non-selective state schools, and 47.6% from selective state schools (O'Leary and Kendall, 2011). The differences in the admissions rates to highly selective universities cannot be attributed solely to the schools' average A-level or equivalent results. The rewards for social mobility and career advancement tend to be greatest at the more selective universities (O'Leary and Kendall, 2011).

Apart from the results they produce, schools also differ considerably in aspiration levels of their pupils and in preparation for selection for higher education (O'Leary and Kendall, 2011). Investigations by The Sutton Trust (O'Leary and Kendall, 2011) and the University of York (Bennet, Hampden-Thompson and Lubben, 2011) found the following factors are influential in schools that are successful in sending students to selective universities and/or to study physics and chemistry.

- High attainment at GCSE and A-level.
- Curriculum − different science options offered at GCSE (or equivalent).
- Information, advice and guidance − proactive recruitment by science departments.
- Parental socioeconomic backgrounds.
- Selection of A-level subjects based on future aspirations (not past experiences).
- Teaching by subject specialists.
- Types of school − 11–18 larger schools are best.
- Well organised and appropriately timed work experience and opportunities to interact with the world of work.

It also appears that students from lower-income backgrounds are not aware of the range of bursaries on offer, and make their choice of university before investigating the funding available (Davies *et al.* 2008).

Admissions staff in several of the most selective universities report that it is common for able candidates to seek places on degrees for which they do not have the appropriate qualifications. The Russell Group of universities (The Russell Group, 2012) prepared a report "Informed Choices" in the light of this finding. It includes a list of "facilitating" subjects that are valued more highly for university entrance than some of the newer vocational A-levels. Over the past 15 years, there has been a fall in the numbers taking "facilitating" subjects at A-level. Comprehensive schools and colleges have introduced other subjects in order to appeal to a wider range of young people, whereas the curriculum in independent schools is designed with university entrance in mind (O'Leary and Kendall, 2011).

Cockermouth School in Cumbria is a comprehensive school that is particularly successful at sending its pupils to university. Although the numbers of FSM pupils are below average, it is a mixed-ability comprehensive that serves the local community. A-level results are not exceptional but 80% of those applying find a place at university, with more than 30% going to highly selective universities. This is achieved by early discussions about higher education and partnerships with Newcastle, Cumbria and Oxbridge universities. Considerable time is spent investigating where former pupils have studied and time is devoted to making choices and writing personal statements (O'Leary and Kendall, 2011).

6.7.1. Barriers when applying to university

In general, those who apply for and obtain places at university in science subjects come from higher SES backgrounds than the general student population and physics applicants tend to come from a higher SES background than those studying biology or mathematics. The pattern for acceptances is independent of social and occupational class, so it seems that the admissions process as a whole does not lead to any further stratification of the student

body (Gorard and Bevins, 2008).

For students from lower SES backgrounds, especially girls, entrance to higher education can be highly influenced by family ties and loyalties as well as a lack of aspiration to university education (Evans, 2009). The location of a university is more important for girls compared with boys (57% compared with 50%) and is particularly important for students in Northern Ireland (75%), the North East of England (67%), Scotland (65%) and Wales (63%) (CIPR Education & Skills Group, 2012). For working-class students in London, living at home while studying was seen to be the most financially viable way of studying at university. The idea of being in a lot of debt after university is a major factor in the consideration of higher education (Evans, 2009). This is true for socially disadvantaged students across the UK who may be financially restricted to studying at a local university. Despite the numerous bursaries on offer from elite universities, a large further education college in the North East of England reported that only 13.2% of students moved away from home to study at university in 2009. Between 2004 and 2009 only eight students left the area to study physics at university (Hill, 2010b).

Closure of several university STEM departments in recent years has meant that these subjects are often not available locally (CaSE, 2008) (Connor, Tyers and Tackey, 2003). In some areas of the country, closures of physics departments have left some students with few options to study physics locally after finishing school. Between 2003 and 2013, students wanting to study physics in the North East of England only had the option of studying at Durham University. The entry requirements for this course are very high[11] (A*AA at A-level). For students achieving good A-level results, but not high enough for entry into Durham University, there were no alternative physics degree courses in the area. This led to some students changing their choice of degree course in order to stay in the area (Hill, 2010b). Northumbria University has recently started two new degree courses

in physics and physics & astronomy from September 2013[12] with entry requirements of 320 UCAS points (ABB at A-level), so this provides a new opportunity for students in the North East to study physics while staying in the region. Newcastle University is also planning to start a physics degree course from September 2015[13].

For many students from poorer backgrounds, a visit to Oxbridge or other elite universities merely shows that world to be unimaginable (Evans, 2009). To try and overcome this perception, The Sutton Trust runs summer schools for pupils from non-privileged backgrounds at elite universities; these seem to have some effect in encouraging applications to such universities, particularly those that run the summer schools. The summer schools also assist the universities in meeting their widening participation targets (Hoare and Mann, 2011). These longer residential courses appear to give potential students more time to adapt and envision themselves attending the university compared with a traditional open day.

> **“** Even after a visit, the world inhabited by students at Oxbridge is unimaginable.
> **Evans, 2009**

A current study in Bristol is following students from different SES backgrounds attending two universities in Bristol (University of Bristol, 2011). An interim paper (Bradley and Ingram, 2012) from this project found that there was a strong awareness across the whole sample that higher education was a necessity if one aspired to a career rather than just a job. Some students from lower SES backgrounds had decided to go to university after watching their parents (who had not been to university) struggle with money. Such students tended to study subjects they believed would lead to a career (e.g. law, economics and engineering rather than drama, geography and history). They often had to work before starting and during

[11] www.dur.ac.uk/physics/undergraduate/howtoapply/entryrequirements/

[12] www.northumbria.ac.uk/?view=CourseDetail&code=UUSPYC1

[13] www.ncl.ac.uk/undergraduate/degrees/physics/courseoverview/

university to fund their living expenses; these jobs were usually not related to their degree (e.g. waitressing), whereas their peers from higher SES backgrounds were able to expand their cultural capital by more relevant work experience or by travel. Students with jobs during term time also had less time to study for their course and cultivate social relationships that might further their future career.

Even after getting to university, UK students from disadvantaged backgrounds are significantly more likely to drop out after one year compared with the most advantaged students. This gap remains even after accounting for personal characteristics, prior achievement and university profile (Powdthavee and Vignoles, 2009). In Denmark, dropping out of a STEM degree course was strongly linked to students' grades and their parents' educational background (IRIS, 2012). A report on student retention in the UK found that a sense of "belonging" and "engagement" are key factors in students completing university (Thomas, 2012); perhaps this could be one of the reasons why students from lower SES backgrounds are more likely to drop out. Such students may feel out of place and often cannot afford to socialise with their richer peers (Bradley and Ingram, 2012).

Glossary

A-level Advanced-level examinations (usually taken around age 18 in two to four subjects). Taken over two years and split into AS and A2.

AS-level The first year of an A-level course and a standalone qualification by itself worth half an A-level.

ASPIRES The Science Aspirations and Career Choice: Age 10–14 project is a five-year longitudinal study, funded by the Economic and Social Research Council (ESRC) as part of their Targeted Initiative on Science and Mathematics Education (TISME). More information can be found at **www.kcl.ac.uk/sspp/departments/ education/research/aspires/index.aspx**.

D&T Design and technology.

EBacc English Baccalaureate – introduced as a performance measure in the 2010 performance tables. It is not a qualification in itself. The measure recognises where pupils have secured a C grade or better across a core of academic subjects – English, mathematics, history or geography, the sciences and a language.

FE Further education.

FSM Free school meals – available to school pupils whose family have a low income (<£16k roughly) or are in receipt of certain benefits.

G&T Gifted and talented is used to describe children who have the potential to be significantly ahead of their peers. This may be in academic subjects or practical skills such as sport and music. Schools should provide enrichment activities to meet the needs of these children.

GCSE General Certificate of Secondary Education (usually taken around age 16).

HE Higher education.

IOP Institute of Physics.

JRF Joseph Rowntree Foundation.

KS Key stage (levels of the national curriculum in England and Wales). KS1 and KS2 are generally taught in primary schools, KS3 and KS4 in secondary school. Students usually work to GCSE (or equivalent) exams in KS4. KS5 usually refers to post-compulsory education to the age of 18 or 19.

OECD The Organisation for Economic Co-operation and Development. The OECD aims to promote policies that will improve the economic and social wellbeing of people around the world. More information at **www.oecd.org/about/**.

Ofsted Office for Standards in Education.

RAP Raising Aspirations in Physics – the title of the IOP project this report was prepared for.

SEB Socioeconomic background.

SEN(D) Special educational needs (and disabilities).

SES Socioeconomic status.

SPN Stimulating Physics Network – an IOP project to develop teaching and learning of physics in secondary schools.

STEM Science, technology, engineering and mathematics.

8

References

Archer, Louise *What shapes children's science and career aspirations age 10–13?* Interim Research Summary, ASPIRES Project 2013a

Archer, Louise, Jennifer DeWitt and Billy Wong "Spheres of influence: what shapes young people's aspirations at age 12/13 and what are the implications for education policy" *Journal of Education Policy* 2013b

Archer, Louise, Jennifer DeWitt, J Osborne, J Dillon, B Willis and B Wong "Science Aspirations and family habitus: How families shape children's engagement and identification with science" *American Educational Research Journal* 2012 **1**

Archer, Louise, Jennifer DeWitt, Jonathan Osborne, Beatrice Willis and Billy Wong "'Not girly, not sexy, not glamorous': primary school girls' and parents' constructions of science aspirations" *Pedagogy, Culture & Society* **21** 2013c

Archer, Louise, Jennifer DeWitt, Jonathan Osborne, Justin Dillon, Beatrice Willis and Billy Wong " "Doing" science versus "being" a scientist: Examining 10/11-year-old schoolchildren's constructions of science through the lens of identity" *Science Education* **94** 2010

Archer, Louise, Jonathan Osborne and Jennifer DeWitt *Ten science facts & fictions – The case for early education about STEM careers* London: The Science Council (ASPIRES Project), 2012b

Baram-Tsabari, Ayelet and Anat Yarden "Characterizing children's spontaneous interests in science and technology" *International Journal of Science Education* **27** 2005

BBC News "Newcastle axes physics courses" 3 December 2004

Bennet, Judith, Gillian Hampden-Thompson and Fred Lubben *Schools that make a difference to post-compulsory uptake of science. Final project report to the Astra Zeneca Science Teaching Trust* The University of York, Department for Education, 2011

Bond, Joanna and Terence Harbinson "Parental engagement with science" *School Science Review* **339** 2010

Bradley, Harriet and Nicola Ingram "Banking on the future: choices, aspirations and economic hardship in working-class student experience" In *Class Inequality in Austerity Britain* by W Atkinson, S Roberts and M Savage (eds) Basingstoke: Palgrave Macmillan, 2012

Broughton, Nida *In the balance – The STEM human capital crunch* Social Market Foundation, 2013

Carrington, B, P Tymms and C Merrell *et al.* 2008 Role models, school improvement and the gender gap – do men bring ot the best in boys and women the best in girls? *British Educational Research Journal* **34**

Carter-Wall, Charlotte and Graeme Whitfield *The role of aspirations, attitudes and behaviour in closing the educational attainment gap* Joseph Rowntree Foundation, 2012

CaSE *Delivering Diversity. Making Science & Engineering Accesible to All* Policy Document, The Campaign for Science and Engineering in the UK, UK: CaSE, 2008

CBI *CBI Education and Skills Survey* 2012 **www.cbi.org.uk/business-issues/education-and-skills/in-focus/education-and-skills-survey/** (accessed 12.16.2012)

CIPR Education & Skills Group *Education Influence Study* Chartered Institute of Public Relations, 2012

Cochrane, Matt *Spoilt for Choice? Pupil perceptions of the options process at year 9* British Educational Research Association Annual Conference, Institute of Education, University of London, London, 2007

Connor, Helen, Claire Tyers and Djan Nii Tackey *Minority Ethnic Students in Higher Education Interim Research Report*, DfES, Institute for Employment Studies, 2003

Coughlan, Sean *UK schools 'most socially segregated* 11.09.2012 **www.bbc.co.uk/news/education-19548597** (accessed 08.10.2013)

Craven, Rhonda G *Can Evaluating Indigenous Students' Aspirations Make a Difference?: Results of an Evaluation Study* 21st Australasian Evaluation Society International Conference. SELF Research Centre, University of Western Sydney, 2003

Crawford, Claire, Lindsey Macmillan and Anna Vignoles *Progress made by high attaining children from disadvantaged backgrounds* Research report, Centre for Analysis of Youth Transitions, Social Mobility and Child Poverty Commission, 2014

Dabney, Katherine P *et al.* "Out-of-School Time Science Activities and Their Association with Career Interest in STEM" *International Journal of Science Education, Part B: Communication and Public Engagement* **2** 2012

Davies, Peter, Kim Slack, Amanda Hughes, Jean Mangan and Katy Vigurs *Knowing Where to Study? Fees, Bursaries and Fair Access* Institute for Educational Policy Research and Institute for Access Studies, Staffordshire University, The Sutton Trust, 2008

Dawson, Emily "Science museums, science centres and non-participation" *The Informal Learning Review* **115** 2012

Department for Business Innovation & Skills *The returns to higher education qualifications* BIS Research Paper Number 45, BIS, 2011a

Department for Business, Innovation and Skills *Higher Education. Students at the Heart of the System,* 2011a

Department for Education *Statistical First Release. Schools, pupils, and their characteristics,* 2010

Department for Education *Early Years Evidence Pack* London: Department for Education, 2012

Department for Education *Maths and science education: the supply of high achievers at A level* Research report, London: Department for Education, 2011b

Department for Education *Statistical First Release – Schools, pupils and their characteristics* Department for Education, 2013a

Department for Education *Statutory Guidance – The duty to secure independent and impartial careers guidance for young people in schools* Department for Education, 2013b

DeWitt, Jennifer, Louise Archer and Jonathan Osborne "Nerdy, Brainy and Normal: Children's and Parents' Constructions of Those Who Are Highly Engaged with Science" *Res Sci Educ,* 2013

European Commission *Special Eurobarometer – Science and Technology* European Commission, 2010

Evans, Sarah "In a Different Place: Working-class Girls and Higher Education" *Sociology* **43** 2009

Falk, J and M Needham "Measuring the impact of a science centre on its community" *Journal of Research in science teaching* **48** 2011

Fine, Cordelia *Delusions of gender* 2011

Finegold, Peter, Peter Stagg and Jo Hutchinson *Good Timing Implementing STEM careers strategy in secondary schools. Final report of the STEM Careers Awareness* Department for Education, UK: Department for Education, 2011

Flouri, Eirini "Parental interest in children's education, children's self-esteem and locus of control, and later educational attainment. Twenty-six year follow-up of the 1970 British Birth Cohort" *British Journal of Educational Psychology* **76** 2006

Francis, B, C Skelton, B Carrington, M Hutchings, B Read and I Hall "A perfect match? Pupils' and teachers' views of the impact of matching educators and learners by gender" *Research Papers in Education* **23** 2008

Gill, Tim and John F Bell "What factors determine the uptake of A-level Physics?" *International Journal of Science Education* 2011

Goodall, Janet, John Vorhaus, Jon Carpentieri, Greg Brooks, Rodie Akerman and Alma Harris *Review of best practice in parental engagement* Research report, Department for Education, 2011

Goodman, Alissa and Paul Gregg *Poorer children's educational attainment: how important are attitudes and behaviour?* Joseph Rowntree Foundation, 2010

Gorard, Stephen and Beng Huat See "The impact of socio-economic status on participation and attainment in science" *Studies in Science Education* **45** 2009

Gorard, Stephen and Stuart Bevins "Exploring the relationship between socioeconomic status and participation and attainment in science education" The Royal Society, 2008

Hamnett, Chris, Mark Ramsden and Tim Butler "Social Background, Ethnicity, School Composition and Educational Attainment in East London" *Urban Studies* **44** 2007

Harackiewicz, Judith H, Christopher S Rozek, Chris S Hulleman and Janet S Hyde "Helping Parents to Motivate Adolescents in Mathematics and Science; An Experimental Test of a Utility-Value Intervention" *Psychological Science* 2012

Harris, Alma and Janet Goodall *Engaging Parents in Raising Achievement. Do Parents Know they matter?* Research Report, University of Warwick, 2007

Hazari, Zahra, Gerhard Sonnert, Philip M Sadler and Marie-Claire Shanahan "Connecting High School Physics Experiences, Outcome Expectations, Physics Identity, and Physics Career Choice: A Gender Study" *Journal of Research in Science Teaching* **47** 2010

Henshaw, Pete "Sixth formers miss out on careers advice" *The Guardian* 29.05.2013

Hernandez, Donald J *Double Jeopardy. How Third-Grade Reading skills and Povery Influence High School Graduation* The Annie E Casey Foundation, 2011

Higgins, Steve, Dimitra Kokotsaki and Robert Coe *Toolkit of Strategies to Improve Learning. Summary for Schools Spending the Pupil Premium* The Sutton Trust, 2011

Hill, Marianne *Progression from GCSE to A level Physics,* 2010a

Hill, Marianne *The progression of A level students into physics degree courses* PhD thesis, North East England, 2010b

HM Government *Opening Doors, Breaking barriers: A strategy for social mobility* HM Government, 2011

Hoare, Tony and Rosanna Mann *The impact of the Sutton Trust's Summer Schools on subsequent higher* University of Bristol, 2011

Homer, Matt, Jim Ryder and Indira Banner "Measuring determinants of post-compulsory participation in science: a comparative study using national data" *British Educational Research Journal* 2013b

Homer, Matt, Jim Ryder and Jim Donnelly "Sources of differential participation rates in school science: the impact of curriculum reform" *British Educational Research Journal* **39** 2013

Humphrey, Neil and Garry Squires *Achievement for All National Evaluation: Final report* Department for Education, 2011

Hutchinson, Jo and Gordon Parker *How do young people (in the region) form their views on future learning and career options? NE 14-19 Commission* University of Derby, 2009

Hutton, Will "Born poor? Bad luck, you have won last prize in the lottery of life" *The Observer* 15.07.2012

Institute of Physics *Opportunities from Physics: interventions in a multi-ethnic school to increase post-16 participation* Institute of Physics, July 2014

Institute of Physics *Degree-course destinations of accepted applicants with physics and mathematics A-level or Scottish Higher 2006–2011* Statistical bulletin, Institute of Physics, 2012b

Institute of Physics *Physics Students in UK Higher Education Institutions* Statistical report, Institute of Physics, 2012a

Institute of Physics *Tracking the careers of UK physics students – 2006 follow-up study* London: Institute of Physics, 2006

Institution of Mechanical Engineers *When STEM? A question of age* Institution of Mechanical Engineers, 2010

IRIS *Factors influencing recruitment, retention and gender equity in science, technology and mathematics higher education* Interests & Recruitment in Science (IRIS), 2012

James, Richard *Socioeconomic background and higher education participation. An analysis of school students' aspirations and expectations* Commonwealth department of education science and training, 2002

Kintrea, K, Ralph St Clair and Muir Houston *The influence of parents, places and poverty on educational attitudes and aspirations* Joseph Rowntree Foundation, 2011

Kocyigit, Senkoc *The relation among students' gender, socioeconomic status, interest, experience and misconceptions about static electricity at ninth grade level* MSc Thesis, The Middle East Technical University **12** 2003

Kounali, Daphne, Tony Robinson, Harvey Goldstein and Hugh Lauder *The probity of free school meals as a proxy measure for disadvantage* Bristol University, 2008

Lima Junior, Paulo, Fernanda Ostermann and Flavia Rezende *Professors' Perspectives on dropout rates in undergraduate physics courses* The ESERA 2011 Conference: Part 11: Cultural, Social and Gender Issues, 2011

8: References

London Economics *The economic benefits of a degree* Universities UK & PricewaterhouseCoopers LLP, 2007

Lorenz, Mia *Gravitating towards physics. How will higher fees affect the choices of prospective physics students?* Institute of Physics, 2012

Lyons, Terry "The Puzzle of Falling Enrolments in Physics and Chemistry Courses: Putting Some Pieces Together" *Research in Science Education* **36** 2006

MacLeod, Donald "Newcastle drops physics degrees" *The Guardian*, 3 December 2004

Mann, Anthony, David Massey, Peter Glover, Elnaz T Kashefpadkel and James Dawkins *Nothing in common: The career aspirations of young Britons mapped against projected labour market demand* UK Commission for Employment and Skills, b-live, Education and Employers Taskforce, 2013

Martin, Andy *The Impact of Free Entry to Museums* MORI, London: MORI, 2003

McWhinnie, Sean *Accepted applicants to degree courses in UK higher education institutions* Institute of Physics, 2012

Menzies, Loic *Educational aspirations: How English schools can work with parents to keep them on track* Joseph Rowntree Foundation, 2013

Milburn, Alan *Fair Access to Professional Careers* The Cabinet Office, 2012

Miller, Fiona and Gemma Wood *A new conversation with parents: how can schools inform and listen in a digital age* Pearson UK & Family lives, 2012

Moor, Helen, Megan Jones, Fiona Johnson, Kerry Martin, Elizabeth Cowell and Chris Bojke *Mathematics and Science in Secondary Schools. The Deployment of Teachers and Support Staff to Deliver the Curriculum* National Foundation for Educational Research, Department for Education and Skills, 2006

Mujtaba, Tamjid and Michael Reiss *Gender differences in 15-year-olds' perceptions of physics, physics lessons and physics teachers* The ESERA 2011 Conference: Part 11: Cultural, Social and Gender Issues, 2011

Murphy, P and E Whitelegg *Girls in the Physics Classroom: A review of the research on the participation of girls in physics* Institute of Physics, 2006

Nelson, Libby A *Why They Chose STEM* Inside Higher Ed, 7 September 2011

Newman, Mark, Mukdarut Bangpan and Janice Tripney *Factors influencing young people (aged 14–19) in education about STEM subject choices: a systematic review of the UK literature* Review, Institute of Education, 2009

NfER *Exploring young people's views on science education* The Wellcome Trust, 2011a

NfER *Summary of the NfER evaluation of STEMNET's services on pupils and teachers* STEMNET, 2011b

OECD *Education at a Glance: OECD Indicators 2012*. Country note: United Kingdom. Organisation for Economic Co-operation and Development, 2012

Ofsted *Girls' career aspirations* Ofsted, 2011

Ofsted *Going in the right direction? Careers guidance in schools from September 2012* Ofsted, 2013

O'Leary, John and Lesley Kendall *Degrees of Success – University Chances by individual School* The Sutton Trust, 2011

Paton, Graeme "A-level results: maths and science 'more popular in the recession' " *The Telegraph*, 19 August 2010

Potvin, Geoff, Zahra Hazari, Robert H Tai and Philip M Sadler "Unraveling Bias From Student Evaluations of Their High School" *Science Education* **93** 2009

Powdthavee, Nattavudh and Anna Vignoles "The socio-economic gap in university drop out" *The B.E. Journal of Economic Analysis & Policy* **9** 2009

Pronin, E, C M Steele and L Ross "Identity bifurcation in response to stereotype threat: Women and mathematics" *Journal of Experimental Social Psychology* **40** 2004

Ramirez, A Y "Survey on Teachers' Attitudes Regarding parents and parental invovlvement" *The School Community Journal* **9** 1999

Reay, Diane, Gill Crozier and John Clayton " 'Strangers in Paradise'? Working-class Students in Elite Universities" *Sociology* **43** 2009

Reay, Diane, Miriam David and Stephen Ball "Making a Difference?: Institutional Habituses and Higher Education Choice" *Sociological Research Online* **5** 2001

Riddell, Sheila "The education class ceiling" *The Scotsman* 30 May 2013

Riegle-Crumb, Catherine and Chelsea Moore "The Gender Gap in High School Physics: considering the context of local communities" *Social Science Quarterly* 2013

Rock, Lucy "Thousands of pupils shamed out of free school meals. 300,000 prefer to take a packed lunch rather than face 'stigma' of sitting apart from friends, research shows" *The Observer* 23 September 2012

Rodd, Melissa, Michael Reiss and Tamjid Mujtaba *Undergraduates' stories about why they are studying physics: implications for policy* Institute of Education, 2007

Spada, on behalf of *Professions for Good, Social Mobility Toolkit*, 2014

Spall, K, M Stanisstreet, D Dickson and E Boyes "Development of school students' constructions of biology and physics" *International Journal of Science Education* **26** 2004

Stagg, Peter, Richard Laird and Paul Taylor *Widening Participation in the Physical Sciences – An investigation into Factors influencing the uptake of physics and chemistry* The University of Warwick, 2003

Stigler, J W and J Hiebert *The teaching gap: Best ideas from the world's teachers for improving education in the classroom* New York: Free Press, 1999

Sutcliffe, Jeremy "Standing out from the crowd" *TES Magazine* 12 August 2011

Teacher Support Network *Beyond the school gate. How schools and families can work better together* Parentlineplus, 2010

The Guide Association *What girls think about...Education, training, skills and careers* 2011

The Royal Society *Preparing for the transfer from school and college science and mathematics education to UK STEM higher education. A "state of the nation" report* The Royal Society, 2011

The Royal Society *Science and mathematics education, 14–19. A "state of the nation" report on the participation and attainment of 14–19 year olds in science and mathematics in the UK, 1996–2007* The Royal Society, 2008

8: References

The Royal Society *Science and mathematics education, 5–14. A "state of the nation" report* London: The Royal Society, 2010

The Russell Group *Informed Choices* The Russell Group, 2012

The Russell Group *STEM Briefing* The Russell Group of Universities, 2009

The Sutton Trust *Improving the impact of teachers on pupil achievement in the UK – interim findings* The Sutton Trust, 2011

The Sutton Trust *Responding to the new landscape for university access* The Sutton Trust, 2010

Thomas, Liz *Building student engagement and belonging in higher education at a time of change. What Works? Student retention and success* Paul Hamlyn Foundation, 2012

University of Bristol *Does class spell success at university* Press Release, 2011

Waldfogel, Jane and Elizabeth Washbrook *On your marks: Measuring the school readiness of children in low-to-middle income families* Resolution Foundation, 2011

Whitelegg, Elizabeth, Richard Holliman, Jennifer Carr, Eileen Scanlon and Barbara Hodgson *(In)visible witnesses: Young people's views of images of scientists, technologists, engineers and mathematians on UK children's television from a gender perspective* Research Briefing, The Open University, 2008b

Whitelegg, Elizabeth, Richard Hollimann, Jennifer Carr, Eileen Scanlon and Barbara Hodgson *(In)visible witnesses: Investigating gendered representations of scientists, technologists, engineers and mathematicians on UK children's television* Research Briefing, UK Resource Centre for Women in Science, Engineering and Technology, Bradford, UK, The Open University, 2008a

Willis, Beatrice *ASPIRES Interim summary paper 1: Findings from the phase one survey and interviews. Science aspirations and career choice: age 10–14* King's College London, ASPIRES Project, 2011

Wilson, Helen and Jenny Mant "What makes an exemplary teacher of science? The pupils' perspective" *School Science Review* **93** 2011

Yildrim, Ufuk and Ali Eryilmaz "Effects of gender, cognitive development and socioeconomic status on physics achievement" *Journal of Education/Hacettepe Universitesi Egitim Fakultesi Dergisi* **15** 1999

Notes