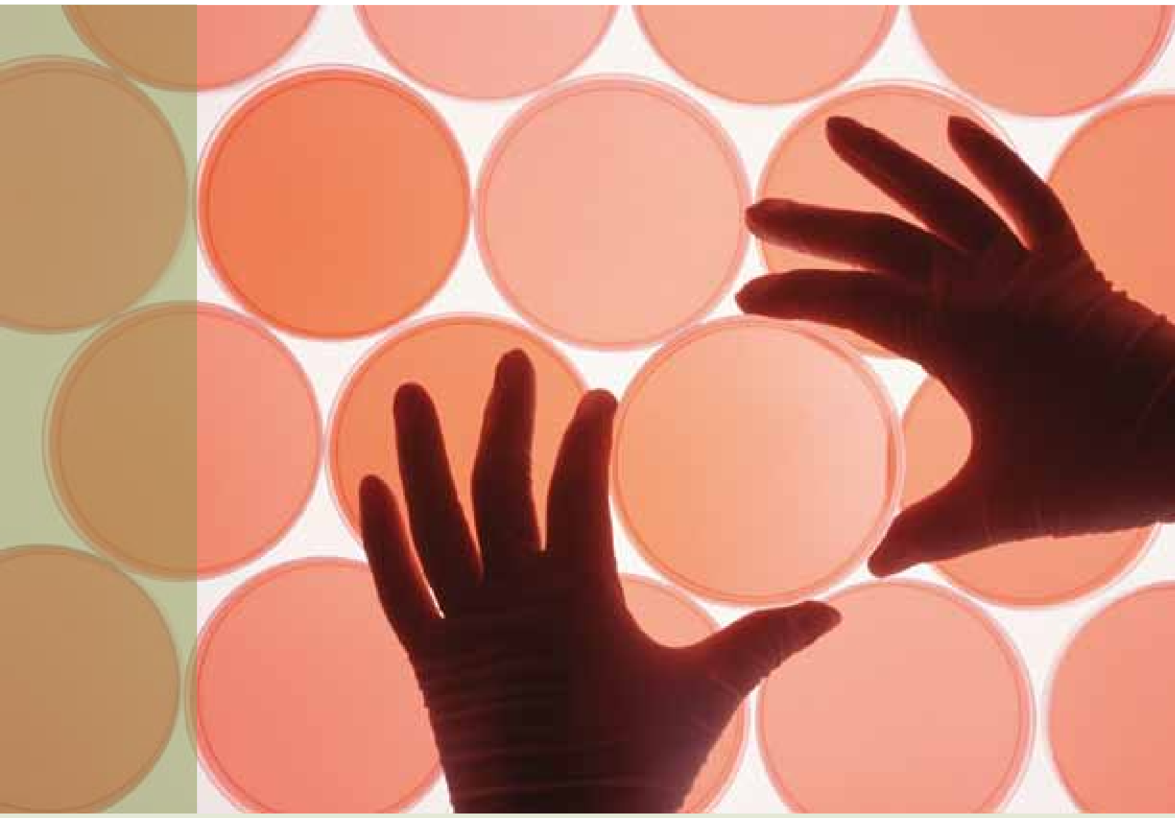
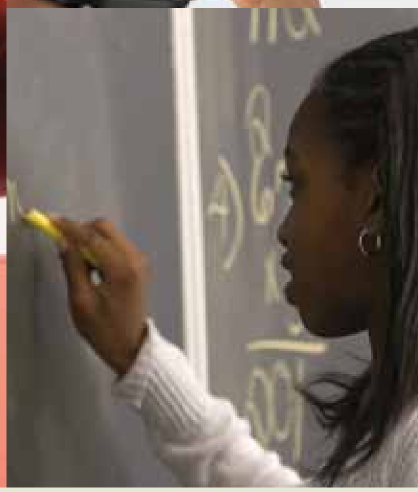
ESRC Targeted Initiative on Science and Mathematics Education

TISME
Researching Science & Mathematics Education

'What influences participation in science and mathematics?' A briefing paper from the Targeted Initiative on Science and Mathematics Education (TISME)





TISME

The Targeted Initiative on Science and Mathematics Education (TISME) is a programme of research funded by the ESRC in partnership with the Gatsby Charitable Foundation, the Institute of Physics and the Association for Science Education. Through research projects and dissemination activities, TISME aims to find new ways to encourage children and young people to greater achievement and participation in – and understanding of – science and mathematics.

TISME is comprised of five research projects:

ASPIRES – *Science Aspirations and Career Choice: Age 10 – 14*. A five year, longitudinal study of how children develop science and career aspirations, using a national survey of children (Year 6 – Year 9) and interviews with parents and children, based at King's College London.

EISER – *Enactment and Impact of Science Education Reform*. A study of school responses to recent changes in the science curriculum for 14 – 16 year olds in England, using interviews with students and teachers and quantitative analysis of the National Pupil Database, based at University of Leeds.

epiSTEMe – *Effecting Principled Improvement in STEM Education: Student Engagement and Learning in Early Secondary-School Physical Science and Mathematics*. A study which has designed and evaluated a research-informed intervention suitable for widespread use in ordinary schools during early-secondary education, incorporating key pedagogical features known to improve student attainment and attitude, based at University of Cambridge.

ICCAMS – *Increasing Competence and Confidence in Algebra and Multiplicative Structures*. This study investigated ways of raising students' attainment and engagement by using formative assessment to inform teaching and learning of mathematics in secondary school, based at King's College London.

UPMAP – *Understanding Participation rates in post-16 Mathematics and Physics*. A three year longitudinal study of the factors that cause school students to continue with mathematics or physics after the age of 16, using a UK-wide survey of year 8, year 10 and year 12 students with interviews of year 10, 11, 12 and first year undergraduate students, based at Institute of Education, University of London.

TISME is coordinated by a team of academics from the Department of Education and Professional Studies at King's College London. Further information: **www.tisme-scienceandmaths.org**

Acknowledgements

This briefing paper was written by Louise Archer with help and support from Anthony Tomei, and valuable input from the TISME Advisory Committee. We are very grateful to all TISME Committee members and to Sir John Holman and Andrew Hunt for their helpful comments and advice on earlier drafts.

Overview

In the UK students can choose what subjects to study after the age of 16. It is a commonly held view that more young people, from a more diverse range of social backgrounds, should be encouraged to continue to study STEM subjects (particularly the physical sciences and/or mathematics) at A level and degree level[1]. We ask why do many students choose not to study these subjects post-16? What are the characteristics of those who do and do not make that choice? And what might be done to improve the rate of participation?

In this paper we draw on research from the TISME (Targeted Initiative on Science and Mathematics Education) programme and elsewhere to discuss these issues. TISME is a programme of five projects, funded by the ESRC in partnership with the Institute of Physics, the Gatsby Foundation and the Association for Science Education. We draw particularly on two of the projects: **ASPIRES**, a five year longitudinal study of how children in years 6 – 9 develop science and career aspirations; and **UPMAP**, a three year longitudinal study of the factors that influence school students to continue with mathematics or physics after the age of 16.

Drawing on our own research and on the wider literature our aim in this paper is to give an overview of the state of knowledge about the key factors that shape the patterns of participation, engagement and achievement in STEM. We present new insights from the TISME research into the key factors affecting participation. For instance, TISME research shows that a lack of interest in science is not 'the problem' underlying low post-16 participation rates. Despite liking science (and expressing an interest in further study) many young people do not plan to study science post-16 because: (i) they have very narrow ideas about the 'usefulness' of science qualifications and (ii) they do not feel 'clever' enough to pursue post-16 science and science careers. New evidence is also presented regarding how families provide a key influence on young people's STEM aspirations.

The evidence from TISME research reinforces findings from other studies about the factors influencing participation. For instance, our work confirms that many of the factors that affect student choices are deeply embedded in social and educational structures and processes. They cannot be easily shifted and there are no ready policy prescriptions that will change the picture. However, this is not to say that matters cannot be improved and the paper concludes with a summary of findings and outlines our views on the possible implications for policy and practice. Our belief is that by understanding the causes and process that determine pupils' choices, and reflecting on their implications, we will be better placed to develop the policies and practices that will lead to improvements.

1 Why is STEM participation important?

1.1 In the UK, as in virtually every developed country, it is widely accepted that we need more people studying and working in Science, Technology, Engineering and Mathematics (STEM) at all levels[2]. For example, a 2009 report, on the demand for STEM graduates and postgraduates by the Council for Industry and Higher Education, states that "the workforce of the future will increasingly require higher-level skills as structural adjustments in the economy force businesses to move up the value chain. These jobs of the future will increasingly require people with the capabilities that a STEM qualification provides". STEM industries are vital elements of the UK economy and are predicted to expand relative to other fields. There is widespread consensus that there is STEM skills gap and that this gap is growing. There is a lack of both graduates and technically qualified workers in particular STEM sectors, and a fear that this will impact negatively on the UK's long term economic competitiveness[3].

1.2 There is also a broadly accepted case for widening, and not just increasing, levels of STEM participation, to ensure high levels of numeracy and scientific literacy in society. There is an equity argument to be made for diversifying the gender, ethnic and class profile of those who study STEM subjects at A level and beyond. In the 21st century all citizens need to be able to understand, participate in and shape national STEM developments[4].

2 About the TISME programme

2.1 TISME is a programme of five research projects, funded by the ESRC in partnership with the Institute of Physics, the Gatsby Foundation and the Association for Science Education. The overall aim of TISME is to encourage greater participation, engagement, achievement and understanding of Science and Mathematics on the part of children and young people. Brief details of all the projects are given inside the front cover. In this briefing paper we focus mainly on the evidence from two of the projects:

ASPIRES – *Science Aspirations and Career Choice: Age 10 – 14*. A five year, longitudinal study of how children develop science and career aspirations, using a national survey of children (Year 6 – Year 9) and interviews with parents and children, based at King's College London.

UPMAP – *Understanding Participation rates in post-16 Mathematics and Physics*. A three year longitudinal study of the factors that cause school students to continue with mathematics or physics after the age of 16, using a UK-wide survey of year 8, year 10 and year 12 students with interviews of year 10, 11, 12 and first year undergraduate students, based at Institute of Education, University of London.

Future briefing notes will describe the findings from other TISME projects.

3 What are the influences on STEM participation?

Why do some students continue with their STEM studies while others give up at the earliest opportunity? What are the factors that influence their choices, and what changes might make a difference?

Research over many years and from many countries has shown that a young person's views about where they are heading and the choices they want to make are formed early[5]. Analysis of US national longitudinal data by Tai and his colleagues[6], for example, showed that by age 14, students with expectations of science-related careers were almost three and a half times more likely to gain a physical science and/or engineering degree than students without similar expectations.

Students' aspirations by the age of 14 give a good indication as to whether they will continue with STEM when they get older. The implication is that any attempts to increase rates of participation in STEM need to start early. Understanding what influences children's attitudes at these early stages was therefore one of the key themes of our research.

3.1 Young people's views about careers in science

3.1.1 Evidence from the ASPIRES project's large national surveys of pupils between the ages of 10 and 14 shows that *liking science is not enough* – most young people report enjoying science in and out of school, yet few aspire to science careers. Our survey of over 9,000 ten and eleven year olds showed that while the great majority found science interesting, and thought that scientists do valuable work, fewer than 17% would contemplate science as a career (see Figure 1).

3.1.2 Science careers (excluding medicine) are not popular aspirations among 10 – 14 year olds. By the age of 10 or 11 a significant proportion of pupils have already decided that the idea of studying science after the age of 16 and the idea of a career in a STEM area is 'not for me'. Careers in the arts, sports, medicine, teaching and business are much more popular. Our surveys showed that over 60% of 12 – 13 year olds agree that they would like a career in business and over half aspire to a job in the arts, compared with fewer than 17% who want a career in science.

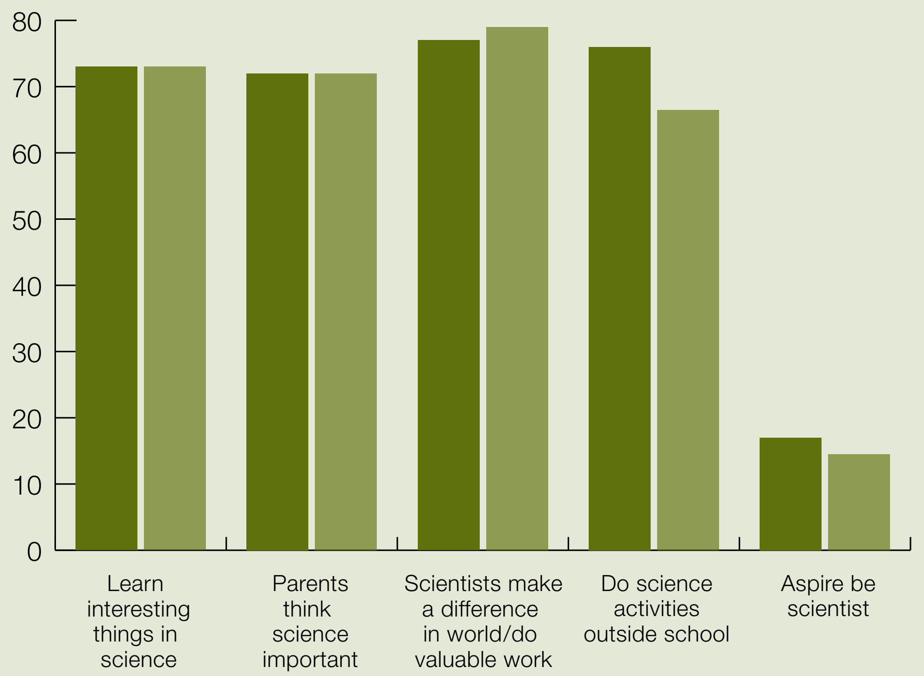


Figure 1. ASPIRES project survey responses from Y6 (age10/11) and Y8 (age 12/13) pupils (% agreeing with statement)

3.1.3 The ASPIRES project found little awareness among pupils and parents of the transferability or usefulness of science qualifications. Science qualifications are predominantly seen as leading only to jobs as a scientist, science teacher or doctor, whereas in fact they open the door to a very wide range of future occupations. Furthermore STEM qualifications carry a premium. Analysis conducted by Greenwood and colleagues[7] for the Royal Academy of Engineering found that many qualifications (e.g. A levels, degrees) have a higher labour market value when in a STEM subject. Findings from the National Child Development Study[8] also show that an A-level in mathematics can enhance lifetime earnings by 10% or more.

3.1.4 Despite liking science, reporting positive parental support for the importance of science, and expressing positive views of scientists and science careers, the majority of young people do not see any point in continuing to study science after the age of 16 if they do not aspire to this narrow set of 'science careers'. The ASPIRES project found little understanding among young people and their families of the fact that science and mathematics can open the door to a wide range of occupations and careers – or that STEM fields are predicted to grow in importance. We found that the great majority of students and parents saw science qualifications as only leading to careers as a scientist or medical doctor. The reaction of one of the boys in our study, 'Hedgehog' (see box) is typical. Here is a pupil who enjoys and does well at science, but does not intend to continue with it because he believes that it will not support his ambition, which is to become a teacher.

CASE STUDY EXAMPLE
Liking science is not enough – 'Hedgehog'

'Hedgehog' is a 13 year old boy who chose his pseudonym to reflect his spiky hair style. He loves science and previously enjoyed reading about space and doing science-related activities in his spare time. He is attaining well in the subject but doesn't plan to continue studying science because he thinks science only leads to a narrow range of future careers (e.g. scientist), which does not include his ambition of becoming a teacher. His parents do not have much science capital (see 3.2.1) or interest. Hedgehog says "my dad's a postman, so he doesn't really think about science".

3.1.5 Findings from the UPMAP study, which investigated participation rates in mathematics and physics, indicate that pupils are more likely to continue with mathematics and/or physics after the age of 16 if they recognise that studying one or more of these subjects post-16 stands them in good stead in terms of achieving a well paid and interesting job. UPMAP's survey of 7000 Year 10 and Year 12 students found that perceived material gain (' I think Physics will help me in the job I want to do in the future') is one of most important factors predicting whether students will choose to study the subject post-16.

3.2 Science capital – the importance of families

3.2.1 A key factor influencing children's aspirations is what we have called the availability of **'science capital'** among pupils and their families. Science capital refers to science-related qualifications, interest, understanding ('scientific literacy') and social contacts (for example knowing people who work in STEM-related jobs). Our evidence shows that the more science capital a family has, the more likely a child is to express interest in science as a career and/or aspire to wish to study science further. Evidence from the ASPIRES survey of over 5600 Year 8 students shows that children with a family member working in a science-related career tend to have significantly stronger aspirations in science than their peers[9]. For instance, 47% of students with a parent who works in a science-related job (compared to just 29% of the whole cohort) say that they would like to work in

science themselves in the future. Those with parents who work in science are also more likely to say they would like to study more science in the future (58%, as compared to 43% of the whole sample), to become a doctor/work in medicine (46%: 35%) or would like to have a job that uses science (50%: 32%).

3.2.2 In the ASPIRES project we found that families constitute the greatest source of influence on 10 – 14 year olds' aspirations (see also Holman and Finegold's[10] STEM Careers review, which shows that young people report families and friends as the most trusted sources of careers advice). Children from families that possess high amounts of science capital are much more likely than their peers to want to study science post-16 and/or work in science careers. Analysis of longitudinal interviews with 92 children and 78 parents (tracked from Year 6 to Year 9) found that even where these children do not aspire to science careers as such, they are more likely to plan to study science and value it for what it can bring to them in their future lives.

3.2.3 The UPMAP project had a similar finding. Survey and interview analyses show that young people are more likely to take mathematics and/or physics post-16 if a significant adult – typically a family member or a teacher – has, over time, conveyed to them the worth of mathematics and physics, along with a belief that the student can do well in the subject.

3.2.4 The uneven distribution of science capital in society means that these children are more likely to be from middle-class and White or South and East Asian families. The substantial cultural and economic resources within these families combine to make science aspirations more conceivable and achievable for these children.

3.2.5 New research is currently developing an index for measuring science capital. This will help ascertain the effectiveness of interventions and the extent to which they can increase science capital[11].

3.3 Careers education

3.3.1 TISME research found that currently most 11 – 14 year olds receive little, if any, careers education. For instance, of the 85 young people that the ASPIRES project re-interviewed at age 13, only 4 could recall engagement with any form of careers education, advisors or resources over the previous two years. Generic forms of careers advice also appear to have little effect: The UPMAP study found almost no evidence of general careers advice having any effect on the likelihood of a student taking a degree in mathematics or science. The STEM careers review conducted by Holman and Finegold in 2010 (see 3.2.2) also found little evidence for the influence of generic careers advice on young people's STEM aspirations.

3.3.2 As reported recently by the House of Lords Science and Technology Select Committee[12], concerns have been expressed by a number of STEM organisations regarding the impact of the new National Careers Service in schools and the need to ensure that young people receive appropriate, high quality STEM careers advice, information and guidance. The report also calls for greater incentives to be made available to teachers to update and improve their expertise for delivering STEM-related careers information and advice.

3.3.3 An alternative approach would be to integrate STEM careers awareness into mainstream science and mathematics teaching over the 10 – 14 age period. Evidence from the UPMAP surveys and interviews shows that mathematics and science teachers who convey messages about the importance of their subject and the value of such qualifications for students' future careers, can be highly influential (as exemplified by Amir, see box). Indeed, the UPMAP study found that receiving specific encouragement from a science teacher is one of the most powerful predictors of a student's intention to continue with physics post-16.

3.3.4 This echoes findings by Munro and Elsom[13], showing that science teachers can be a major influence on young people's motivation and enjoyment of science and can be influential by providing information about the content of post-16 science courses, and through discussing with individual pupils and their parents how the pupils would cope with more advanced study. However, this research also found that science teachers do not tend to see themselves as sources of careers information about careers in STEM and do not feel able to keep up to date with relevant careers education information. As a report by the CBI explains "for many young people, teachers are the first port of call for advice about subject choices and future study or work. But with most teachers having limited experience of work outside the education system, their insights can be restricted"[14]. This suggests that it would be necessary to provide additional support to subject teachers to support the integration of STEM careers awareness into mainstream teaching.

CASE STUDY EXAMPLE

The importance of good teachers and support – 'Amir'

Amir is of Pakistani heritage and is studying for a mathematics degree. He felt that his teacher's encouragement, particularly underlining the importance of mathematics and how it could benefit his future career, was very influential in fostering his interest in mathematics at A Level and motivating his choice to study mathematics at degree level.

3.3.5 A large-scale international report by the OECD (2012) shows that high-performing economies tend to have embedded forms of careers education[15]. A randomised control trial is currently being conducted in the United States, assessing the value of integrating career-relevant instruction across a range of subject areas[16]. Work is also currently being undertaken to identify good practice in STEM careers guidance overseas and in UK independent schools to create benchmarks for what 'good' careers education might look like in the UK[17].

3.4 Attainment and teaching

3.4.1 It is no surprise that attainment is important –- students are more likely to study science and/or mathematics pre- and post-16 if they do well in the subject[18]. According to DfE (2012)[19] figures, around 79% of students gaining an A* in GCSE mathematics go on to study it at AS level, compared to 48% of those gaining grade A, 15% with grade B and almost none of those with a grade C (1%). (By contrast twice as many students with a grade B in English, History and Geography go on to AS, as do around 10% of those with a grade C.)

3.4.2 In Physics, only 43% of those with A* in GCSE Physics, 30% with grade A, 16% grade B and 4% grade C continue on to AS level Physics.[20]` UPMAP's survey of 7000 Year 10 and Year 12 students gave similar results, showing how attainment is an important predictor of taking A Level Physics. TISME research conducted by the ICCAMS project also shows that students who understand mathematics better are more likely to say that they will choose to study mathematics post-16[21] and analysis conducted by ASPIRES suggests that students with higher attainment are more likely to express science aspirations.

3.4.3 Teaching approaches also matter. TISME research shows that good teaching can increase engagement, achievement and/or participation in science and mathematics. By good teaching we mean approaches that enable students to engage with the subject in meaningful ways[22]. Good teaching extends and deepens students' thinking not only in class but also long after the teaching is over[23]. Indeed, young people are more likely to go on to study physics and/or mathematics post-16 if they have been taught well and experienced a meaningful engagement as a learner with the subject[24]. Approaches which use pupil 'talk', discussion and debate as a tool for learning in mathematics and science can be particularly powerful in this respect, for both teachers and pupils. For example, preliminary evidence from the epiSTEMe project (which designed and evaluated an intervention for teaching mathematics and science classes at early secondary level) indicates that increasing the dialogic (discussion-based) nature of lessons correlates with higher learning gains, particularly in mathematics classes.

3.4.4 It is now widely recognised that **Formative assessment**[25], when accompanied by teacher awareness of students' understandings and common misunderstandings, can produce significant gains in learning. The ICCAMS study (aimed at increasing competence and confidence in algebra and multiplicative reasoning) developed a series of research-informed lessons and professional development activities to enable teachers to integrate formative assessment within the secondary mathematics curriculum. Evaluation indicated that the rate of learning doubled over the course of an academic year for those students who received the intervention compared to a matched comparison group[26].

3.4.5 Somewhat surprisingly the ASPIRES survey data show that students' levels of *interest* in science are little affected by attainment. For instance, in the surveys over 70% of students in Year 6 and Year 8 say they find science lessons interesting (see Figure 1) and this high level of interest is found across a range of Year 6 SAT attainment levels and with little difference between science sets in Year 8. However many young people with average or good levels of attainment feel unable to continue studying science because they see post-16 science qualifications and careers as being only for the 'brainy' few. In the ASPIRES surveys 80% of 10 – 13 year olds agreed that scientists are 'brainy'[27]. Interview data also confirmed that many "middling" achievement 12/13 year olds believe that post-16 science was 'not for them" because they felt they were not clever enough. This was despite being highly engaged with and interested in science – and is exacerbated by the narrow views reported in section 3.1.3. That is, engagement with science does not translate into participation for the majority of young people.

3.5 Post-16 pathways in science and mathematics – what are the options?

3.5.1 There are currently few options for those who want to continue with science and/or mathematics but who do not want to take traditional A levels in these subjects.

3.5.2 Overall fewer than 20% of students in the UK continue with mathematics after the age of 16. This is exceptionally low by international standards. In a recent study of 24 OECD countries no country outside England, Wales and Northern Ireland had a participation rate lower than 50% and most had participation rates of 75% or better[28].

3.5.3 The ICCAMS project survey of 1,291 students aged 14 years found that 30% of upper-middle attaining students said that they would like to continue to study mathematics after the age of 16. Some of these will go on to study A level but for the rest there is little or no provision. (Almost all schools and colleges providers require those taking A-level mathematics to have a grade B at GCSE, and many require at least a grade A.) For middle to lower attainers there is little on offer beyond GCSE retakes and remedial courses.

3.5.4 Researchers at the University of Manchester have reported how students with a grade B at GCSE, who would not normally consider taking a traditional A level in mathematics, have continued successfully to study AS level 'Use of Mathematics'[29]. This kind of evidence demonstrates that there is demand for an alternative mathematics course post 16 and it is widely recognised that many subjects both within and outside STEM need higher levels of mathematical ability. This issue is now receiving serious policy attention and changes are being proposed to create more routes for continuing the study of mathematics post-16[30]. For instance, the 2012 House of Lords report[31] on Higher Education in STEM Subjects states "We recommend that, as part of their National Curriculum review, the Government make studying mathematics in some form compulsory for all students post-16. We recommend also that mathematics to A2 level should be a requirement for students intending to study STEM subjects in HE" (para 32).

3.5.5 The ASPIRES surveys show that 43% of 12/13 year olds would like to study more science in the future, yet this interest fails to translate into actual post-16 participation at A Level and degree. Contributory factors discussed earlier e.g. perceptions of science careers as for the 'brainy few', (section 3.4.4) and lack of knowledge about the diversity of careers from science, (section 3.1.3) are exacerbated by the fact that there are few options for continuing to study science at A level beyond traditional subject A-levels (particularly for those who do not achieve grade A/A* at GCSE). Research by Donnelly[32] shows that GCSE applied science courses have been successful in engaging learners and producing higher than expected attainment, particularly among less socially advantaged groups.

3.6 Equity

3.6.1 In the UK, as in many countries, participation in post-16 science and mathematics varies considerably by gender, ethnicity and social class. Women, working-class students and those from particular minority ethnic backgrounds (e.g. Black Caribbean and Pakistani/ Bangladeshi) are under-represented in the physical sciences, engineering and mathematics at degree level. These uneven patterns of participation are not the result of 'biological' predispositions, nor are they simply the product of individual preferences. Deep-rooted social issues play a key role.

3.6.2 Societal norms popularly tend to regard science and mathematics as white, male, middle-class pursuits – with popular scientists and mathematicians tending to be seen as White men within the media and popular imagination[33]. And in some areas of the sciences this is indeed the case. Middle-class, White and Indian or Chinese young men are most likely to study the physical sciences and engineering at degree level, a pattern which has not changed for many years[34].

3.6.3 Teachers' stereotypical assumptions about gender and ethnicity are prevalent in science and mathematics classrooms. Research from the USA showed how teachers tend to attribute girls' achievement in Physics to their 'hard work' but regard boys as 'naturally bright' at Physics, even when they attain less highly than their female peers[35].

3.6.4 The ASPIRES survey of over 5,600 Year 8 students found that 18% of Black students were interested in a career in science compared to 13% of White British students – but these figures appear not to translate into participation rates. Analysis of national data sets by Elias and colleagues[36] shows that among those eligible to study Physics at degree level (i.e. those with sufficient and appropriate grade points to be eligible for entry to a physics degree programme), British Pakistani, Bangladeshi and Black Caribbean students are proportionately under-represented, compared to White students. While differential attainment may contribute in part, it does not fully explain the failure to translate aspiration into participation. Indeed, Strand's (2012)[37] analysis of UK longitudinal data found that minority ethnic (but particularly Black Caribbean) students are less likely to be entered into higher tier examinations than White students, even after controlling for prior attainment and a range of other factors (46% of White British students were entered to the higher tier science test at age 14 compared to 28% of Pakistani and 28% of Black Caribbean students).

3.6.5 International studies (such as the ROSE project[38]) and reviews[39] have indicated that many school curricula are not sufficiently relevant to the lives of the young people studying them. Criticisms have been made of the wider culture of science and mathematics, which tend to be male-orientated and present a white male public face of science, failing to adequately address or reflect diverse values and interests[40].

3.6.6 Inequalities interact with personal and social identities to shape the extent to which young people see science as 'for me'. Our research shows, perhaps not surprisingly, that those who are traditionally under-represented in post-16 physical sciences and mathematics (notably girls, working-class and certain minority ethnic pupils) tend to be less confident in their own abilities and are less likely to identify themselves as being 'good' at science and/or mathematics – irrespective of their actual abilities and attainment[41].

3.6.7 An UPMAP survey of 23,000 12 – 15 year olds found that girls who want to study Physics post-16 have lower confidence in their abilities than boys, despite tests revealing no difference in their actual conceptual abilities. Similarly interviews conducted by the ASPIRES project with 85 students who were interviewed in Year 6 and again in Year 8 revealed that girls find it harder than boys to reconcile aspirations for a career in science with their gender identity (seeing oneself as a 'normal' girl or boy), because most science careers tend to be associated with masculinity. This is exemplified by the case of Danielle – see box. As discussed earlier, middle-class families tend to be better equipped to foster and support their children's science aspirations[42].

3.6.8 While powerful, the effects of social inequalities are not immutable. The context, values and practices of families and schools can greatly encourage more girls to study STEM subjects. For instance, a recent report by the Institute of Physics shows that single-sex schools are more successful in getting more girls to study A level Physics – girls are two and a half times more likely to take A level Physics if they come from a girls' school rather than a co-educational school[43].

3.6.9 In 2011, 49% of maintained, co-educational schools in England sent no girls on to A level Physics – in stark contrast to the figure for boys, at just 12%. Indeed, in 2012, fewer than 22% of A level physics entrants were female. The Institute of Physics also found that schools with higher proportions of students eligible for FSM send fewer pupils on to A level Physics. The Institute of Physics research also shows that independent schools have a higher proportion of students studying Physics than in the maintained sector, and that the effect is particularly marked for girls.

3.6.10 The Institute of Physics' Stimulating Physics Network[44] has been successful in tripling the number of girls taking AS level Physics in participating schools between 2007 and 2012. Other research also shows that initatives for promoting gender equality in schools can be effective, particularly those which support teachers and young people in learning how to deconstruct gendered stereotypes and assumptions[45], giving cause for optimism that supporting teachers and young people to learn how to deconstruct taken-for-granted stereotypes and assumptions could make a difference in addressing some of these deep-seated inequalities.

3.6.11 Policy also plays an important role – for instance the EISER project[46] shows that the growth in Triple Award Science GCSE participation is associated with an increase in the proportion of girls within Triple Award Science. For the 2004 – 06 GCSE cohort, the percentage of girls within Triple Award Science was 41.8%, rising to 44.8% for the 2008 – 10 cohort.

CASE STUDY EXAMPLE
Gender barriers – 'Danielle'

Danielle is a 13 year old girl. She is a middle-achiever. In primary school she loved science (her favourite lesson) but worried that only geeks and boys study science and felt she was not clever enough to continue with it. With encouragement from her mother, she attended a Science after-school club but soon left because it was 'all boys' and she had no one to talk to. By age 13 she has started to regain some of her confidence in Science and still enjoys it but she now prefers PE. She thinks most girls at school find science "a bit boring".

Summary of findings and implications

Informing pupils' thinking about subject and career choices

- Choices and decisions about STEM are formed early – careers education needs to also start earlier, ideally from age 11.
- Liking science is not enough. Many children (especially girls) rule out STEM choices even though they like science, are good at it, and think what scientists do is valuable. Children, young people and their families have a narrow view of the careers that STEM qualifications can lead to. Many think in terms only of the obvious and traditional routes (scientist, engineer, doctor) and are unaware of the wide range of careers that STEM qualifications make possible. They need to be informed that science and mathematics qualifications can 'keep options open' and lead to a range of well paid and interesting careers both within and beyond STEM.
- Families constitute the greatest source of influence on 10 – 14 year olds' aspirations. Children from families that are familiar with the world of science and technology are much more likely than their peers to want to study science post-16 and/or work in science careers.
- Most young people form their attitudes to science between the ages of 10 – 14, a time when most receive little or no careers education to support or inform their ideas. An alternative approach that is used in other countries is to embed information about how STEM is used in the world, and about the people who use it throughout the curriculum. However teachers will need support and training if this is to be adopted.

Attainment

- Attainment is important. Unsurprisingly students who achieve well at GCSE in mathematics and science subjects are more likely to continue post-16. Improving attainment generally should increase the pool of students who are able to participate in post-16 STEM.
- But attainment is not the whole story. Some students, especially girls, are less likely to have confidence in their own abilities and may require additional encouragement and support.
- Many middle attaining students enjoy mathematics and/or science but do not see post-16 participation as possible for them. They see science careers as only for the 'brainy' few – a perception that needs to be challenged.

Post-16 Options

- The small range of options available to students after the age of 16 is an important limiting factor. More options would mean more students would be likely to continue post-16, especially in mathematics where rates of participation are exceptionally low by international standards.
- The recent policy moves towards developing an alternative to the traditional A level in mathematics should be helpful in this respect. The evidence suggests there will be significant take-up.
- The lack of choices for continuing with science post-16 (beyond traditional A levels in the separate sciences) for those achieving a grade B in GCSE science could be a missed opportunity.

Equity

- The gender, socio-economic and ethnic inequalities in STEM participation are deep seated. They are not simply the product of individual preferences but are profoundly influenced by social norms and processes. However they are not immutable.
- Teachers' stereotypical assumptions about gender and ethnicity are prevalent in science and mathematics classrooms. It is likely that they contribute to differential rates of participation.
- Female, working-class and some minority ethnic students lack confidence and experience lower teacher expectations of their abilities – even when they achieve well[47]. This is exacerbated within high-status, 'masculine' subjects[48]. Targeted support for students and professional development for science educators could be beneficial.

Endnotes

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[22] "meaningful engagement" of students would be operationalised in classroom terms as their engaging in > thinking about the problem in question and their following/participating in discussion of the problem. in ways that engage with their pre-existing values and interests are notably effective in increasing attainment and participation. Students do not necessarily need to enjoy the subject, but they should have the opportunity to appreciate the value and power of mathematics.

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The Targeted Initiative on Science and Mathematics Education (TISME) is a programme of research funded by the Economic and Social Research Council (ESRC) in partnership with the Gatsby Charitable Foundation, the Institute of Physics and the Association for Science Education. TISME comprises projects based at the University of Cambridge, the Institute of Education, King's College London and the University of Leeds. TISME is co-ordinated by a team of academics based at King's College, London.