ASPIRES 2

Young people's science
and career aspirations,
age 10–19

Acknowledgements

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We hope that through the various project publications and outputs we have done justice to your rich experiences and views – and please know that your participation has made a real and measurable difference to how issues of science participation are both understood and addressed around the world.

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Executive Summary

Understanding and improving STEM participation – the ASPIRES 2 study

Participation in STEM (Science, Technology, Engineering and Mathematics) is widely recognised as being highly important for national economic competitiveness, greater upward social mobility and active citizenship. There is a strongly-held belief that our future society and workforce will need more, and more diverse, young people continuing with STEM post-16. Increasing and diversifying participation in STEM is a pressing concern for policy-makers, practitioners and researchers across the globe. Moreover, despite longstanding investments of time and resource in attracting more young people, patterns in STEM participation in post-compulsory schooling remain stubbornly resistant to change.

The ASPIRES 2 research sought to generate new understandings of how and why young people come to see science as being 'for me', or not, with the goal of informing policy and practice to support increased and more equitable participation in STEM.

ASPIRES 2 is a large, national mixed-methods project which investigated young people's science and career aspirations from ages 14 to 19. The study extended previous research conducted with the same cohort of young people, who took part in the first ASPIRES project at ages 10 to 14. ASPIRES 2 provides an authoritative and valuable source of evidence as to how young people view science (and STEM) and how these views change over time, offering insights into key factors that influence their views and aspirations. In particular, it provides fresh insights into factors shaping young people's STEM participation and why existing participation patterns are so resistant to change.

The study explored:

- What shapes young people's desire to continue with science qualifications and career ambitions after compulsory education (science aspirations)?
- What are the factors that influence how young people identify as being 'good at science' and/or being 'science-y' (science identities)?

The study offers new understanding on the interplay between personal, social, familial, institutional and structural factors, alongside practices that influence young people's potential to engage and continue with science. While the study's primary focus is on the three core school science subjects, the report also summarises findings relating to technology, engineering and mathematics.

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Methods

The ASPIRES and ASPIRES 2 projects tracked a cohort of young people in England from age 10 to 19 (2009 – 2018), through over 40,000 surveys and 660 in-depth interviews with young people and parents/ carers. Data were collected from the cohort at five time points (when the young people were in school years 6, 8, 9, 11 and 13, at ages 10/11, 12/13, 13/14, 15/16 and 17/18, respectively). Follow-up interviews were also conducted at age 19.

Findings

Young people's career aspirations are relatively stable over time

- Patterns of aspiration are relatively consistent from age 10 to 18. Most students' job aspirations persisted over time (e.g. 'arts-related' aspirations).
- There was no evidence of a poverty of aspiration. The majority of young people aspired to university and professional careers, irrespective of their backgrounds. Figure 1 below presents a summary of student aspirations from age 10-18.
- There was no evidence that a lack of aspiration among young people is driving recruitment shortages in areas such as teaching. For example, over a third of secondary school students in our sample aspired to join the teaching profession – a sector which has failed to meet recruitment targets in recent years.[i]
- The proportion of young people specifically aspiring to be a scientist is around 16% (see Figure 2), is established fairly early and remains stable from age 10 to 18. However, as noted below, the demographic profile of *who* expresses these science aspirations becomes less diverse over time.

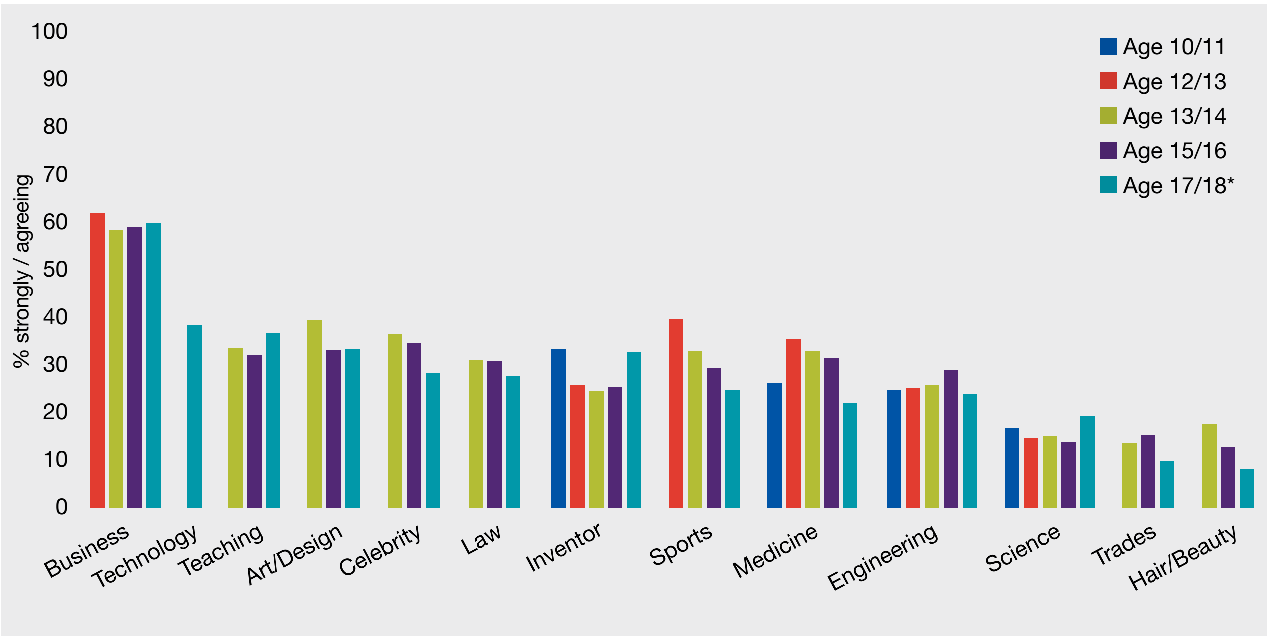


Figure 1. A summary of young people's career aspirations by age – survey data from over 40,000 students aged 10-18.
Note: *The data from students aged 17/18 is weighted to national A Level science entries.

Persistent, low science aspirations are not due to lack of interest in science

- ASPIRES 2 further confirmed the findings of the original ASPIRES study that low levels of science aspiration were not a consequence of a low interest in science, a lack of family support or the effect of negative views about scientists – see Figure 2 on the following page.

Science aspirations and science identity age 10-19 show patterns of inequalities

- Inequalities in science identities and aspirations were evident in primary school and exacerbated through secondary school. High achieving, middle-class students identifying as male and students with high levels of family science capital were much more likely to aspire to a career in science and to feel, and be recognised by others as being, 'science-y'.

i Foster, D. (2018). *Teacher recruitment and retention in England*. House of Commons Briefing Paper Number 7222. London, House of Commons Library.

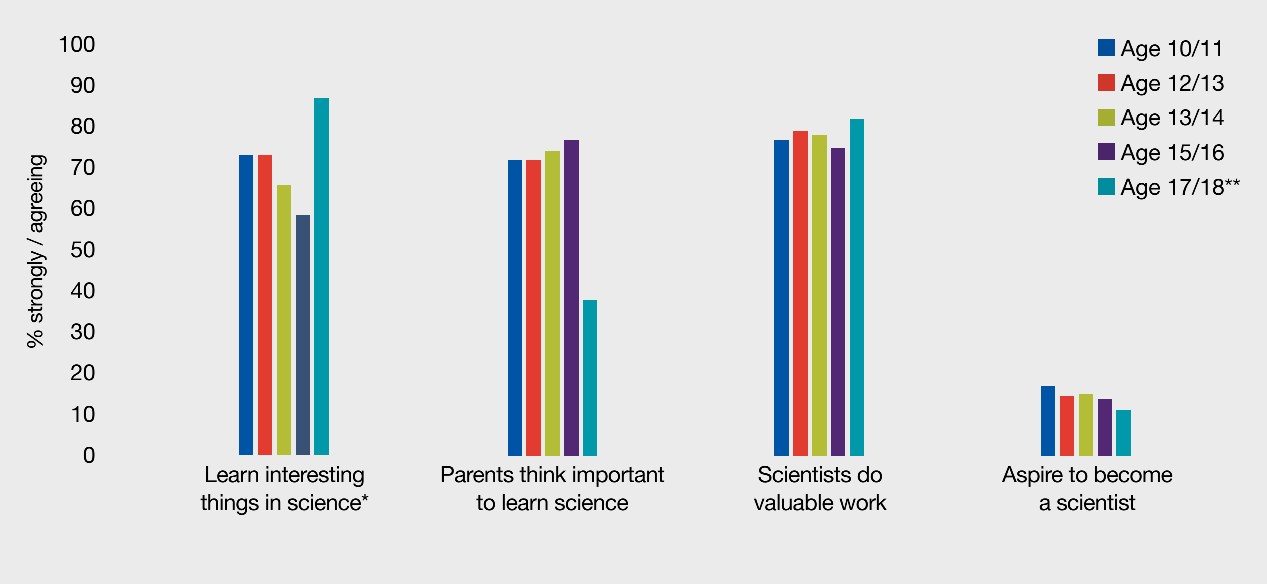


Figure 2. A summary of young people's science interest, perceptions and aspirations by age – survey data from over 40,000 students aged 10-18. ***Note:*** *Only asked of students aged 17/18 studying at least one science A Level. **The data from students aged 17/18 is weighted to national A Level science entries.

- Students identifying as Black expressed high levels of science aspiration and science self-concept, yet these do not seem to translate into post-16 science participation and/or intentions towards science careers. We discuss this disjuncture as arising from racism and other social inequalities, which we refer to as the 'science debt' that is owed to these students by society.

Factors shaping science aspirations and identities

ASPIRES 2 has enabled us to identify several key factors that shape young people's science identities and aspirations. We found that these factors are very heavily influenced by existing social inequalities such as class, gender and ethnicity, and by whether a young person has had opportunities to experience, do well in, feel connected with, be recognised in, and continue with STEM.

The factors influencing young people's science identities and aspirations are complex and multiple. They can be grouped into three overarching themes: capital-related inequalities; dominant representations of science and educational factors and practices.

The model presented in Figure 3 on the following page is a representation of these factors, and shows how there is no one single influence on science aspirations. Instead, a multitude of inequalities and experiences interact to either support or constrain a young person's science identity and/or aspiration.

We conceptualise social class, gender and ethnicity as socially constructed identities/inequalities. Social class was attributed using a proxy measure of cultural capital. This report uses participants' self-reported gender (e.g. where the text says 'young women'/'female/'girls' it refers to those who self-identified as female). Some participants self-identified as non-binary and this is noted where applicable. Ethnicity for the purposes of our work relates to students' self-reported identities within the following categories; Black (Caribbean, African), South Asian (Indian, Pakistani, Bangladeshi), Chinese or East Asian (Chinese, Japanese, Korean), White (British), Middle Eastern, Other (Mixed Black and White, Asian and White, Asian and Black). Within each of the ethnicity subgroups students were also able to select and specify Other and Prefer not to say.

'Capital', as proposed by the sociologist Pierre Bourdieu, refers to a person's resources, experiences or assets.[ii] We developed the concept of **science capital** during the first phase of the ASPIRES study as a way of encapsulating all the science-related knowledge, attitudes, experiences and social contacts that an individual may have. The concept of science capital helps us to understand why some people engage with science and others do not. For more information visit: **www.ucl.ac.uk/ioe-sciencecapital**

ii Bourdieu, P. (1984). *Distinction*. Cambridge, MA, Harvard University Press.

Figure 3. A model of factors shaping young people's science identities and aspirations age 10-19.

1. Capital-related inequalities

- Our research showed that how much, and what type, of capital a young person has (and continues to acquire throughout their education) will feed into how likely they are to pursue science and/or feel confident about their abilities in science.
- Students with lower levels of science capital were less likely to aspire to continue with science. For instance, of our longitudinally tracked students, 80% of those who had 'never' aspired to science had 'low' science capital. By contrast, 83% of those who continued with science post-18 had 'high' science capital.

We use the terms 'low' and 'high' with caution, as provisional, accessible terms for the academic concepts of exchange-value and use-value capital, while recognising that important nuance is lost in translation and that the terms can unhelpfully reify and lend to unintended deficit interpretations of capital.

2. Dominant educational and social representations of science

- We found that how science is represented (e.g. through science education, the media and in everyday life) can be very influential in shaping whether young people go on to form science aspirations or consider themselves 'suited' to science.
- The pervasive dominant association with 'cleverness' and 'masculinity' is detrimental and makes many young people feel that science is 'not for me'.
- Even very high attaining students, but particularly young women, worried that they might not be 'clever enough' to continue with science, but particularly physics.
- Over time, many young women who continued with physics progressively 'downplayed' their femininity in order to better fit the masculine image and culture of the subject.

3. Educational factors and practices

- Our data showed that teachers' attitudes and behaviours, young people's experiences of school science, and the nature of the curriculum all play a part in reinforcing or undermining science aspirations and identities.
- Young people's science choices, aspirations and progression were channelled and constrained by a range of educational gatekeeping practices, most notably through the stratification of science routes at Key Stage 4[iii] (into 'Double' and 'Triple'[iv] routes) and through stringent grade entry requirements for science A levels.
- The most socio-economically disadvantaged students were two and a half times less likely to study Triple Science compared to the most advantaged.
- Teacher specialism, supply and retention impacted on students' likelihood of identifying with and aspiring to science although these issues impacted particularly on working-class and minority ethnic students, who reported the most teacher turnover and teaching quality issues.
- Boys and students with high cultural capital were the most likely to report receiving support and encouragement from their teachers to achieve well in, and to continue with, science.
- Less than two-thirds (63%) of students aged 15-16 reported having received any careers education and only half had undertaken work experience. We found that careers education provision was patterned by social inequalities, with working-class, minority ethnic students, girls and lower-attaining students being significantly less likely to receive and benefit from high quality careers support.

Discipline-specific issues

In addition to looking at general science aspirations and identities we analysed the impact of these key factors on young people's identities and aspirations in relation to **physics, chemistry and biology**. We found that these factors had different degrees of influence in relation to each science. For example, we found that:

- Physics imposed the strictest educational gatekeeping practices of all the sciences. Students who did not achieve the top GCSE grades described being barred from embarking on a **physics** A Level courses.
- Students taking **chemistry** A Level had the highest levels of science capital (including those taking physics and biology).
- In **biology**, gender was found to be one of the biggest influences (biology A Level students were three times more likely to be female than physics students, and one and a half times more likely to be female than chemistry students).

Beyond science – young people's view of engineering, technology and maths

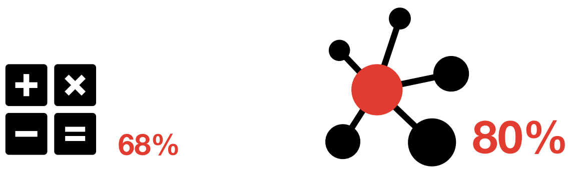
For the first time, ASPIRES 2 data allowed us to consider how the different areas of STEM relate, and are influenced by external factors. For example, we found that:

- Science capital can be used as a partial proxy for 'STEM capital' - a student with high levels of science capital was significantly more likely to express positive attitudes towards all four STEM disciplines and was more likely to aspire to pursue a degree in science or engineering.
- Gender plays a very strong role in technology, engineering and maths aspirations and identities. For example, fewer girls than boys agreed that a **technology** qualification can help you get a wide range of jobs. Girls were also much less likely than boys to aspire to careers in technology and reported less parental support to continue with technology.
- Gender had a very large effect on **engineering** aspirations that was evident from the age of ten. For instance, only 11% of girls aged 10 aspired to engineering careers, compared to 44% of boys.

iii Key Stage 4 (KS4) is the stage of school education in England that incorporates national GCSEs examinations, over Years 10 and 11, and sometimes Year 9.

iv 'Triple Science' is the study of three separate science GCSEs, whereas students studying 'Double Science' (or Combined Science) study all three sciences for two GCSE awards. Students then have the option to study multiple routes including; A level (considered the prestigious route to university entrance), AS level, BTEC (more applied training route) and International Baccalaureate.

- Compared to their peers, students who aspired to **engineering** expressed distinctive views, being more likely to be motivated to earn a lot of money, make a difference in the world and to create things. Young women who aspired to engineering were highly distinctive (compared to both young women in general and young men who aspired to engineering), being exceptionally confident in their science academic abilities and relatively less likely to be motivated by a desire to help other people through their future careers.
- **Mathematics** was one of the consistently popular (liked) subjects throughout school from age 10-18, although the percentage of students intending to study maths post-16 declined as students progressed through secondary school. The majority of students (68%) agreed that maths is relevant and useful for their everyday life, although this percentage was lower than for science (80%). The students least likely to express high self-confidence in maths were young women.



The majority of students (68%) agreed that maths is relevant and useful for their everyday life, although this percentage was lower than for science (80%).

Recommendations

What do our findings means for policy and practice?

We suggest that STEM education policy and practice communities might usefully consider changes to how we think about STEM engagement and inspiration work and changes to what we do in practice (see Figure 4 below).

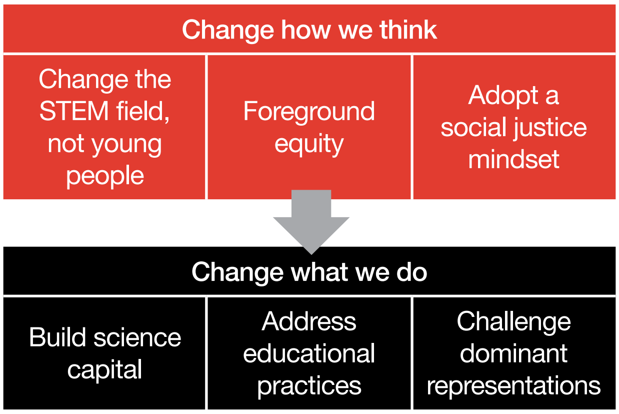


Figure 4. Overview of recommendations for policy and practice.

Changing how we think

- **Focus on changing STEM education, not young people.** The sector needs to recognise, and challenge the processes that maintain and perpetuate the elitism of STEM, which underpin and drive low and unequal participation. Widening participation in STEM requires changes in power relations and cannot be achieved by continuing with 'business as usual'.
- **Foreground equity in all STEM education policy and practice.** Acknowledging how social inequality drives aspirations and self-identity in science; equity and social justice should be placed at the heart of STEM education. Where equity is not foregrounded, the default will be the reproduction of inequalities.
- **Employ a social justice mindset.** Applying a social justice framework to STEM education policy and practice can support more equitable and informed approaches to improving STEM participation.

Changing what we do

In line with the three overarching key factors that we found shaped young people's science identities and aspirations, we suggest the following changes in practice would be beneficial: focus on **building science capital,** rather than just inspiring and informing young people about STEM; and identify and transform **educational gatekeeping practices** that restrict access or resources to certain groups of young people and **dominant representations of STEM** that reinforce the elitism of science.

Building science capital: building science capital in young people requires relatively long-term changes to core pedagogical practice and cannot be achieved solely through short-term and/or 'one-off' approaches. Key recommendations for building science capital include:

- Starting as early as possible (ideally from early in primary school).
- Moving away from single experience initiatives towards longer term, regular partnership work with young people.
- Focusing efforts and resources particularly on working with under-represented communities.
- Focus not only on the science content, but prioritise the mind-set through which science is taught, to better connect with and value the identities, knowledge and interests of all students.
- Using the principles of the science capital teaching approach (see http://bit.ly/SCTeach).
- Use the YESTEM compass to help you develop and apply a social justice mind set to policy-making and practice.[v]
- Working with others across the sector. Change will only happen when we work together towards the same aims (see http://bit.ly/PolicySciCap).

Identifying and transforming educational practices

- Focus on reforming the systems and practices that support and perpetuate notions of 'clever' science and 'masculine' science, especially gatekeeping practices that restrict access and/or resources for certain groups of young people in your setting.
- Lobby for changes to educational gatekeeping practices that restrict and narrow the pool of young people continuing with science/ STEM.
- Support increased resourcing for earlier, better quality, targeted careers provision for all young people.

Identifying and challenging dominant representations of STEM

- Audit and address how science and STEM are portrayed, represented and accessed in any given setting.
- Support a meaningful discourse among STEM educators and professionals to help identify, reflect on and challenge common practices and ideas about who does science and what gets recognised as 'being good at science'.
- Challenge notions of STEM as being 'hard', 'difficult' or for the 'clever' and the idea of there being a 'science brain'.

Impact

This research has achieved considerable impact on policy and practice across primary, secondary and informal science education sectors, both nationally and internationally. We were awarded the British Educational Research Association 2018 prize for Impact and Public Engagement, were finalists for the ESRC Societal Impact prize and were winners of the 2019 ESRC Panel's Choice award for impact.

v Archer, L., Godec, S., Calabrese Barton, A., Dawson, E., Mau, A., & Patel, U. (under review). Changing the field: A Bourdieusian analysis of educational practices that support equitable outcomes among minoritized youth on two informal science learning programmes.

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1. Introduction

Q

- What do young people aspire to and what shapes these aspirations?
- What makes a young person choose a STEM (Science, Technology, Engineering, Mathematics) route, or not?
- How do factors vary between the different sciences?
- Why do so few young women continue with physics?
- To what extent are the issues shaping science participation the same, or not, for technology, engineering and maths?
- What can policy and practice do to support increased and broadened science participation?

These are questions that are often asked within STEM education policy and practice circles. This report helps to answer these questions by summarising key evidence, findings and recommendations from the ASPIRES 2 project. ASPIRES 2 was a large, national mixed methods research project which investigated young people's science and career aspirations age 14 to 19. The study was funded by the UK's Economic and Social Research Council (ESRC), and was originally based at King's College London, then moved in 2017 to the UCL Institute of Education. The study built upon research conducted previously with the same cohort of young people who took part in the first ASPIRES project from age 10 to 14. This report is written with policy and practice audiences in mind and is underpinned by extensive academic research and publications.

The ASPIRES studies seek to understand what shapes young people's *science aspirations* (the extent to which they are interested in continuing with post-compulsory science qualifications and potentially careers in science) and their *science identities* (the extent to which they see themselves, and are recognised by others, as being 'good at science' and/or 'science-y'). Our research identifies which (and how) personal, social, familial, institutional and structural factors influence young people's potential to engage and continue with science. While our primary focus is on science (notably physics, chemistry and biology), the report also summarises findings relating to technology, engineering and maths. Our interest in these questions is informed by policy concerns about the STEM skills 'gap', as well as our belief that more equitable participation in science is important for social justice, social mobility and active citizenship[a].

The main body of the report contains more detail and has been designed so it can be read either as a single document or as stand-alone topic-based sections (e.g. for the reader who wants the evidence on, say, girls and physics, or careers education). For this reason, there are some points of overlap and/or cross-referencing across the main text. We also present a summary of recommendations for policy and practice (e.g. those working in schools or the informal learning sector).

a Our interest in improving student participation in science is underpinned by a social justice rationale. That is, we believe it is important to address social injustices in, and as perpetuated by, STEM, particularly with regard to supporting improved social mobility, active citizenship, agency and fulfilment among all, but especially among communities traditionally underrepresented in STEM.

2. ASPIRES 2 Methodology

The ASPIRES 2 study built upon research conducted previously with the same cohort of young people, who took part in the first ASPIRES project from age 10 to 14. Together, the ASPIRES and ASPIRES 2 projects tracked a cohort of young people in England from age 10 to age 19, using surveys and in-depth interviews.

As detailed in Table A, data were collected from the cohort at six time points. In total, the study conducted over 40,000 surveys and 660 interviews with young people and parents in England over the ten-year period.

For both the quantitative survey instrument and qualitative interview protocol, we decided against defining the term 'science' explicitly, as we did not want to influence responses. Although this means that multiple understandings are possible, how students understand the term was explored in focus groups and, as would also be expected from other research, the term was generally understood to cover topics aligned with the school curriculum (broadly related to physical and biological sciences), as well as prevalent images such as 'explosions'. It was not understood to cover areas such as social sciences or maths.

Cohort born September 1998 - August 1999		ASPIRES			ASPIRES 2		
		Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6
Key Information	Academic Year	2009 - 2010	2011-2012	2012-2013	2014-2015	2016-2017	2017-2018
	Cohort Age	10/11	12/13	13/14	15/16	17/18	18/19
	Education Stage	Year 6 – End of Key Stage 2 primary school	Year 8 – Key Stage 3/ Second year of secondary school	Year 9 – End of Key Stage 3/Start of Key Stage 4	Year 11 – End of Key Stage 4/ National GCSE exams	Year 13 or equivalent – End of Key Stage 5/ College	First year of university or employment /gap year/ continuation of sixth form or college studies
Quantitative Sample	Students surveyed	9,319 (279 primary schools)	5,634 (69 secondary schools)	4,600 (147 secondary schools)	13,421 (340 secondary schools)	7,013 (265 schools/ colleges/sixth forms)	
Qualitative Sample	Students interviewed	92	85	83	70	61	61
	Parents interviewed[c]	79 (84 parents)	[parents not interviewed]	66 (73 parents)	63 (67 parents)	61 (65 parents)	

Table A[b]: Details of project samples and methods.

b A longitudinal approach was applied to the qualitative data collection, meaning that the same students and parents were interviewed at each phase of data collection. A cross-sectional approach was applied to quantitative data collection, meaning that students participating in one survey had not always completed a previous survey. To account for this, efforts were made to ensure that each survey sample was nationally representative of the overall school student population in England (taking into account school type, gender, ethnicity, and eligibility for free school meals). Additionally, in this report, 'significant' refers to statistically significant findings from a variety of analyses. Please refer to our referenced publications within this report or contact us for more details.

c For parent interviews the first number denotes the number of parental interviews conducted at each time point. Numbers in brackets denote the number of parents – some interviews involved more than one parent of a child.

3. What do young people aspire to age 10-19?

Aspirations can be understood as expressions of people's hopes or ambitions:

From intensely held goals and desires to looser, more nebulous interests; from 'high' or lofty ambitions to more prosaic, mundane or realistic expectations; from 'already known' and concrete expectations to fragile dreams that are constantly mediated and shaped by external constraints[1].

In our research on ASPIRES/ASPIRES 2, we see aspirations as being profoundly shaped by social identities and inequalities, particularly in relation to intersections of social class, 'race'/ethnicity and gender. These are also produced through the interaction between people's identities, socialisation, resources ('capital'[2]) and the social and institutional contexts and spaces of power relations that they move in, across and between.

But why focus on young people's aspirations? Especially, as many of us know from personal experience, aspirations can, and often do, change over time. We have chosen to study this field because research shows that a young person's aspirations can give an indication of what type of careers they may have as an adult[3], especially in the case of science[4]. There is arguably also a value in looking critically at aspirations, given the widespread policy assumption that 'raising aspirations' will lead to wider educational participation.

3.1 Young people's career aspirations are relatively stable over time

Looking at our data on young people's aspirations over time, we were surprised by the relative consistency in patterns of aspiration. While individual students often expressed different aspirations at different time points, overall there was less variability than we expected. Indeed, the interview data often revealed the persistence of broad aspirational trends over time.

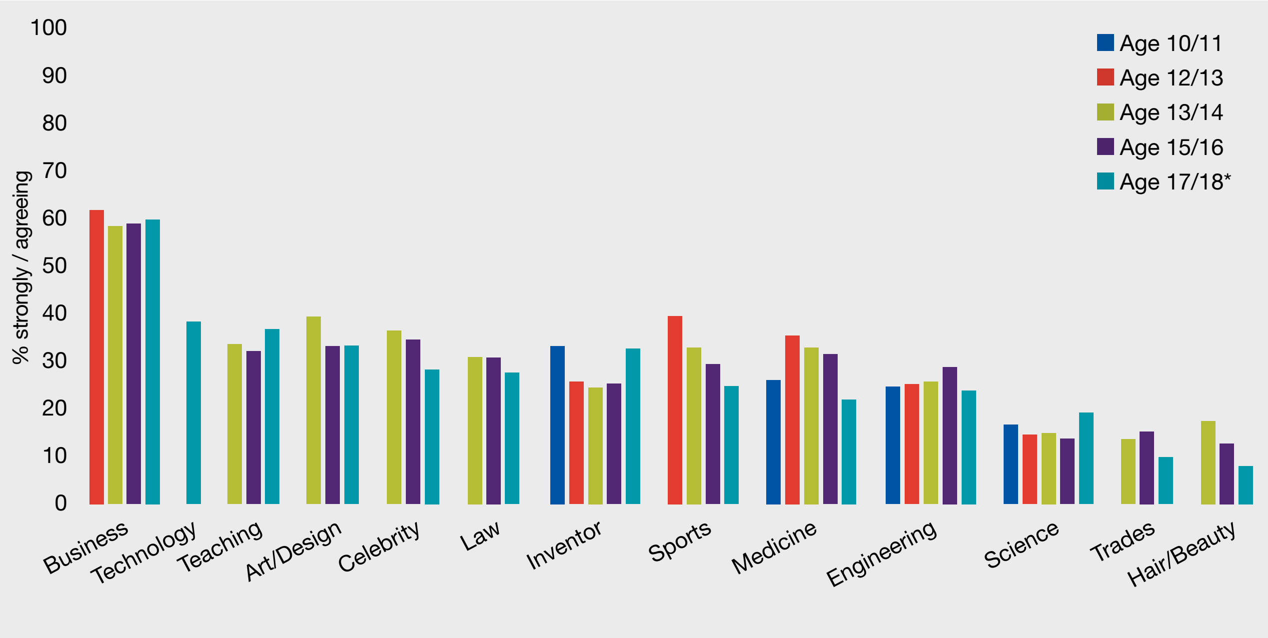
d Whilst the majority of students from all backgrounds and at all ages surveyed aspired to go to university, students from the most advantaged backgrounds were over twice as likely to plan to go to university than those from less socially advantaged backgrounds – with the latter being six times more likely to report that they had never considered going to university.

CASE STUDY: A science theme ran through the aspirations of Joanne (White British, lower-middle-class young woman), who aspired to be a naturalist at age 10/11, a chemist or biologist at age 12/13, a research chemist at age 15/16, and a doctor at age 17/18. She went on to study for a natural sciences degree and, when we last spoke with her, was considering a biomedical research career.

As illustrated by Figure 1, the ASPIRES and ASPIRES 2 survey data revealed the consistency of aspirational patterns in young people from age 10 to 18. Business was consistently the most popular aspiration (with a diverse appeal, across gender, ethnicity and social class) with almost two thirds of survey respondents of all ages reporting that they would like to run or work in a business. In comparison, c.16% of young people agreed that they would like to be a scientist (see Figure 2), with no significant change in the proportion of young people aspiring to be a scientist from age 10-18. However, as discussed further below, the demographic profile of who expressed science aspirations became less diverse over time.

16% of young people agreed that they would like to be a scientist.

It is interesting to note, as exemplified by Figure 1, that contrary to education policy discourse, overall there was no evidence of a widespread poverty of aspiration. The majority of young people aspired to university[d] and professional careers, irrespective of their backgrounds. It is also notable that there was no evidence that a lack of aspiration among young people is driving later recruitment concerns in areas such as teaching, engineering (and technology), as the data show that these are consistently popular aspirations. For instance, on average, around 34% of secondary school students in our sample aspired to teaching careers. Yet these high levels of student aspiration appear not to be translating into comparable levels of application to initial teacher education and/or jobs in teaching. We interpret these findings as suggesting that recruitment issues may be less a matter of low aspiration and that other factors may be later blocking or mediating the persistence or achievement of these aspirations.



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Note: *The data from students aged 17/18 is weighted to national A Level science entries.

3.2 Persistent, low science aspirations are not due to a lack of interest in science

As detailed in section 3.1, around 16% of the 40,000 young people aged 10-18 surveyed for the ASPIRES studies agreed that they would like to become a scientist in the future[e]. This suggests that, compared with the other occupations presented, a science career appeals to relatively few young people.

One common assumption – underpinning many interventions aimed at attracting more people to pursue science – is that many young people do not find science sufficiently interesting. Other common assumptions underpinning science outreach work are that young people may be put off science careers due to negative views of scientists and/or that their families do not value science. However, our data suggest that these assumptions may not be the case. As illustrated by Figure 2 on the following page, the majority of students age 10-18 agreed that they learned interesting things in science classes – even through the GCSE examination preparation years (age 15/16)[f]. Moreover, students reported relatively strong parental valuing of science (at least until the point at which science is no longer compulsory) and expressed generally positive views of scientists, such as that they do valuable work.

The data presented in Figure 2 indicates that generally high levels of student interest in and valuing of science and scientists are not translating into correspondingly high levels of science aspiration – a relationship that we have previously termed the **'being/doing divide'**[5] – in that students appear to like 'doing' science, but this does not translate into aspirations to 'be' a scientist.

e See 'ASPIRES 2 Methodology' section for the age ranges of the cohort when surveyed.

f General Certificate of Secondary Education (GCSE), refers to the English national examinations sat by all students at age 15/16 (Year 11).

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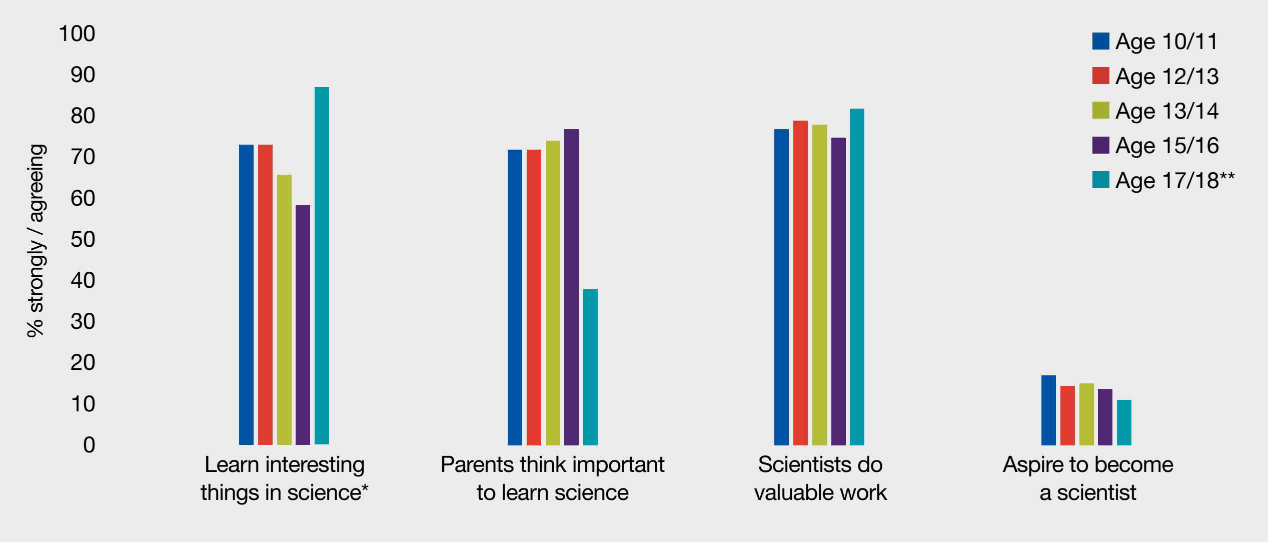

Figure 2. A summary of young people's science interest, perceptions and aspirations by age – survey data from over 40,000 students aged 10-18. ***Note:*** *Only asked of students aged 17/18 studying at least one science A Level. **The data from students aged 17/18 is weighted to national A Level science entries.

3.3 Science aspirations and identity age 10-19 show patterns of inequalities

3.3.1 Inequalities in science aspirations

Our survey data revealed clear and persistent patterns in terms of who aspires to a career in science[g]. These patterns were evident from the end of primary school and not only persisted, but became more pronounced through secondary school. In short, students who were significantly more likely than others to aspire to a career in science were the most socially advantaged students, but particularly boys and those from middle-class families, and especially those with a family member who has a science qualification and/or science-related job.

Across all ages, students were significantly more likely to express science aspirations if they were from socio-economically advantaged families. The largest gap in science aspirations was found at age 17/18, when the most socio-economically advantaged students were over two and half times more likely to aspire to be a scientist compared to their less advantaged peers.

Specifically, at all ages, boys were significantly more likely than girls to agree that they would like to become a scientist. While this gap was evident from age 10, it increased over time, with the biggest gender difference in science aspirations being found at Year 13 (age 17/18).

Trends by ethnicity were also found, with South Asian and Chinese students being most likely to agree that they would like to become a scientist. Black students also expressed higher science aspirations than White students (see Section 3.3.3).

3.3.2 Inequalities in identification with science

We are interested in understanding the extent to which young people identify as being 'good at science' and/or being 'science-y', or not[h]. This is because research has shown that a young person's engagement with science is strongly shaped by the extent to which they are able to identify with, and feel good at science, and by whether they are recognised by others as being 'science-y'[6].

Across both the qualitative and quantitative data, we found that some young people were much more likely to feel, and be recognised by others as being 'science-y'. Notably these were high achieving, middle-class boys and students with high levels of family science capital.

CASE STUDY: Tom4 is a middle-class boy of South Asian heritage. His father works as a medical professional and the family possess considerable science capital. Tom4 had aspired to a career in STEM or medicine from a young age and decided to study maths and physics at university. He attains highly and had a long-standing identification with 'cleverness', having been recognised (and recognising himself) as being 'gifted and talented' from primary school.

g We use the terminology of science jobs/careers and careers in science to refer to occupations, such as 'scientist', that are very closely allied to the natural and physical sciences. We use the terms STEM careers and careers in STEM to refer to jobs that are substantively to do with science, engineering, maths and/or technology.

h Conceptually, we understand identity as a complex phenomenon that is produced within specific contexts. Young people's identities can draw on, and be restricted by, a range of social and cultural resources.

While the interviews provided a rich dataset for exploring the intricacies of how and why some young people came to see science as 'for me', or not, we used more pragmatic measures to identify wider trends in young people's identification with science in the survey data. For instance, we used a measure of *science self-concept*[i7] to explore the extent to which young people felt that they were 'good at science'. Our survey data indicated that, overall, students' science self-concept decreased as they progressed through secondary school. That is, the longer most students studied science, the less good they felt they were at it. The only group whose science self-concept significantly increased were those who continued with science A Levels post-16.

We also identified that the most notable decreases in science self-concept were occurring at different time points for different students. For instance, the biggest proportional decline in science self-concept was noted between Year 6 and Year 8 among girls, students from the least advantaged backgrounds and White students. During Year 9 to Year 11, science self-concept declined most sharply for boys and Black students, whereas in Year 11 to 13, the main decreases were seen among South Asian students and those from the most advantaged backgrounds.

Gender, ethnicity and social class were also related to the extent to which students reported feeling 'good at science', or not. For instance, girls and students from lower socio-economic groups were both significantly less likely to agree that they were good at science and were significantly more likely to report that they found the subject difficult[j]. Moreover, across all survey age points, students with lower socio-economic status were significantly less likely to feel that their teacher cared whether they understand science.

CASE STUDY: Charlie is a working-class, White British, young girl who lives with her mother. Over the years, Charlie has had a range of ideas about what she would like to do in the future, although she has never aspired to a science or STEM Career. At age 18/19 she was studying beauty at college. Although Charlie enjoyed participating in science experiments at school, she found science lessons in general 'boring'. In Year 8, she described feeling very different to the ***"proper clever people"*** in her science class who were ***"like always asking all these technical questions"*** but "no one has a clue what they're talking about". In Year 11 she chose not to take Triple Science at GCSE, saying that she ***"could not"*** study science for that many hours a week, and in Year 13 she said that she no longer participated in any science activities outside of school because ***"it's got nothing to do with what I want to be, then there's no point in… it doesn't relate"***. Charlie felt that the identity of science students, but particularly physicists, was very distant from her own and her friends' feminine identities. For instance, saying in Year 11, ***"when I hear of physics I think of… nerdy boys in my year… I don't really think of girls like because they're all into beauty and that in my school"***.

3.3.3 The 'science debt' experienced by Black students

The ASPIRES 2 data also revealed a further conundrum – namely, that Black students are distinguished by their relatively high levels of science aspiration and science self-concept (as discussed previously). However, these do not seem to translate into participation in post-compulsory science courses, academic scientists, or the wider science workforce. These issues are amplified by intersectional injustices[8], as kat cecil poignantly discusses in relation to the experiences of senior Black women STEM academics in the UK[9]. We refer to this disjuncture as the 'science debt', drawing on Gloria Ladson Billing's (2006) notion of the 'education debt'[10], in which she powerfully reconceptualised educational 'gaps' in attainment (between Black and White students) as a debt that is accumulated over time, through relations of injustice and experiences of both overt racisms and repeated microaggressions, and that is consequently 'owed' by the system to racialised communities[11].

i We define science self-concept as students' global perceptions of their abilities in science.

j With Cramer's V values indicating small effect sizes respectively.

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4. What influences young people's science aspirations and participation age 10-19?

4.1 Factors shaping young people's science participation age 10-19

Our research found that the factors influencing young people's science identities and aspirations (from age 10 to 19) are complex and multiple. There was no single decisive or causal factor.

As detailed in Figure 3 below, analysis of the ASPIRES 2 qualitative and quantitative data identified three main sets of factors influencing young people's science identities and aspirations:

- **Capital-related inequalities**
- **Educational factors and practices**
- **Dominant educational and social representations of science**

These are discussed in detail in sections 4.2-4.9 of this report. These areas are all shaped by wider structural inequalities, such as social class, gender and ethnicity. Together, these factors influence the nature and extent of the opportunities young people have to experience, do well in, feel connected with, be recognised in, and continue with science. That is, the extent to which young people express science identities and aspirations.

The model below model attempts to convey how inequalities of gender, ethnicity and social class cut across and shape all other influences on a young person's science aspiration and/or identity. These inequalities interact and permeate all other factors shown on the model.

Figure 3. A model of factors shaping young people's science aspirations and identities age 10-19.

For instance, a Black, working-class young woman may continually experience multiple social injustices (e.g. racism, classism, sexism) potentially making it harder for her to access, relate to, and progress in science or be recognised as 'science-y'[12]. In contrast, while a White, middle-class young woman will be disadvantaged by gendered inequalities, these may be partially mediated by White middle-class privilege.

At the centre of Figure 3, is a young person's science identity and aspiration. This is nested within the opportunities, capacity and potential for them to engage with, do well in, be recognised for, and continue with science.

It should be noted that while the conceptual model in Figure 3 depicts each area as being of equal size, the relative 'weight' of each area was found to vary for different students.

Capital-related inequalities

4.2 Science capital

We developed the concept of science capital during the first phase of the ASPIRES study[13]. Science capital refers to all the science-related interests, attitudes, resources, behaviours and social contacts that a person might have. We have since elaborated the concept[14] and found that it is a useful tool for understanding science aspirations. Science capital provides a way of differentiating between different (science and non-science related) forms of capital[15], but also helps to explain why some students' science-related capital may be valued and translated into science progression, whereas others' may not[16].

Together, the ASPIRES 2 qualitative and quantitative data showed that the level of a young person's science capital was strongly and consistently related to the likelihood that they would aspire to, and participate in, post-compulsory science.

The survey data[17] and the interview data showed that a student with 'high' science capital was significantly more likely to take one or more science A Levels[k] and aspire to pursue a science degree (particularly in physics, see section 5.1) and/or career in science. Likewise, students with 'low' levels of science capital were more likely to not aspire to continue with science.

Students with high levels of science capital tend to come from very 'science-y' families. The ASPIRES 2 data showed us that these families strongly value and identify with science, and provide children with extensive science-related resources and experiences. In these families, science is part of daily family life, it was 'what we do' and 'who we are'.

CASE STUDY: In all of their interviews Davina and her father Dawkins – who held a science degree – described their regular family mealtime discussions about science-related TV programmes, books and articles in New Scientist magazine (both upper-middle-class, White British). As Davina put it in Year 11 ***"my house is just like – science is just where it's at basically".***

In contrast, students and parents with low science capital were more likely to say that their family *"never talk about science"* and felt that *"you don't really need science in your everyday life". (Jack, lower-middle-class, Black African, male, Year 6).*

As illustrated in Figure 3, how much science capital a young person has is influenced by their gender, ethnicity and social class. Accordingly, our survey analyses showed that boys and students with very high cultural capital were more likely to have higher levels of science capital. South Asian students were also proportionately over-represented among students with high levels of science capital. In comparison, students from underserved communities were proportionally overrepresented among students with low science capital.

While exerting a significant influence on students' science identities and aspirations, science capital was not, of course, deterministic.

CASE STUDY: A handful of students with high science capital in our interview sample did not pursue science routes. However, many of these students, like Robert M who took physics, maths and French at A Level but went on to pursue an art foundation course, did exhibit strong identification, interest and achievement in science. In contrast, some students with lower levels of science capital in our interview sample completed science A Levels and went on to study science degrees – although, as we discuss elsewhere in the case of Danielle[18] (a working-class, White British, young woman), some students on this pathway had to work particularly hard to maintain their identities and achievement. That is, their science trajectories were harder and required considerable effort from themselves and their families, and not all succeeded.

k Results showed that students who were taking A Level science had significantly higher levels of science capital than their peers taking non-science subjects at A Levels and 'other' routes (both science and non-science).

4.3 Specific inequities and risks

A small number of students from our interview sample experienced specific challenges in their lives which impacted on their potential to continue with science and education in general. While such issues did cut across the sample, they disproportionately impacted working-class students. For instance, tragic experiences of bereavement had an even greater impact on educational and career plans when the death of a parent meant that a young person had to take on new caring and/or earning responsibilities. We also spoke with students who encountered issues on the basis of neurological differences and mental health issues that were inadequately supported, meaning that previous aspirations were delayed or abandoned.

4.4 Other capital and passions

As detailed in Figure 3, the presence of significant capital and passions relating to other (non-science) subjects or occupations (e.g. arts, teaching) was associated with students aspiring to and pursuing other (non STEM) routes.

CASE STUDY: Gus (an upper-middle-class, White British, young man) possessed considerable arts-related cultural capital, but very little science capital. It was perhaps not surprising that over the course of the study, despite attaining well in science and finding some areas, such as physics ***"interesting"***, that he aspired to arts-related, and never STEM, careers.

Educational factors and practices

4.5 Schools, teachers and classroom science

The practices of schools, teachers and classroom science all played a part in shaping the possibility and desirability of science for different students. As is the case with all the factors identified, and as illustrated by Figure 3, educational factors were structured by inequalities of social class, 'race'/ethnicity and gender.

For instance, **teachers** played a part in supporting or constraining students' science aspirations and identities in a range of ways. Our data showed that issues of teacher specialism, supply and retention impacted on a young person's likelihood of identifying with and aspiring to science. Working-class and minority ethnic students were particularly likely to be disadvantaged by high teacher turnover and reports of poor quality teaching. Boys and students from more affluent backgrounds were the most likely to report receiving support and encouragement from their teachers to achieve well in, and to continue with, science.

Issues of teacher specialism, supply and retention impacted on a young person's likelihood of identifying with and aspiring to science.

Although most students reported finding school science interesting on the whole, the qualitative data highlighted that the physics **curriculum** was highlighted as particularly off-putting – see section 5.1.

The survey data suggested that having a **STEM club** at their school was related to students expressing more positive attitudes towards science and scientists and higher science self-concept, although the effect sizes were small. Students who reported that there was a STEM club at their school (even if they themselves did not attend it) were significantly more likely to report intentions to pursue Triple Science[l] at GCSE compared to students reporting there was no STEM club at their school[m]. Those students who reported attending a STEM club were considerably more likely to take or aspire to take Triple Science (60.1%) compared to students who did not attend the clubs (46.5%) and to express science aspirations. Students who attended STEM clubs largely reported enjoying the spaces and the opportunities they afforded for engaging with science outside the structure of school science.

"I like being able to learn science away from the class. In a class, you can have everyone there and sometimes it can be a bit pressured to get on with what you want to do. But [in the club] you're at your own pace... and have fun while learning..." (Bobster, working-class, White British, male, Year 8).

However, some girls reported how they had been put off (and did not return) when they attended clubs that were dominated by boys.

l 'Triple Science' is the study of three separate science GCSEs, whereas students studying 'Double Science' (or Combined Science) study all three sciences for two GCSE awards. Students then have the option to study multiple routes including; A level (considered the prestigious route to university entrance), AS level, BTEC (more applied training route) and International Baccalaureate.

m Our data do not provide clues as to why this might be, although one potential explanation might be that STEM clubs are more likely to exist in schools where science is prioritised and particularly resourced and supported.

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4.6 Educational Gatekeeping

The ASPIRES 2 survey and qualitative data revealed how young people's science choices, aspirations and progression are channelled and constrained by a range of educational gatekeeping practices, most notably through the stratification of science routes at Key Stage 4[n] (into 'Double' and 'Triple' routes) and through stringent grade entry requirements for science A Levels.

Our data show that the stratification of students into **Double/Triple Science award** routes at GCSE is contributing to inequitable patterns of participation[19].

For example, the Year 11 survey data showed that the most socio-economically disadvantaged students were two and a half times less likely to study Triple Science compared to the most advantaged. Only 22% of students from our sample from the least advantaged backgrounds studied Triple Science compared to 71% of students from the most advantaged backgrounds. Research by Wellcome Trust[20] and the Open Public Services Network[21] also found that there is considerable variation between which types of state schools offer Triple Science, with students in deprived areas much less likely to attend schools that offer Triple Science. The Sutton Trust also found that 20% of higher-attaining students who were eligible for free school meals attended a school that did not offer Triple Science, compared to just 12% of higher-attaining young people from more affluent homes[22].

We found that most students do not have a 'choice' of science route at GSCE. Many schools either explicitly allocated students to a particular route, or implicitly steered them towards making the 'right' choice – a practice particularly experienced by working-class students.

"I think I was sort of pressured to take it, because we had like different sets, so if you were in the top set you were like expected to take Triple Science." (Caitlin, middle-class, White British/German, female, Year 13).

Triple Science was widely regarded as the high-status option for those who were 'clever' and 'science-y'. Those taking Triple Science were more likely to identify as 'clever/good at science', express more positive attitudes towards science and were more likely to both study science post-16 and aspire to work in STEM.

In contrast, those placed on Double Science or alternative qualification routes were pushed away from science, as exemplified by Georgia, who despite wanting to take Triple Science and having aspired to become a marine biologist since the age of 10, was not allowed to do so by her school. This decision crushed her dreams and made her re-evaluate whether science was for her.

"I was quite gutted that I didn't get Triple Science, but obviously I'm not as good in lessons… I was planning on doing Triple Science and then obviously going on and doing a science career, but I didn't get Triple Science, I didn't get picked for it." (Georgia, lower-middle-class, White British, female, Year 11).

In the end, Georgia did not pursue a STEM-related pathway, and went on to study media at university.

The research also highlighted how the **high grades required for entry to A Level science** (compared to many other subjects) served to dissuade many students from considering post-compulsory science. In some cases students who wanted to study science further but who did not achieve an A/A* grade at GCSE[o] were prevented by their school or college from pursuing science further. The students in our sample who were particularly affected by this were Black and White working-class girls who achieved B grades in GCSE science.

CASE STUDY: Vanessa is a Black African young woman. Her father works as a school science technician and her mother is a carer. Vanessa had aspired to a career in forensic science since we first met her at the age of 10 and was strongly supported by her father to go to university, although she worried about the costs (e.g. ***"if I don't have the money to pay for [university] in the future then that would probably stop me from going"***). However, because Vanessa 'only' achieved Bs in her GCSEs she was prevented from pursuing science further, as she had originally planned, and went on to study for a social science degree.

n Key Stage 4 (KS4) is the stage of school education in England that incorporates national GCSEs examinations, over Years 10 and 11, and sometimes Year 9.

o The ASPIRES/ASPIRES 2 cohort sat their GCSEs in summer 2015, when A* and A were the first and second highest grades awarded for GCSEs in England. These grades are now roughly equivalent to grades 9, 8 and/or 7.

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4.7 Careers education

In England, there is a statutory requirement for all secondary school students to receive independent careers advice[p]. However, the ASPIRES 2 survey data revealed that less than two-thirds (63%) of students aged 15-16 reported having received careers education and only half had undertaken work experience. We found that careers education provision was patterned by social inequalities, with working-class, minority ethnic students, girls and lower-attaining students being significantly less likely to receive and benefit from high quality careers support, as exemplified by the case of Vanessa (see case study below). For instance, while 65% of White students reported having met with a careers advisor, only 33% of South Asian students reported similar meetings. As Colin (a lower-middle-class, South Asian young man) said in Year 11, "I think only a couple of people had meetings with the careers advisor, not everyone". Self-referral models of careers education provision exacerbated these inequalities.

Less than two-thirds (63%) of students aged 15-16 reported having received careers education and only half had undertaken work experience.

CASE STUDY: Vanessa (discussed previously) attends a school that is located in an area associated with socio-economic deprivation. Vanessa explained how her school provided differentiated careers resources in Year 9, depending on which set a student was in: ***"Yeah, it depends on … it's a booklet and it depends on how your levels [grades] are. If your levels are really low, you get the lowest booklet, if you're middle … then you get another booklet that's a bit higher with more opportunities. And if you're exceeding, like really, really … then you get a booklet of like loads and loads of opportunities".***

As a middle-set student, Vanessa received the 'middle' booklet. In her Year 11 interview, Vanessa mentioned that she had not received any further careers information nor met with an advisor.

CASE STUDY (CONTINUED): Vanessa reported, ***"We had [an advisor], but she came late, so she never got to work with everyone. So it was a bit like 'What's the point?' – she came like literally just before revision started so no one could really be in school because most people were at home revising. And then when we were in school she would just kind of grab you for like 45 minutes, but then not everyone… I never got a chance to speak to her… It was like… I don't know, it's maybe about 15, 20 students out of 240 of us that actually got to talk to her."***

Our survey data showed that, on the whole, students who received careers support were more satisfied than those who did not receive any. However, not all encounters with careers education were positive – some students (but particularly those from underserved communities) reported having their aspirations 'dampened'[23] by careers staff. For instance, Luna described her feelings at being told that her red-brick university aspirations were not possible due to her computer-generated predicted grades (which were based on her primary school attainment and family background).

"I've had like a couple of careers meetings, which I've just organised myself. I think they tried making them like compulsory and everyone had to do them, but they didn't get round to doing everyone, so I just booked one myself and I don't know. I kind of hated it, because I told him where I wanted to go and he basically said 'you can't get in there', so…" (Luna, lower-middle-class, White British, female, Year 13).

Bethany1 also recounted a similar experience of her schools careers advisor.

"I said that I wanted to go to University of Manchester and he said 'ooh, I think you should lower your expectations'" (Bethany1, upper-middle-class, White British, female, Year 13).

We interpret these findings as showing that careers education provision in England is not just 'patchy', but 'patterned'[24] – with those students who might benefit most from high quality, supportive careers education and support being the least likely to receive it.

p In 2010 this duty shifted from local authorities to individual schools.

Dominant educational and social representations of science

4.8 'Masculine' science

Analysis revealed that students' identification with and aspirations in science were shaped by the alignment of science with masculinity[25]. Girls were particularly likely to identify this issue as negatively impacting their science identification and aspirations.

Consistently across all five surveys from age 10-18, boys were significantly more likely than girls to report that their teacher expected them to do well in science, and to feel that their teacher cared whether they understood science. Conversely, girls were more likely than boys to agree that they are not good at science and that they find it difficult. Across all the surveys, boys were significantly more likely to report wanting to study more science in the future.

In our qualitative dataset, young women were more likely than young men to comment on the alignment of science with masculinity. This was particularly notable in the reasons given by girls who did not identify with or aspire to science.

"I wasn't interested in it because I thought, like, girls didn't do science or whatever, […] Like from like Year 5 or 6, I was like, I thought like science wasn't for girls because mostly like boys liked it and like girls didn't, so I thought that maybe I actually don't like it because of that" (Celina1, working-class, White British, female, Year 13).

"In primary school definitely it was like more … they spoke about like… to boys, I remember they spoke to boys and they were like oh, um, a lot of boys used to think they wanted to be scientists and I remember thinking like okay, well there's a lot of boys being scientists, this is like a male dominated subject, and then like when I got into high school like I spoke to a few teachers about what would you do in science. And they were like scientists and stuff, but they still spoke about a great male scientist and they don't really like discuss like how women can be great scientists. They didn't. And it was like a subject you do at school and you don't further your career in it." (Carol, lower-middle-class, White European, female, Year 13).

In line with existing literature[26], we also found that young women who continued with physics (the science most closely aligned with masculinity), tended to identify themselves as being less 'girly' than their peers. Some described becoming 'less feminine' over time, but notably the longer they continued with physics. We interpret this as a response to masculine priviledge in physics – the young women we spoke to who wanted to be recognised as 'real' physicists felt the need to downplay their feminine characteristics[27]. For instance, in early secondary school Davina described herself as quite 'feminine' but in Year 11 described notable changes in her style, clothes and ways of speaking.

"I mean you know like I swear quite a lot [laughs]… I swear like a sailor, it's ridiculous. You know I don't… first of all I don't really dress particularly feminine, like I tend to wear jeans and like band t-shirts and hoodies and stuff, and I wear boys' like skater shoes. So I mean yeah I'm not… I don't have a particularly feminine voice either… and I think well, so what? Like there's nothing wrong with that, it's just like that's just what I am. And so yeah, maybe that's a bit different, but it makes life more interesting I guess" (Davina, upper-middle-class, White British, female, Year 11, pursuing physics A level).

4.9 'Clever' science

Our analysis of the ASPIRES 2 survey and qualitative data underlined the pervasive association of science with 'cleverness' – an association that made it difficult for many students to continue with the subject. This association was cultivated over time, with data showing that while most students at age 10 did not think someone had to be 'clever' to do science, the association grew and was cemented over time as a result of a range of structural, systemic and educational practices.

The pervasive association of science with 'cleverness' – an association that made it difficult for many students to continue with the subject.

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The surveys revealed a widespread and consistent association between science and 'cleverness'. For instance, across all five surveys, around 80% of students agreed that scientists are 'brainy'. Common reasons given for not continuing with science were that "It seems really hard" (Gemma, lower-middle-class, Black African, female, Year 11) and we found that young women in particular found it difficult to feel 'clever enough' to continue with science, especially in the case of physics (see Section 5.1). For instance, girls were more likely than boys to report finding science difficult, especially in year 11 where almost twice as many young women than young men strongly agreed that they found science difficult – a figure that does not reflect gendered patterns in attainment, as evidence suggests that girls tend to perform at least as well as boys in science[28].

Those who did not see themselves, and/or were not recognised by others, as being 'brainy' were less likely to identify with and aspire to science. We interpret this as an example of what Bourdieu and Passeron call *symbolic violence*[29] – that is, when students come to 'blame themselves' (e.g. for not being 'clever enough') for the injustices they experience in relation to science, rather than recognising the role of structural inequalities in producing these patterns of participation[30]. As we discuss elsewhere, students who did want to continue with science therefore needed to engage in considerable identity work to navigate a relationship with 'cleverness'[31].

As discussed in the wider literature, identifications with 'cleverness' are not simply derived from academic attainment but are profoundly racialised, classed and gendered - cleverness is aligned with middle-class, White, masculinity[32]. In other words, girls, working-class and minority ethnic students found it hard to be recognized as 'clever', and hence as 'scientists', regardless of their attainment. This was particularly amplified in the case of physics[33] – which we now discuss.

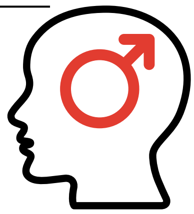
5. Science subject-specific issues

5.1 Discipline-specific issues: Physics

The factors and issues identified as shaping students' science identities and aspirations (see Figure 3) also influenced young people's likelihood of continuing with physics specifically post-16. In this section we provide some additional detail on analyses specifically relating to students' engagement with and participation in physics[34], including analyses that were conducted as part of a collaboration between ASPIRES 2 and the Institute of Physics.

For instance, while **science capital** was significantly related to the likelihood of a young person identifying with and aspiring to post-16 science, it was particularly strongly related to post-18 physics intentions. The students in our sample with high science capital were almost six times more likely than students reporting medium and low science capital to report that they intended to study physics at university.

Physics was the area of science that was most strongly seen as being masculine, and it was considered the 'hardest'.



The **association of science with masculinity and cleverness** was particularly pronounced in the case of physics compared with chemistry and biology. That is, physics was the area of science that was most strongly seen as being masculine, and it was considered the 'hardest'. Compared to their descriptions of other sciences, participants considered physics as requiring 'natural cleverness' rather than seeing it as a subject that anyone can improve at over time with hard work. These associations dissuaded many students from feeling that physics was possible or desirable, but a gendered dimension was also noted, in that young women were disproportionately disadvantaged and excluded by popular notions of the "effortlessly clever male physicist"[35]. This trope impacted the decisions of even the highest attaining students in our study, like Kate, who did not achieve lower than an A* at GCSE and liked physics but felt it was 'too hard' for her to continue with at degree level.

"I probably I wouldn't do like a straight physics degree, because it would be too hard. Like I think I'm just a bit put off by thinking that it would be really hard." (Kate, upper-middle-class, White British, female, Year 13)

Some of the strictest educational **gatekeeping practices** were also recorded in relation to students' access to, and retention of, physics A Level. For instance, from our interview sample, Danielle was unable to access physics A Level due to not attaining an A/A* grade in GCSE science, and Thalia and Victoria were both debarred part way through their physics A Level course due to not attaining at a required level during their first year of study (there were no reported cases in our dataset for this happening in biology or chemistry).

We also identified specific practices enacted by **school physics teachers and curricula**, which worked to dissuade students from continuing with physics. This included the separation of 'real' and school physics, which helped cultivate the notion that 'real' physics is only for the privileged few[36].

Consequently, compared to other students (both generally and those taking other sciences but not physics), those taking physics A Level were more likely to be male, have high levels of cultural capital, be in the top set for science, have taken Triple Science and have family members working in science. Young women who continued into post-16 physics were highly exceptional, having very high levels of attainment and science capital and being more likely to downplay their femininity.

Analysis also revealed that A Level physics students were significantly more likely than others to express stereotypical views of scientists as 'odd', male and 'geeky'. We interpret this as evidence of how the field of physics (in and beyond school, including via the media) cultivates specific dispositions within those who continue with the subject. This has the effect of reproducing the elite status of the subject, and 'weeding out' those who do not comply[37].

A Level physics students were significantly more likely than other A Level students to express stereotypical views of scientists as 'odd','male' and 'geeky'.

5.2 Discipline-specific issues: Chemistry

The factors and issues identified as shaping students' science identities and aspirations (see Figure 3) also shaped and influenced young people's likelihood of continuing with chemistry specifically post-16. In this section we provide some additional headline details relating to our data on students who took A Level chemistry, which was generated as part of a collaboration with the Royal Society of Chemistry[38]. Note that the level of detail here is not as extensive as for physics, reflecting the different scope of the collaboration.

ASPIRES 2 survey data showed that chemistry was the most gender balanced of the three sciences when it came to A Level participation. However, we noted in the qualitative data that this did not necessarily mean that students perceived no gender associations with the subject.

CASE STUDY: Poppy (an upper-middle-class, White British, young girl), who went on to study chemistry at university, felt that more men study chemistry than women, but she liked challenging gender stereotypes by taking the subject.

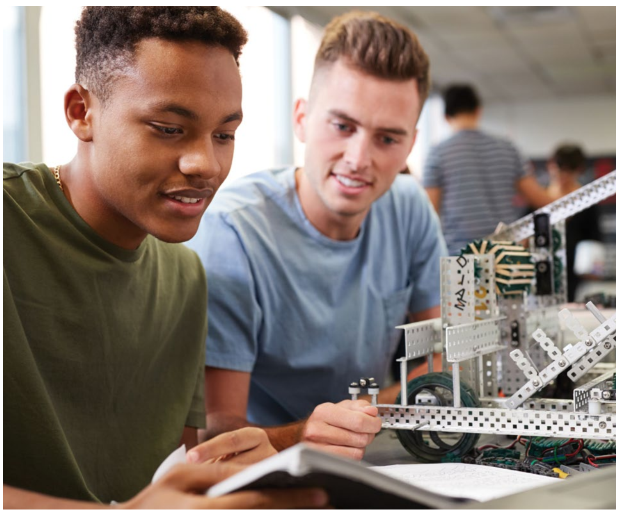
See 5.1 for similar accounts from young women who took physics.

We also found that chemistry A Level students had a distinctive ethnic profile. When comparing all students, chemistry A Level students were more likely to be South Asian, and were less likely to be White. Chemistry students were also more likely than other A Level students to be from the most affluent backgrounds (25% vs 19%), and they also had significantly higher science capital than students taking any other subject (including physics and biology). They were more likely to have a family member working in science and have friends who were interested in science.

Chemistry students were more likely than other A Level students to be from the most affluent backgrounds (25% vs 19%).

Whereas A Level physics students expressed the most stereotypical views of scientists (as being 'odd', male, and 'geeky' – see Section 5.1), chemistry A Level students reported less stereotypical views than the other A Level students.

CASE STUDY: Mienie is a South Asian young woman whose father works in a restaurant and mother works in financial administration. She studied Triple Science at her comprehensive state school and around the age of 15/16, became fascinated with chemistry, following her discovery that science underpins the development and production of beauty products and cosmetics, notably her favourite brand. Mienie passed an entrance examination for the sixth form of a selective single-sex state school, where she studied the sciences with a view to going into cosmetic chemistry. Her aspirations were supported by her parents and teachers. She is currently studying chemistry at university.



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5.3 Discipline-specific issues: Biology

The factors and issues identified as shaping students' science identities and aspirations (see Figure 3) also shaped and influenced young people's likelihood of continuing with biology specifically post-16 (see case study of Hailey presented next). In this section we provide some additional detail relating to our data on students who took A Level biology. Note that the level of detail here is not as extensive as for physics and chemistry, as we were unable to undertake further collaborative work with biology stakeholder organisations within the scope of the current project.

ASPIRES 2 survey data revealed that biology A Level students were three times more likely to be female than physics students, and were one and a half times more likely to be female than chemistry students.

Biology A Level students were three times more likely to be female than physics students and were one and a half times more likely to be female than chemistry students.

We also found that, compared to other A Level students, those taking biology were proportionally more likely to be South Asian. Biology students also tended to be from more advantaged backgrounds, and were more likely than other A Level students to have a family member working in science.

CASE STUDY: Hailey is a White British young women from an upper-middle-class family with high science capital. Both of Hailey's parents have science degrees and work in STEM-related fields. Hailey's grandparents also studied or worked in STEM fields. Hailey had consistently expressed aspirations to work in science or medicine since we first met her, aged 10, which were actively supported by her family. She took A Levels in chemistry, biology and maths and achieved A grades in all subjects. Hailey went on to study biomedical sciences at university and aspires to work in biological research after completing her degree, saying that ***"I decided that biology was probably the one I wanted to focus on, but there were some parts of the biology course that I don't like too much, they're more plant based… So I just went for the like medical side of biology and arrived at that."***

6. Beyond science - young people's views of technology, engineering and maths

6.1 Science capital vs. STEM capital?

As detailed in section 4.2, analyses of the ASPIRES 2 data revealed that a student's level of science capital was significantly related to the likelihood that they would identify with and aspire to science. However, to what extent might science capital also relate to students' attitudes and aspirations with respect to technology, engineering and/or maths?

Analysis of the Year 13 survey data found that students with high levels of science capital were significantly more likely than their peers to aspire to pursue a degree in science or engineering. For instance, a student with high science capital compared to peers with medium and low science capital is roughly six times more likely to pursue a physics degree and two and a half times more likely to aspire to an engineering degree. We also found that a student with high levels of science capital was significantly more likely to express positive attitudes towards not just science, but all four STEM disciplines[39]. This relationship was strongest for engineering and maths, and was evident but somewhat weaker with respect to attitudes and aspirations towards technology.

A student with 'high' levels of science capital was significantly more likely to express positive attitudes towards not just science, but all four STEM disciplines.

6.2 Engineering

While the main focus of the ASPIRES studies has been on science, we also collected some data relating to students' attitudes and aspirations towards engineering – some key headlines are summarised here.

Survey data from both ASPIRES and ASPIRES 2 showed that engineering aspirations, like science aspirations, remain relatively low and stable between ages 10 and 16, with approximately 26% of students aspiring to a career in engineering. Among A Level science students, those taking physics were the most likely to express engineering aspirations, and biology students were the least likely to aspire to engineering.

At age 10 and age 16, students reporting engineering aspirations were relatively less likely to be White and were comparatively more likely to be from affluent backgrounds.

Compared to their peers, students who aspired to engineering were more likely to be motivated to earn a lot of money, make a difference in the world and to create things.

Gender had by far the most significant relationship with engineering aspirations. Even from the age of 10, girls were four times less likely than boys to aspire to engineering careers. Analysis revealed that young women who did aspire to engineering had a particularly distinctive profile – exhibiting very different attitudes compared to other young women, and indeed young men, who aspired to engineering[40]. In particular, young women who aspired to engineering tended to feel exceptionally confident in their science academic abilities and were relatively less likely to be motivated by a desire to help other people through their future careers.

In our interview sample, the two young women who pursued engineering post-16 both cited their engagement with the armed forces through cadets programmes as being highly influential in sparking, maintaining and growing their interest in engineering and providing strategic routes to continue with engineering to avoid the prohibitive gatekeeping practices of A Level physics.

CASE STUDY: Victoria1 is a White British middle-class young woman who was doing a Foundation Engineering course when we last spoke to her (aged 19), with a view to studying for an electrical engineering degree. Victoria took Triple Science at school, based on her father's advice ***("Triple Science - because my dad he just knows best basically")***. Her engineering aspirations were sparked and sustained by her experience of being in the air cadets, which she joined around the age of 13. These interests led her to military College, where ***"almost everyone"*** went on to study engineering. Multiple experiences of educational gatekeeping (e.g. being prevented from continuing with A Level physics and gatekeeping for her original preference of a mechanical engineering degree, to name but two examples) meant that Victoria had to work very hard and be highly strategic to keep pursuing her engineering aspirations. She also reported having to navigate sexism and gendered associations of engineering with masculinity.

6.3 Mathematics

While the main focus of the ASPIRES study has been on science, we also collected data relating to students' attitudes and aspirations towards maths – some key headlines are summarised here.

ASPIRES and ASPIRES 2 survey data showed that maths is one of the consistently popular subjects throughout school. However, the percentage of students intending to study maths post-16 declined as students progressed through secondary school.

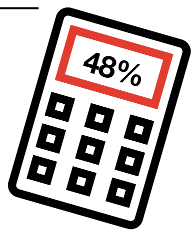
A greater proportion of students (48%) felt that maths was one of their best subjects compared with science (37%). However, we found that the students who were least likely to express high self-confidence in maths were young women.

When compared with other subjects, students were more confident in their maths ability compared with physics, although confidence in both subjects was lower than for biology and chemistry.

The majority of students agreed that maths is relevant and useful for their everyday life, although this percentage was lower than for science, with 68% agreeing that maths is helpful for everyday life, compared to 80% for science. Students studying maths post-16 were more likely to agree that the subject is useful or important.

CASE STUDY: Neb is White British upper-middle-class young man pursuing maths at university. He achieved highly in his A Levels (which included maths and Further maths) and enjoys building computers in his spare time. He told us as he got older how he has became increasingly interested in maths, and feels that it comes ***"naturally"*** to him; ***"I can happily just sit at my desk and do maths for a while"*** (Year 13). However, in addition to feeling confident in the subject, Neb consistently reported how useful maths was for a variety of careers and skill sets.

48% of students felt that maths was one of their best subjects, while only 37% felt the same about science.



6.4 Technology

We also collected data relating to students' attitudes and aspirations towards technology[q] – some key headlines are summarised here.

In our dataset, a young person's gender was the strongest factor shaping their attitudes towards, and aspirations in, technology. For example, we found that girls were significantly less likely than boys to aspire to work in the technology sector (28% vs 60%). Similarly, girls were less likely than boys to agree that a technology qualification can help you get many different jobs (55% vs 68%), and were less likely to report that their parents supported them to continue with technology.

Students from Chinese and South Asian backgrounds were significantly more likely than White students to report having aspirations in technology, and White students were significantly less likely to aspire to work in technology.

Students from socially advantaged backgrounds were significantly more likely to strongly agree that they would like a career in technology.

Technology seemed to be considered a good choice by the majority of those students pursuing it - of those studying technology post-16, 60.5% reported they would choose the same course again.

In the qualitative sample, two young men went on to study computer science at university.

CASE STUDY: Josh (White British, male) and Bob (mixed White/South Asian male). Both were from middle-class families with high levels of science capital, with at least one parent with a STEM degree who worked in a STEM job. Both young men had also expressed consistent STEM aspirations from an early age **(for instance, marine biologist, IT and pharmacist in Josh's case, and Bob aspiring to electrical engineering and later computing)**. Both young men had high academic achievement and took Triple Science at GCSE. They also both enjoyed programming and/or building computers in their spare time and, together with their families, made strategic subject and university choices. For instance, Josh described meticulously assessing university league tables and charts of graduate earnings when making his decisions. His motivation to study computer science was driven both by enjoyment of the subject but also by the potential for a clear career path in a growth area (cyber security).

q We have chosen to use the term 'technology' in line with the use of the term within the STEM acronym. However, we note that there are tensions in including computer science (the theory and practice of which also combines the constituent elements of STEM) and information technology under the banner of technology.

7. Recommendations – what do our findings means for policy and practice?

The ASPIRES/ASPIRES 2 research found that the factors influencing young people's science identities and aspirations (age 10-19) are complex and multiple. There was no single decisive or causal factor which shaped a young person's likelihood of pursuing science or feeling 'science-y'. Consequently, efforts to improve (increase and widen) science participation will need to work broadly and will likely require multiple agencies working together in partnership in order to have the best chance of effecting equitable change. However, study evidence suggests that efforts might most fruitfully be directed at addressing the key factors identified in Figure 3.

We suggest that STEM education policy and practice communities might usefully consider changes to ***how we think*** about STEM engagement and inspiration work and changes to ***what we do*** in practice (see Figure 4 below).

Change how we think		
Change the STEM field, not young people	Foreground equity	Adopt a social justice mindset

Change what we do		
Build science capital	Address educational practices	Challenge dominant representations

Figure 4. Overview of recommendations for policy & practice.

Changing how we think

- **Focus on changing STEM education, not young people.** The sector needs to recognise, and challenge the processes that maintain and perpetuate the elitism of STEM, which underpin and drive low and unequal participation. Widening participation in STEM requires changes in power relations and cannot be achieved by continuing with 'business as usual'.
  - E.g. Fundamentally challenge of the idea of STEM being 'difficult'/'hard' and 'masculine' and that being good at science is based on 'natural talent' (and or having a 'science brain'). Identify and challenge practices that reinforce the elitism of STEM, and recognise the intersectional nature of inequalities in STEM participation.
- **Foreground equity in all STEM education policy and practice.** Acknowledging how social inequality drives aspirations and self-identity in science, equity and social justice should be placed at the heart of STEM education. Where equity is not foregrounded, the default will be the reproduction of inequalities.
  - E.g. Think about how science and STEM are portrayed and represented and accessed through your work and surroundings. Particular attention needs to be given to changing the systems and practices that support and perpetuate notions of 'clever' science and 'masculine' science, especially where there are gatekeeping practices that restrict access or resources to certain groups of young people. For example, if you work in a school, consider whether students are free to choose their GCSE science routes themselves, or whether these are based on, e.g., exam performance. Ask yourself if decisions are made by the school rather than the student, and what impact this could have on future career paths. In particular, we must recognise, reflect on and challenge the injustices that create and sustain the 'science debt' experienced by Black students.
- **Employ a social justice mindset.** Applying a social justice framework[41] to STEM education policy and practice can support more equitable and informed approaches to improving STEM participation.
  - E.g. Think about how to build science capital, rather than having a vague aim to 'inspire and inform' young people. The ASPIRES 2 research highlights how participation 'problems' are produced by and through educational institutions, systems and practices. We therefore recommend that greater emphasis is placed on changing these, rather than focusing on trying to change the attitudes, values, behaviours or aspirations of young people, as is often the case in many existing interventions and approaches.

Changing what we do

In line with the three overarching key factors that we found shaped young people's science identities and aspirations, we suggest the following changes in practice would be beneficial: Focus on **building science capital**, rather than just inspiring and informing young people about STEM; Identify and challenge **educational gatekeeping practices** that restrict access or resources to certain groups of young people and **dominant representations of STEM** that reinforce the elitism of science.

Building science capital

Building science capital in young people requires relatively long-term changes to core pedagogical practice and cannot be achieved solely through short-term and/or 'one off' approaches. Key recommendations for building science capital include:

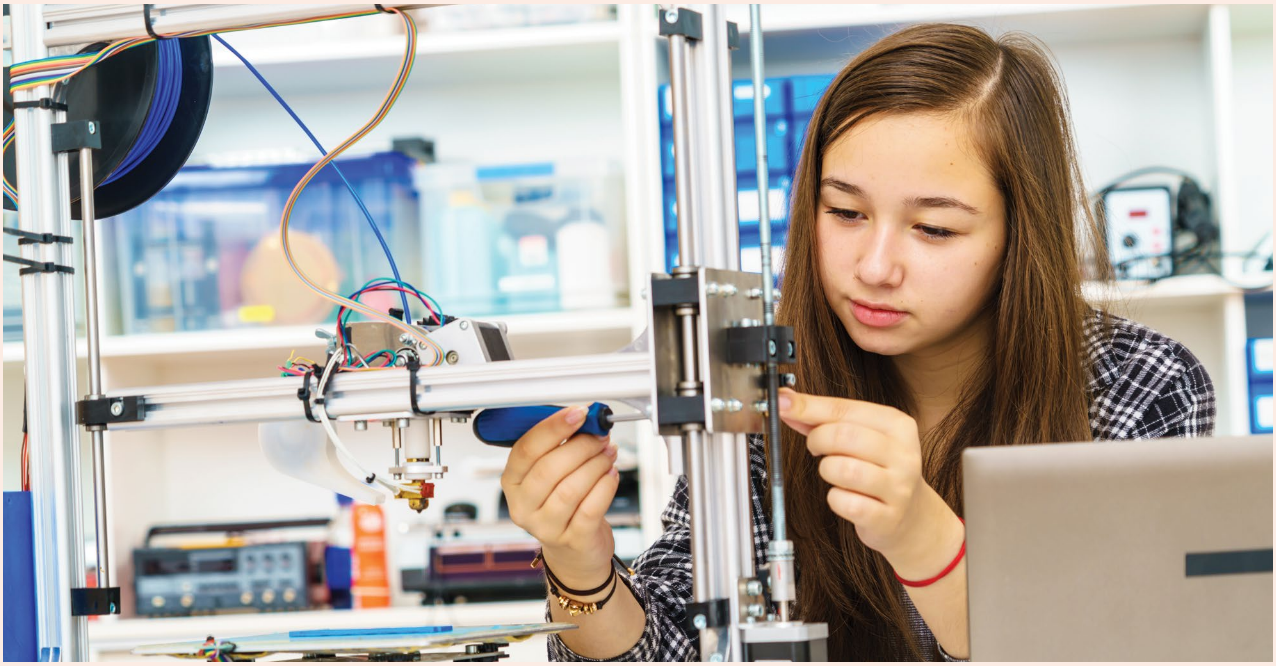
- Starting as early as possible (ideally from early in primary school).
- Moving away from single experience initiatives towards longer term, regular partnership work with young people.
- Focusing efforts and resources particularly on working with under-represented communities.
- Focus not only on the science content, but really prioritise the mindset through which science is taught, to better connect with and value the identities, knowledge and interests of all students.
- Using the principles of **The Science Capital Teaching Approach** (see http://bit.ly/SCTeach)
- Use the **YESTEM compass** to help you develop and apply a social justice mind set to policy-making and practice.
- Working with others across the sector. Change will only happen when we work together towards the same aims (see http://bit.ly/PolicySciCap).

Identifying and transforming educational practices

- Focus on reforming the systems and practices that support and perpetuate notions of 'clever' science and 'masculine' science, especially gatekeeping practices that restrict access and/or resources for certain groups of young people in your setting.
- Lobby for changes to educational gatekeeping practices that restrict and narrow the pool of young people continuing with science/ STEM.
- Support increased resourcing for earlier, better quality, targeted careers provision for all young people.

Identifying and challenging dominant representations of STEM

- Audit and address how science and STEM are portrayed, represented and accessed in any given setting.
- Support a meaningful discourse among STEM educators and professionals to help identify, reflect on and challenge common practices and ideas about who does science and what gets recognised as 'being good at science'.
- Challenge notions of STEM as being 'hard', 'difficult' or for the 'clever' and the idea of there being a 'science brain'.



8. Examples of Impact

At the heart of our work is our commitment to make a difference. Over the course of the ASPIRES research we have developed partnerships with a range of stakeholders to help inform the translation and application of our findings. Some highlights of the impact we have achieved to date are included below.

Supporting and informing STEM education policy

- The ASPIRES-originated concept of **science capital** has been central to several large-scale organisational strategies, including the Science Museum Group's Inspiring Futures Strategic Priorities 2017-2030, the framework of the UK's Network for Evaluating and Researching University Participation Interventions' (NERUPI), the Ogden Trust's work with schools, and the Danish Science and Technology Evaluation and Development Centre's National Science Strategy 2019-2021.
- In 2017, the Primary Science Quality Mark, which reaches over 3,000 primary schools annually, introduced a new core criterion to their award scheme, requiring schools to demonstrate a commitment to developing all children's science capital within their work.

Changing STEM education practice

- A wide range of STEM delivery organisations (such as EDI, the British Science Association, and the Royal Society of Chemistry) now focus their interventions on younger age groups, in line with our findings that the percentage of students aspiring to science careers is, and remains low from age ten.
- Numerous organisations have started and/or extended working with families, in recognition of our findings about family science capital and STEM engagement/aspirations (for example, the Royal Institution, the Francis Crick Institute, the Ogden Trust, and several museums and visitor centres).
- Organisations such as the British Science Association now work specifically with underserved communities and have developed new initiatives and funding streams to support more inclusive and equitable engagement with science for all.
- In 2019, data from a survey of STEM engagement professionals in England and Wales conducted by the National Coordinating Centre for Public Engagement (NCCPE) showed that the ASPIRES research was a commonly-used resource to support approaches to evaluation and audience development. For example, 64% of respondents said that the concept of science capital had informed their work, with 45% said that it had influenced their approach to targeting underserved audiences.
- ASPIRES findings have significantly shaped the work of the Institute of Physics (IOP), who have moved away from seeking to change girls' attitudes and behaviours, focusing instead on changing the barriers girls face engaging with physics and improving physics practice, including training regional coordinators to use (and support teachers in their networks to use) the science capital teaching approach.
- Findings from the ASPIRES research informed the development of the Science Capital Teaching Approach (a freely accessible teaching resource for teachers to help build young people's science capital). To date, the Science Capital Teaching Approach has reached over 4,000 teachers and 600,000 students in over 20 countries. A new primary-specific science capital teaching resource is currently being developed (to learn more, see www.ucl.ac.uk/ioe-sciencecapital).

Shifting thinking and practice in relation to GCSE science routes

- Our findings regarding the inequitable impact of the current Double/Triple Science system in England informed the All Party Parliamentary Group on Diversity and Inclusion and shaped their first inquiry into equity in STEM education.
- A number of schools have adapted their policies in response to the ASPIRES 2 findings on Triple Science. For instance, Ferndown Upper School in Dorset opened up Triple Science for all students and reported a subsequent decline in negative attitudes to science, and increased science participation.

Informing STEM careers policy

- Our findings relating to careers education helped inform the House of Commons Sub-Committee on Education, Skills and the Economy's Inquiry into Careers Advice, Information and Guidance in 2017, and the British Youth Council's Youth Select Committee inquiry into Barriers to Work Experience in 2018.
- Our work was also cited in the Social Mobility Commission's 2016 State of the Nation Report, and went on to inform the Department for Education's 2017 Careers Strategy. This strategy, among other things, specifically introduced new approaches to careers provision with the aim of encouraging young people, especially girls, to consider jobs in STEM. Their efforts were also aimed at improving careers education provision for young people from disadvantaged and vulnerable backgrounds.

Informing science education research

- The concept of science capital has inspired and informed wider academic research, including PhD studentships and/or projects at the University of Uppsala, Sweden (with A. Danielsson), the University of Newcastle, Australia (with J. Gore), the University of Manchester (with L. Bianchi), Northumbria University, England (with C. Davenport), the University of Central Lancashire, England (with R. Walsh).
- The Villum Foundation and the Novo Nordisk Fund have created a large new funded research programme in Denmark inspired by the ASPIRES research.

We are delighted to have been recognised for our research impact:

- Our research was awarded the 2018 British Education Research Association (BERA) Public Engagement and Impact award.
- The ASPIRES 2 project was also the winner of the 2019 Panel's Choice Award at the ESRC's 2019 Impact Prize, where we were also finalists in the Outstanding Societal Impact category.

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For further information on the ASPIRES research including the next phase of the project, ASPIRES 3 (age 20-23), please contact us at:

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ASPIRES 2
science and career aspirations: age 10-19

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The ASPIRES 2 project obtained ethical approval from the UCL Institute of Education Research Ethics Committee: REC 896 ASPIRES 2, Data Protection Registration Number Z6364106 2017 03 124

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