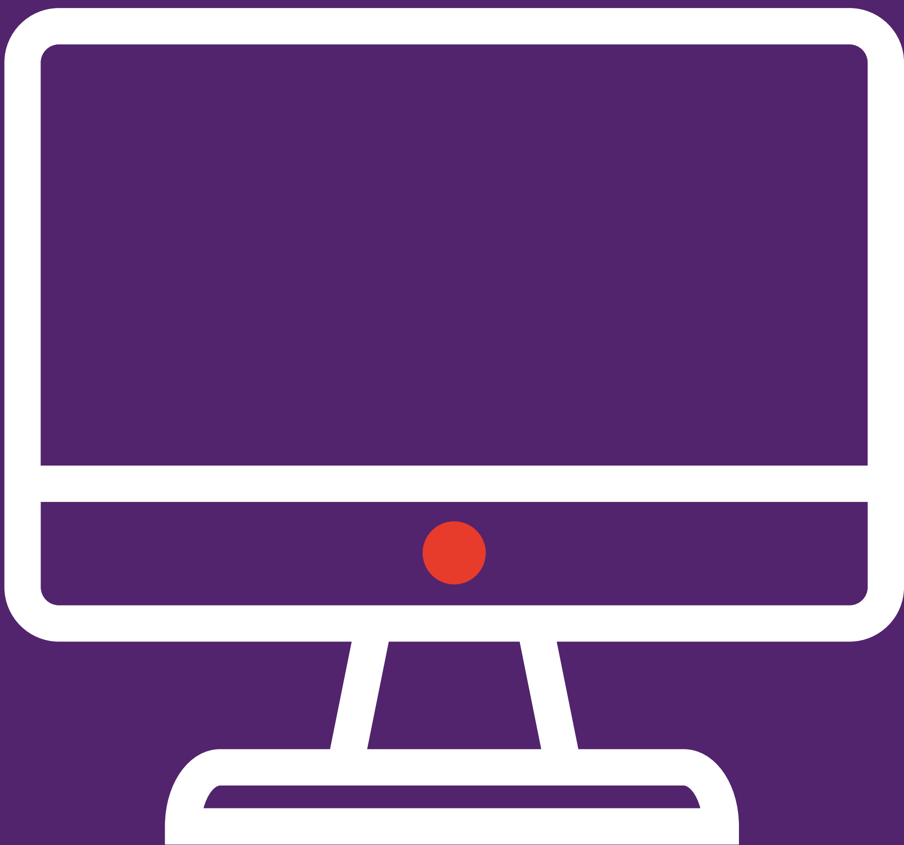
ASPIRES 3

Young People's STEM Trajectories, Age 10-22

COMPUTING

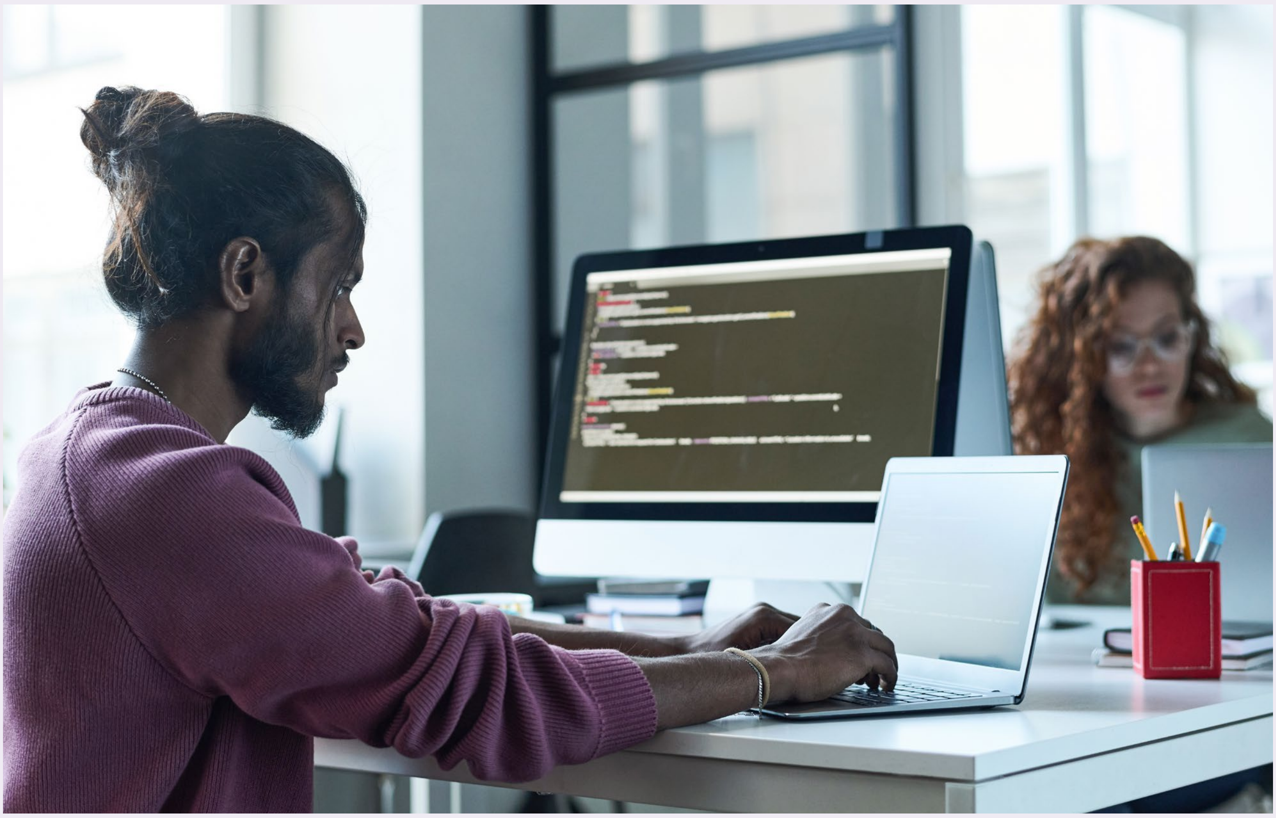


Summary of Contents

1. Executive Summary

In this report, we share evidence from the ASPIRES research project, a fourteen-year, mixed methods investigation of the factors shaping young people's trajectories in, through and out of STEM education (science, technology, engineering and mathematics), with a particular focus on access to STEM degrees. The study collected survey data from over 47,000 young people and conducted over 760 qualitative interviews with a longitudinal sample, which tracked 50 young people (and their parents/carers) between the ages of 10 and 22.

The project also conducted secondary analyses of UK National Statistics and Higher Education Statistics Agency (HESA) data sets on England domiciled students, aged 18 to 24. This report focuses on analyses of survey data collected at age 21/22 and longitudinal interviews conducted from age 10 to 22, to shed light on the factors shaping STEM trajectories, particularly at degree level.



Key Findings

Who studies computing at advanced and degree level in England?

Analyses of HESA and National Statistics data show that:

- **Participation in computing at GCSE and A level remains relatively low** compared with other STEM subjects (e.g. 5.3% of the A level cohort in 2021/22 took computing, whereas participation in other STEM subjects ranged from 12.6% to 30.4%). It is also **heavily male-dominated** (e.g. only 15.1% of those taking Computer Science A level in 2020/21 were female);
- In contrast, **the percentage of students taking computing[1] at degree level remains stable and high,** being consistently the third most popular STEM degree subject between 2015 and 2021;
- **Participation in computing degrees remains heavily male-dominated.** For example, in 2020/21 in England, just 14.1% of computing undergraduates were female – the lowest of all the STEM fields. However, computing degree participation is more inclusive in terms of race/ethnicity and indices of multiple deprivation (IMD) compared with some other STEM subject areas;
- **Rates of non-completion are relatively high among computing students, compared with other STEM degrees.** Between 2015 and 2020, on average 9.4% of first year computing undergraduates aged 18 to 24 from England withdrew from their degree course with no award during, or at the end of, their first year – this is around **double** the percentage recorded among maths and chemistry students, and slightly higher than for engineering.

What shapes young people's computing trajectories?

Analyses of the ASPIRES survey and longitudinal interview data found that:

- The **primary reason given by computing students for their degree choice is subject liking/interest/passion** (50%). This was also the top reason given by STEM students generally for their degree choices, apart from in mathematics;
- **Positive views of computing jobs** were also influential. Like engineering students, this was the second most common reason given by computing students for their choice of degree;
- **Most (60%) of the reasons given by suitably qualified young people for** not **taking a computing degree reflect subject dislike/no interest/hate of the subject**. This is similar to the reasons given by suitably qualified young people for not taking other STEM degrees;
- The second most common reason given for not taking computing relates to **negative perceptions of jobs** – a trend that was also found among those who did not pursue engineering;

- Analysis of longitudinal interview data from age 10 to 22 shows that **interactions of identity, capital and field are key** factors shaping students' subject engagement and trajectories. In particular:
  - A 'wrap-around' of computing-related social, cultural and economic capital over time (and particularly in relation to coding) is important for making a computing identity and trajectory possible and desirable. These experiences tend to be particularly derived from early, informal (home, leisure-time) experiences and are more often reported by young men;
  - The extent of 'fit' between a young person's identity and computing is important, particularly in relation to gender. The field of computing is strongly aligned with masculinity, which has implications for the extent to which a young person's (but particularly young women's) identity and capital can align with the field;
  - Positive and negative perceptions of computing jobs play a part in shaping young people's decisions to pursue the subject, or not.
- Most withdrawals happen within the first year but ASPIRES survey data suggests that a notable proportion of **students in later years of study** also **express concerns about completion, with this being higher in computing (37%) than other STEM degree areas;**
- Across all subjects, concerns about completion most often relate to academic issues and are **most frequently expressed by women, minoritised students, and students from low IMD backgrounds;**
- Generally, computing degree students reported less positive views of their degree experiences compared with those taking other STEM degrees. For instance, they felt notably **less prepared by A levels for degree study than their peers in other STEM disciplines** and were **less likely to have felt comfortable and a sense of belonging on their courses**. For instance, only around half (55%) of computing students said that they felt comfortable and like they 'belonged' on their course, which was significantly lower than among STEM and medicine students overall (70%);
- **Computing degree students tend to be focused on entering the workforce and staying within their field of specialism.** The majority (73%) of those who were studying for, or had recently completed, a computing degree were planning to go into full-time work. 64% planned to stay within technology/computing (which was roughly comparable with maths degree students but lower than among engineering students, 82%).

Key Recommendations

From the overall study findings, we identify six main recommendations for policymakers and practitioners who want to support increased and more diverse participation in computing specifically, and STEM more generally. Five of these (listed below) apply directly to supporting young people's computing trajectories (whereas the remaining recommendation derives from wider study findings, reported elsewhere, relating to GCSE science qualification routes).

1. Support and value young people's computing identities over time and across contexts, focusing particularly on young women's identities.

2. Challenge ideas of STEM competence (but particularly in relation to mathematical areas) as being based on 'natural talent'.

3. Challenge peer sexism and create more inclusive and gender-equitable cultures within computing degrees and outreach programmes.

4. Support more equitable experience and retention on computing degrees, particularly among young women and students from underrepresented communities.

5. Facilitate greater access to key forms of social and cultural capital for young people from underrepresented communities, especially women, to support social mobility in computing and beyond.

These are discussed in more detail at the end of report, with suggestions on how they might be operationalised.

Computing

2. What are the patterns in participation in undergraduate computing?

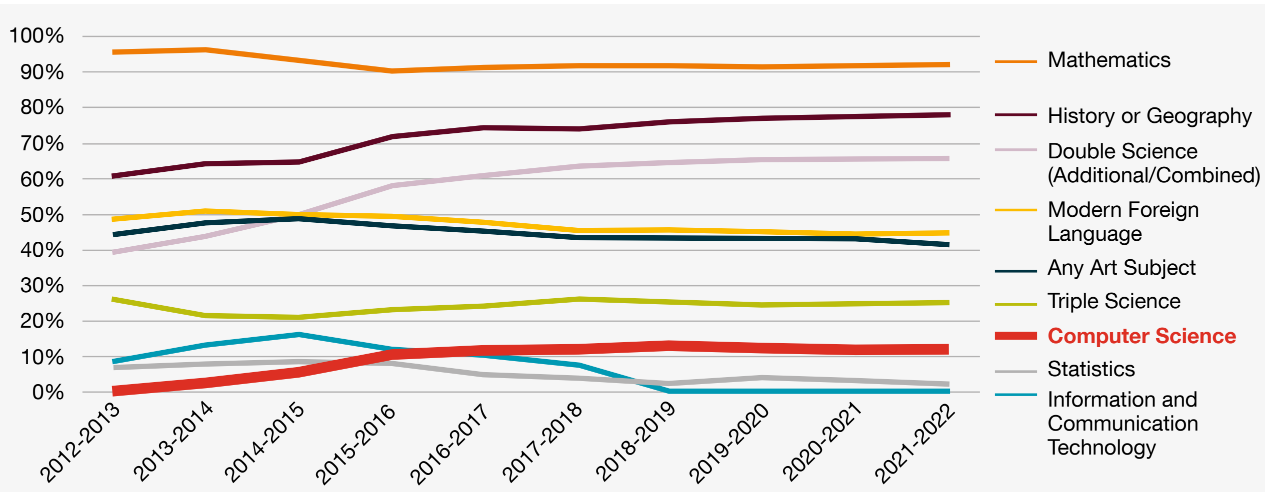
In the UK, as in many other high-income industrialised countries, **there are concerns about a computing sector skills gap and a lack of diversity among those with computing qualifications and skills, particularly a lack of women**. Although, some have questioned the assumed relationship between technological skills and economic prosperity,[2] particularly as AI is increasingly used for coding,[3] these skills gaps are commonly seen to impact the UK's economic competitiveness.[4] They are also social justice issues in their own right.

In this report, we use the HESA terminology to refer to 'computing' at degree level, which includes degrees in: Computer Science, Information Systems, Software Engineering, Artificial Intelligence, and Others in Computing. In relation to GCSE and A level, we used the National Statistics and examination board terminology of Computer Science.

As discussed in more detail next, analysis of national data sets shows that the percentage of young people taking Computer Science at GCSE and A level remains relatively low compared with other subjects, and is heavily male-dominated. However, the percentage taking computing at degree level remains stable and high, being consistently the third most popular STEM degree subject since 2015. Although computing degrees remain heavily male-dominated, figures suggest that it is one of the more inclusive STEM degree fields in terms of participation by race/ethnicity and socio-economic background. However, analysis also shows that rates of non-completion are particularly high among computing degree students.

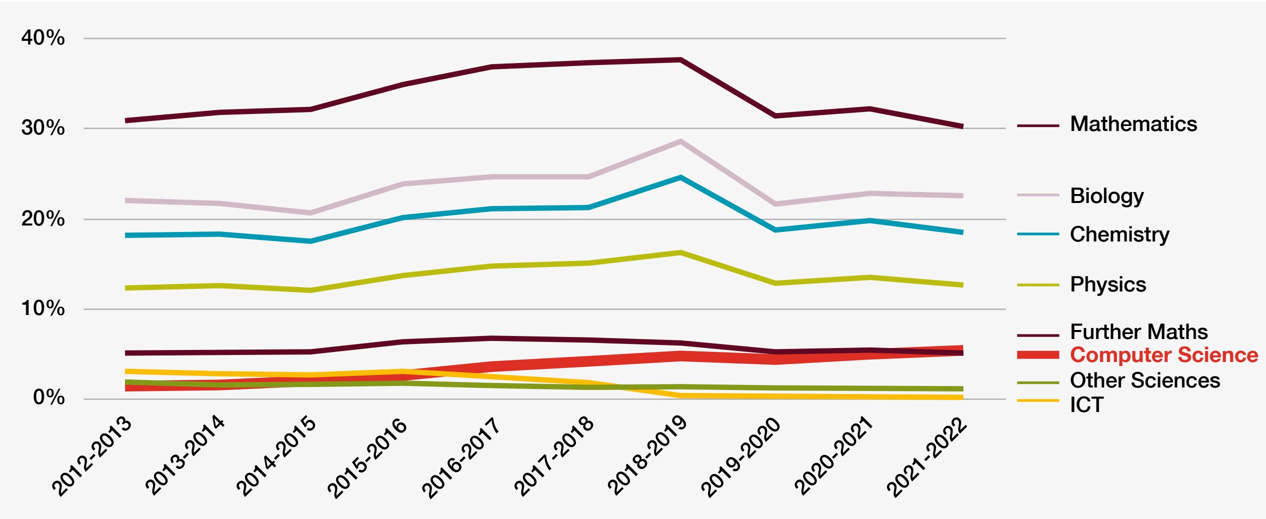
For instance, as Figure 1 shows, just over **10% of young people now take Computer Science GCSE each year, lower than for all other major optional subjects**. Computer Science was introduced into the National Curriculum in 2013, replacing ICT (Information and Communication Technology). Alongside this, the government introduced a new GCSE in Computer Science and phased out the GCSE in ICT. 'Appendix 1: Policy change related to Computer Science in England' maps these changes. The graph below shows the take-up of both Computer Science and ICT at GCSE level, alongside that of other STEM subjects, from 2012/13 to 2021/22, using data from the 'Key stage 4 performance' annual data releases.[5]

Figure 1: Percentage of young people entered into GCSE subjects from 2012/13 to 2021/22



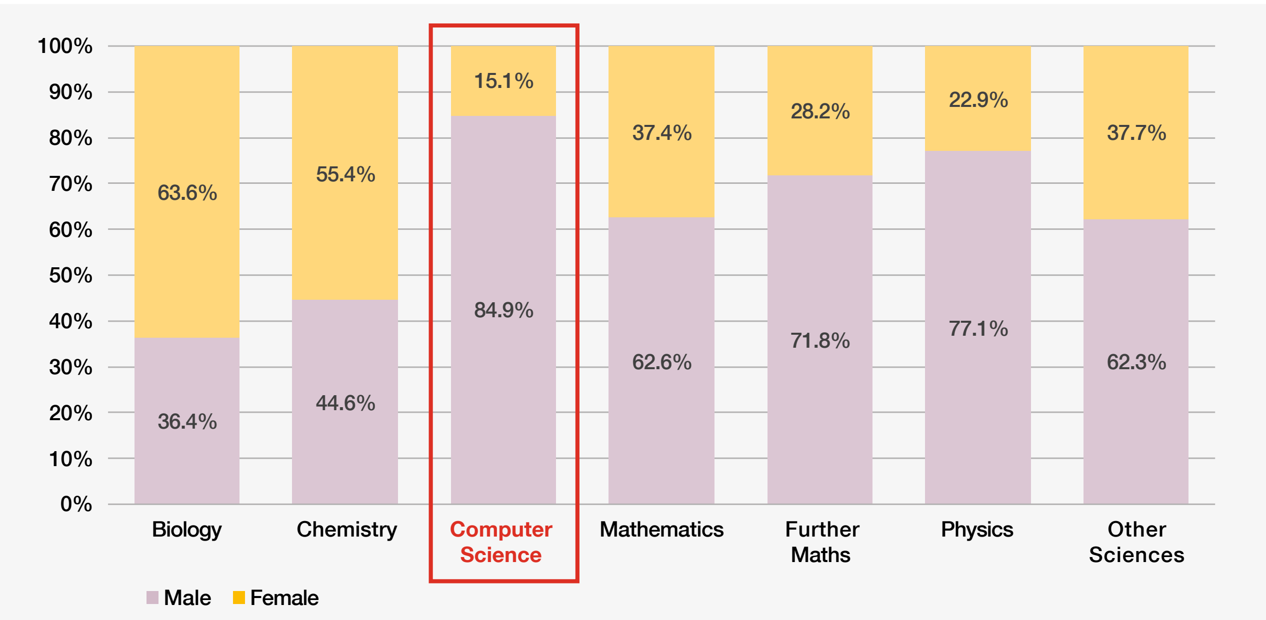
The national 'A Level and other 16 to 18 results' data, as in Figure 2, show that **Computer Science participation has grown in popularity since ICT was phased out, but remains considerably below other STEM subjects**[6] – although Mathematics, which is more consequential for progression in computing is consistently the most popular A level. Between 2012 and 2022, around 83,621 people sat Mathematics A Level, comprising about 33.6% of all those taking A Levels. Comparatively in 2021/22, just 15,000 young people sat A level Computer Science. The low level of take-up is likely related to A level Computer Science not being required for any field of employment or of undergraduate study, including computing degrees.

Figure 2: STEM A level entries as a percentage of young people who sat at least one A level



As Figure 3 indicates, **Computer Science is the most gender imbalanced of the STEM A levels, with only 15.1% of those taking the examination in 2021/22 being female.** This has increased from 9.4% when the ASPIRES cohort sat their A levels in 2016/17. Young women make up about 42.7% of STEM A level entries and about 54.9% of all A level entries.

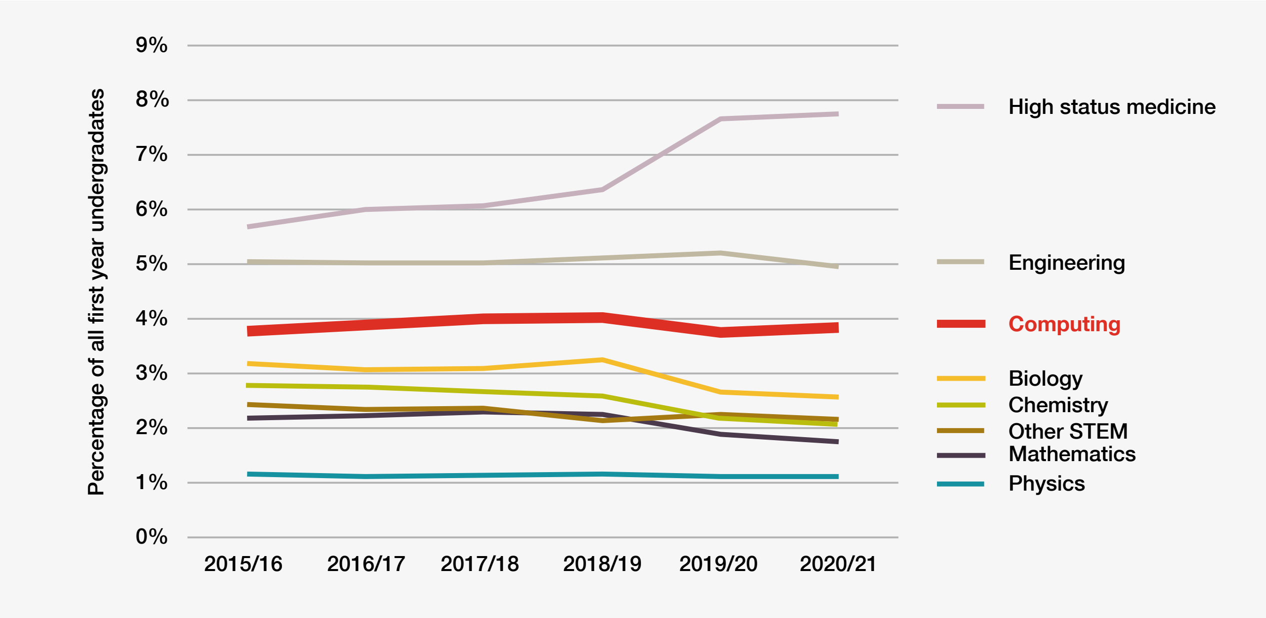
Figure 3: Percentage of male and female students making up each STEM A level cohort in 2021/22



National data from the UK Higher Education Statistics Agency (HESA) show that the low take-up of Computer Science at GCSE and A level does not continue at degree level.[7]

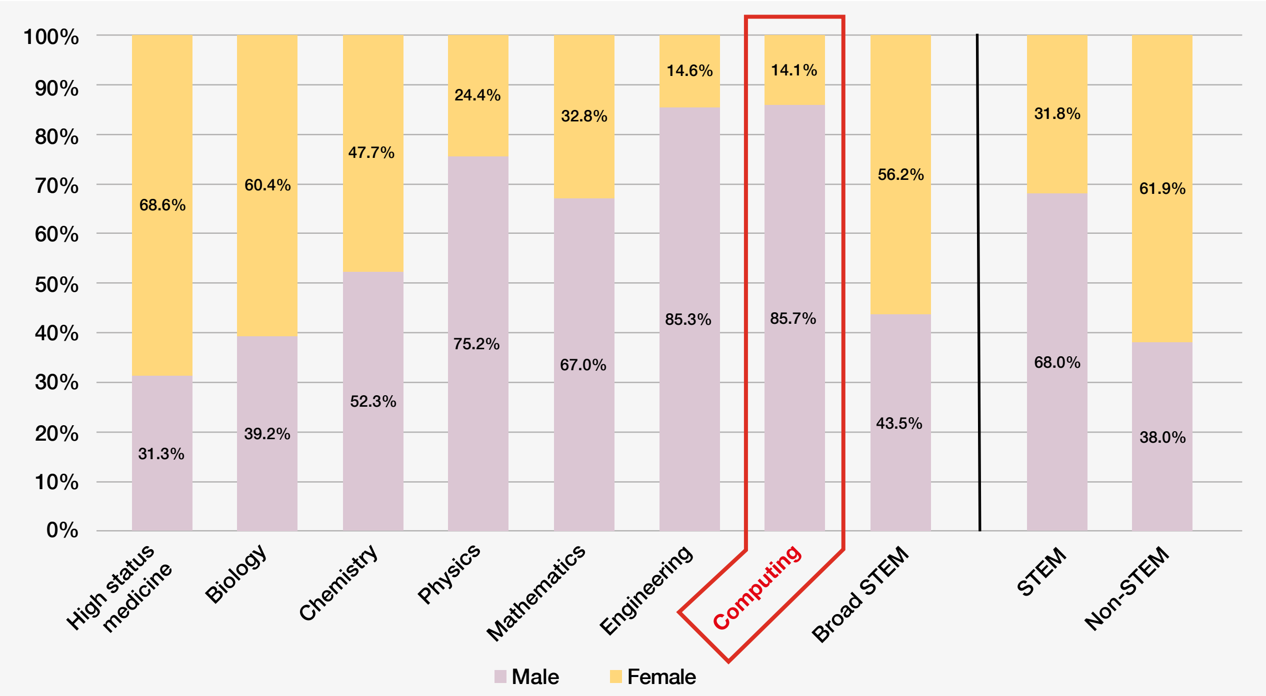
As tracked in Figure 4, computing is consistently the most popular STEM field in England after medicine and engineering.

Figure 4: Participation in STEM disciplines at undergraduate level from 2015/16 to 2020/21



The male dominance of the subject does continue from A level to degree level. As Figure 5 shows, in 2020/21 in England there was a lower proportion of female undergraduates in computing at 14.1% than in all other STEM fields. Analysis of data from 2015/16 suggests that this gender inequality has persisted over time.

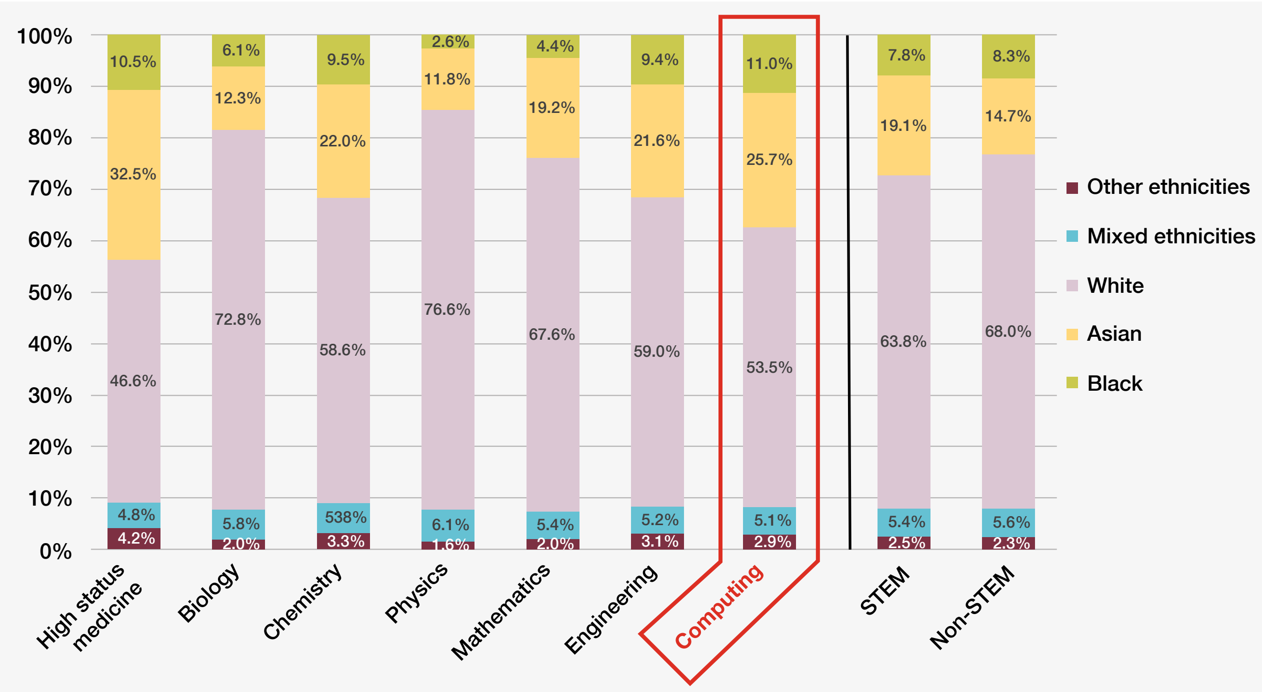
Figure 5: Breakdown by gender of first-year undergraduates in England 2020/21



As Figure 6 indicates, **the proportions of Asian and Black undergraduates in computing degrees are higher than in STEM overall and in non-STEM overall**.

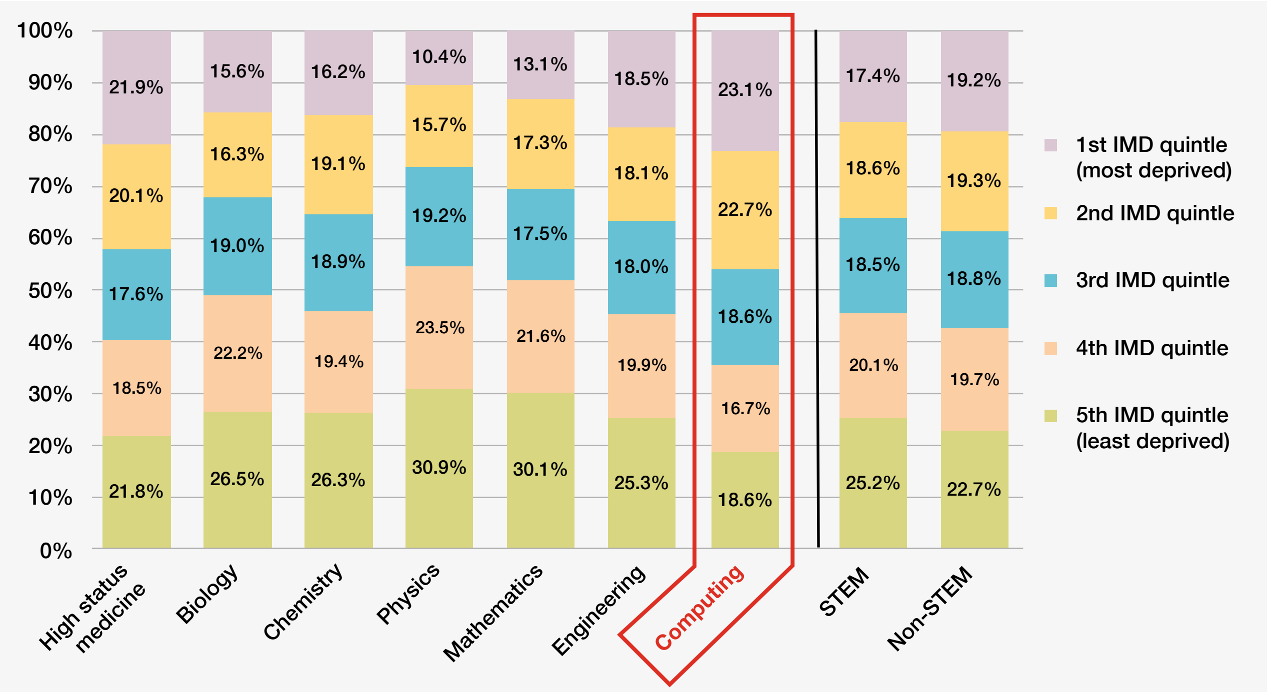
Analysis of 2015/16 data shows similar trends,[8] suggesting that these figures have remained relatively stable over time.

Figure 6: Breakdown by race/ethnicity of first-year undergraduates in England 2020/21



As Figure 7 indicates, **people from more economically deprived backgrounds are better represented in computing than in other fields**. In 2020/21, 23.1% of first-year undergraduates in computing were from the most deprived IMD1 quintile and 22.7% from the IMD2 quintile, both higher than in every other STEM field and in non-STEM fields overall.

Figure 7: Breakdown by IMD of first-year undergraduates in England 2020/21



Between 2015 and 2020, on average 9.4% of first-year computing undergraduates from England aged 18 to 24 left their course with no award during, or at the end of, their first year; 3.9% during, or at the end of, their second year; and 1.4% during, or at the end of, their third year. **Non-completion rates for computing degrees are higher than those for STEM and non-STEM degrees overall**. In 2019/20, those from the most deprived IMD quintile left their computing degree in their first year at a higher rate than those in the most privileged quintile: 9.6% to 4.7%. In the same year, men had a slightly higher rate of non-completion than women: 7.5% to 6.3%.

3. Prior research base and conceptual approach

Research into computing engagement identifies a range of factors shaping computing trajectories, including: stereotypes of technology as 'nerdy' and antisocial that conflict with some learners' identities, particularly women and Black people; young people feeling 'not clever enough' to succeed; and exclusive learning environments.[9] Computing and computer science education research has shown how early and steady exposure to coding and technology in family and extracurricular settings helps young people develop knowledge of how to interact with computers, the materiality of how computers work, what coding feels and looks like, and how different programming languages can be used.[10] Historical and comparative research shows that inclusion is not a straightforward matter of progress as, for example, women were better represented in the UK in the early years of computing than they are now, and currently are better represented in some parts of the Global South than in the Global North.[11]

Existing interventions to promote participation in computing tend to cherry-pick from this research to justify a focus on changing individuals, increasing knowledge of computer science, particularly 'Learn to Code' initiatives, and presenting a more inclusive image of the field, rather than on changing computing practices and cultures. In ASPIRES, we take a sociological approach, using the concepts of capital and identity to enable a focus on those practices and cultures.

The ASPIRES project is informed by sociological and educational research that shows how **interactions of identity and capital (social and cultural resources) shape young people's pathways through schooling and into further and higher education, and employment.**[12] Young people can accrue capital from home, family, school and other educational contexts.[13]

In the ASPIRES research, we explore how **computing-related capital is translated into resources and practices that help produce and sustain young people's high interest, attainment and aspirations.** We show that **interactions of identity and capital are key to producing and sustaining computing trajectories** and that **where there is close alignment between computing-related identity, resources and the field of computing, young people are more likely to feel competent and interested in computing, and so are more likely to choose to continue with the subject.**

Importantly, we also argue that **the strongly gendered nature of the field of computing entails particular challenges for women's participation and the extent to which women experience computing as fitting, or not, with their ways of being and sense of what is normal, possible and desirable 'for people like me'**.

4. What data did the ASPIRES project collect?

ASPIRES is a mixed methods study that focuses on young people from a single cohort, born between September 1998 and August 1999. It comprises survey data from over 47,000 young people from this cohort, and qualitative interview data from a longitudinal tracking of 50 participants from the same cohort (with their parents/carers) between the ages of 10 and 22, totalling over 800 interviews. Table 1 summarises the quantitative and qualitative data collected at each stage of the research.

Table 1: Summary of ASPIRES project data collection

	ASPIRES			ASPIRES2			ASPIRES3
Data point	1	2	3	4	5	Interim catch up	6
Year	2009/10	2011/12	2012/13	2014/15	2016/17	2017/18	2020/21
Age	10/11	12/13	13/14	15/16	17/18	18/19	21/22
School Year Educational stage	Year 6 End of Key Stage 2 – Final year of primary school	Year 8 Key Stage 3 – Second year of secondary school	Year 9 End of Key Stage 3 – Third year of secondary school	Year 11 End of Key Stage 4 / GCSEs – Final year of secondary school	Year 13 End of Key Stage 5 / College	1st year university, work, gap year, other	First year after completing university / continuation of university studies or work
Number of survey participants / schools	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	N/A	7,635 N/A
Number of interviews with young people	92	85	83	70	61	60	50
Number of interviews with parents	84 parents of 79 children	Parents not interviewed	73 parents of 66 young people	67 parents of 63 young people	65 parents of 61 young people	Parents not interviewed	35 parents

The ASPIRES3 survey comprised a large-scale postal survey of young people in England and was conducted by obtaining a sample of young people born between 1st September 1998 and 31st August 1999 who were registered on the Open Electoral Roll. Following data cleaning, the overall achieved sample of 7,635 young people was roughly proportional to (though not fully representative of) official government population estimates in England for 21- and 22-year-olds based on sex, ethnicity, region, Index of Multiple Deprivation, Urban/Rural classification and long-lasting health conditions.[14]

The postal survey sample of 7,635 young people included 3,388 current and/or recently completed degree students, of whom 103 were computing degree students.[15] Among these young people, the demographic breakdown is:

- **Gender:** women 12 (12%), men 84 (82%), other 7 (6.8%);
- **Ethnicity:** White 63 (61%), Black 6 (5.8%), Asian 26 (25%), other 8 (7.8%);
- **Social class:** IMD 1&2 39 (38%), IMD 3 25 (24%), IMD 4&5 39 (38%); a higher proportion did not have a parent who had attended university than for STEM overall at 62% compared to 53%.

5. Why do suitably qualified students take – or not take – a computing degree?

Figures 8 and 9 summarise the open-ended responses from the final ASPIRES survey of:

- The reasons STEM degree students gave for their subject degree choice, classified into: subject interest/passion; feeling 'good at computing'; positive views of computing jobs; family encouragement; and other;
- The reasons young people who had taken A level subjects that would have enabled them to apply for STEM degrees gave for their decision not to pursue these subjects, classified into: subject dislike/hatred; feeling 'bad at computing'; negative views of computing jobs; family discouragement; do not want to go to university; and other.

Figure 8: The reasons STEM degree students gave for their subject degree choice

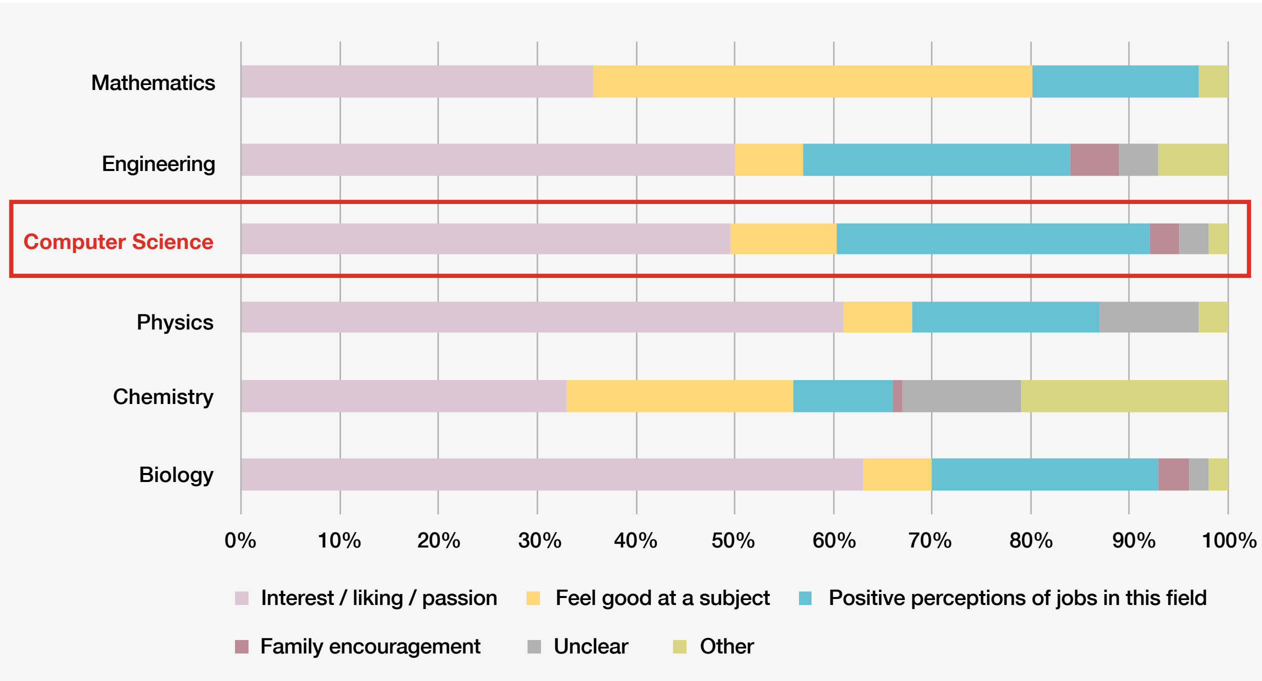
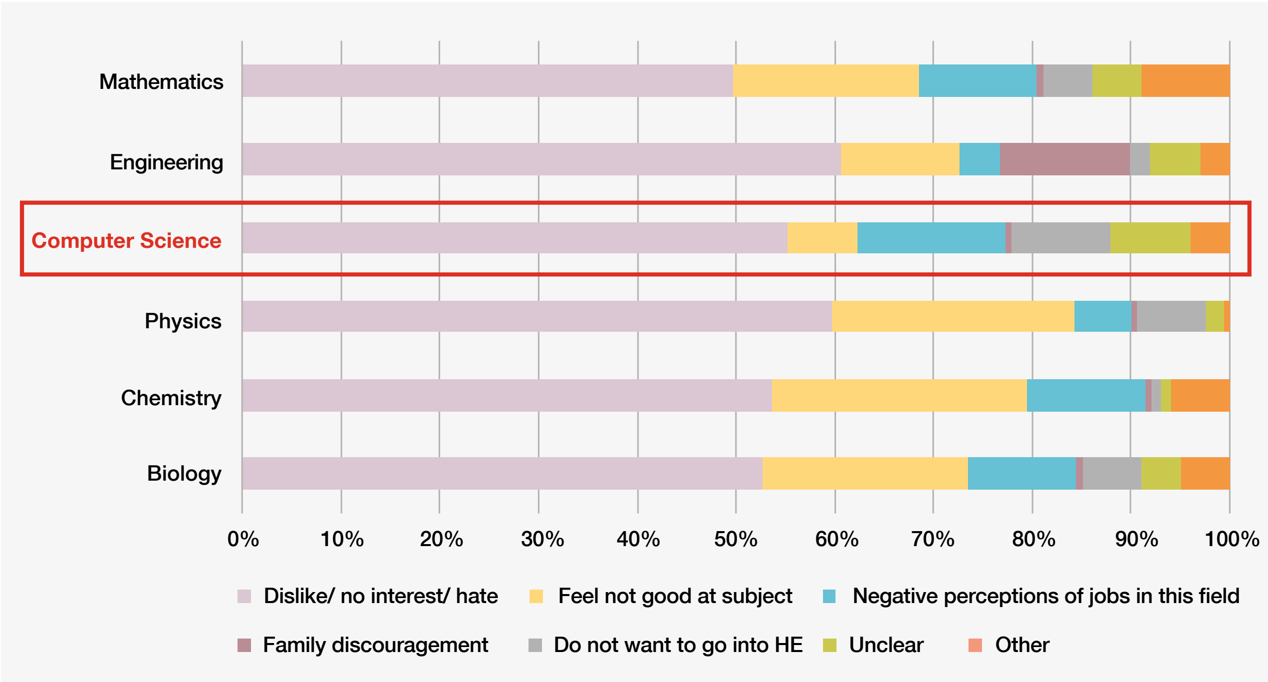


Figure 9: The reasons young people who had taken A level subjects that would have enabled them to apply for STEM degrees gave for their decision not to pursue these subjects



Analysis showed that **among those who went on to study for a degree** in a STEM discipline:

- **Subject liking/interest/passion was the most common primary reason** given by computing students (50%) for choosing their subject. It was also the most common reason expressed by STEM students in all disciplines except mathematics;
- **Positive views of computing jobs and career prospects** were also a common reason, cited by 32% of computing students – a figure that was higher than found in relation to other STEM fields (ranging from 10% of chemistry students to 27% of engineering students);
- **Perceived subject competence** (feeling 'good at' a subject and/or having a 'gift' for it) was the third most commonly cited reason given by computing students (11%). This was roughly comparable with other STEM fields, apart from mathematics and chemistry, where it was cited more often as a reason for taking that subject.

Looking at the reasons given by suitably qualified young people for *not* pursuing degrees in particular STEM subjects, analysis showed that:

- **Subject dislike/lack of interest/hatred was the most common primary reason given for not pursuing computing,** cited by 55% of respondents. It was also the most common reason given for not pursuing all other STEM degrees (ranging from 50% of those who did not take maths to 61% of those who did not pursue physics);
- **Negative views of computing jobs and job prospects** was the second most commonly cited reason for not taking a degree in the subject (15%). This predominantly reflected views of these jobs as being unattractive and was cited most often as reasons for not taking computing and mathematics;
- **Perceived competence (not feeling 'good at' the subject), was given less often as a reason for not taking computing** (7%) compared with other STEM disciplines;

- **Students who chose not to pursue computing were the most likely of all STEM fields to explain their decision in terms of not wanting to go to university** (10%). This was higher than found for other subjects, which ranged from 1% (chemistry) to 7% (physics).

In other words, young people's reasons for taking, or not taking, computing were broadly similar to other STEM subjects, apart from (i) the tendency to frame these reasons in relation to perceptions of computing jobs (both positive perceptions as a reason to pursue the subject and negative perceptions as a reason to not take it), which were more often cited by young people in relation to computing than for other STEM fields; and (ii) the higher percentage of young people explaining their decision to not take computing as due to not wanting to go to university.

As discussed next, the qualitative interview data help us to understand how interactions between young people's identity and capital in relation to the field of computing education shaped their trajectories into, and away from, computing degrees.

6. What factors shape computing trajectories?

Analyses of the longitudinal qualitative data show how **students' choices are influenced by the extent of the fit between their identity, capital and the field of computing, which shapes the extent to which computing pathways are felt to be 'for people like me', or not**.

Analyses of the ASPIRES data show how a range of factors come together to shape pathways into, and out of, computing. These include how **computer science-related capital and experiences during school years are important for developing, and sustaining, an interest and aspiration towards the subject, but particularly through informal experiences.**

Issues of gender and perceptions of computing jobs are also important. These themes are exemplified by three case studies of Josh, Gerrard and Bethany, all White British young people from working-class or middle-class backgrounds, who pursued computing degrees with differing outcomes.

Case Study 1: Josh is a White British, lower-middle-class young man. While he expressed a number of aspirations over the years (including marine biology after going diving on holiday), his computing-related aspirations remained consistent over time and outlived other more fleeting interests. Josh took A levels in Computer Science, Mathematics, Further Mathematics and Physics, achieving A, A*, B and B grades, respectively. He completed a three-year degree in Computer Science and gained a position in a cybersecurity firm.

Aged 21-22, Josh credited his family support and his dad's IT experience as the biggest influence on his computing trajectory. Neither of Josh's parents attended university, but his dad and brothers worked in IT, and his mum ran an online business from home. Josh recounted experiences of coding and building a computer at home in his spare time.

Aged 12/13, he spoke about how his dad and his teacher emphasised computing as a high-demand area: "There's not many people who have those skills because it takes a while to learn them, so I'll probably have quite a good chance". Josh's parents encouraged him to keep a focus on both mathematics and computing, steering him towards a joint degree, which, as his mum put it (when Josh was aged 17/18), "he sort of agreed with us that it opens more of a window" to future careers. Josh undertook extensive independent research into computing degrees and careers using university league tables and data on the job destinations and salaries of recent graduates.

Aged 12/13, Josh explained how he was "one of those people who people get surprised by" because he liked mathematics and was "also good at it". He told us that his grandparents wanted him to become a mathematician and, as above, his parents encouraged him to maintain his mathematics studies alongside computer science.

Aged 17/18, Josh was aware of the importance of mathematics for computing trajectories: "The main thing they want you to have done is Maths. So, for a lot of unis, well some of them, it's a must that you've done Maths. For some it's even a must that you've done Further Maths. Even though it isn't, but it basically is to get in".

Aged 20/21, he reflected that his success, and his experience of working less hard than his peers during his degree, had been facilitated by his prior computing experiences, including having the "right set of A levels" with both Mathematics and Computer Science.

Case Study 2: Gerrard is from a White Eastern European, working-class background. He migrated to the UK with his family aged 6. Gerrard first expressed aspirations towards computing aged 13/14. He achieved A* grades in A level Mathematics and Further Mathematics, and an A in Physics. Aged 21/22, he was struggling with his degree in Mathematics with Computer Science, having had to resit the computing component of his first year.

Nobody in Gerrard's family worked in computing. Aged 10/11, he said: "They don't really talk about science and stuff". Years later, Gerrard explained that his parents wanted him to get "an easy job" with good prospects, unlike their "hard jobs… for example, my dad is a builder and it's really hard for him because he works seven days a week".

Gerrard loved mathematics from the age of 10/11. However, aged 17/18, he rejected doing a single honours mathematics degree because: "I have to study something that I will find a job in after… I was thinking of pure maths but pure maths seems too broad for me… It's because I want to be successful financially as well, just so that I can support my parents and give back to them. If I only studied what I want to enjoy, I think that's a bit selfish". Around this age, he also abandoned pursuing engineering after a negative experience visiting his mum's workplace. He felt computing would offer job opportunities that are "a bit more innovative. It's something for the future, as well. I mean, obviously there'll always be work for engineers, but I just felt computer science – that sector's growing quite a lot".

Aged 21/22, Gerrard reflected on how his problems with the computer science content of his joint degree derived from his lack of prior coding experience: "The skills that you get from computer science aren't really learned from lectures, they're more from just your own practice… It's a lot of practice that you really need to do… Basic stuff is a big hurdle for someone that hasn't done it. And it's completely easy, you know, second nature to someone that has done it before". Because of this, he was feeling uncertain about his future: "I mean, getting a good job and one that you enjoy as well, it's pretty tough, right? It doesn't look hopeful… I'm not really enjoying my degree too much; I'm not really doing too amazing in it. So, yeah, in that sense, you start to question – okay, would I really enjoy working in this area?".

Factor 1: A 'wrap-around' of computing-related social, cultural and economic capital over time (and particularly in relation to coding) is important for making a computing identity and trajectory possible and desirable

The longitudinal data showed how a young person's access to computing-related capital impacts their progress and the extent to which they develop a strong computing identity.[16] While Gerrard had, arguably, higher A level attainment than Josh, the latter enjoyed greater computing-related social and cultural capital, including familiarity with coding. Josh's family capital made computing feel like a natural choice for him, and he was able to engage in a range of activities, including building a computer at home. Gerrard did not have any familial expertise or extracurricular experience in computing to support his trajectory, which he recognises as an obstacle to his progress. Across the dataset, family support and out-of-school activities (but particularly informal experiences) played a key role in shaping the young men's respective chances of success in computing at university.

Computing-related capital can take a range of forms and be generated through various contexts. For instance, computing-related social and cultural capital was often derived through knowing computing; and being encouraged to continue with it by family, friends and/or social contacts with computing qualifications, knowledge and/or jobs, as exemplified by Josh's case and by the following open-ended survey responses:

> *"I like technology and also it runs in the family" (Black man, IMD1);*
>
> *"My friends and family said that I was good with computers and should pursue a degree in that area" (Black woman, IMD1);*
>
> *"My father pointed me in the right direction" (White man, IMD5).*

Across the case studies and the survey responses, attention was also drawn to the value and importance of unstructured, informal computing-related activities (undertaken in one's free time) for building capital, often through hobbies, playing computer games, teaching oneself to code and/or building home computers:

> *"I used to play a lot of computer games as a child/teen" (White other-gender person, IMD2);*
>
> *"I had an interest in computers from a young age" (South Asian man, IMD3);*
>
> *"Computing has always been my strength, as I have been creating/doing things on computers for all of my life" (White man, IMD2).*

Like Josh, Bob (a mixed White/South Asian young man in the longitudinal sample) also went on to take a degree in computing and similarly described the importance of his home coding experiences, and building a computer with his father, in growing both his interest and expertise in computing.

Among the wider longitudinal sample of young people, those who pursued degrees in other science, engineering and mathematical areas also described participation in more formal programmes, clubs and outreach schemes as providing valuable sources of social and cultural capital in relation to their area of study. However, we found less evidence of participation in more structured extracurricular computer science offers among either survey or interview respondents who pursued computing.

Factor 2: The importance of 'fit' between a young person's identity and computing, particularly in relation to gender

Within the wider ASPIRES survey sample of 21-22-year-olds, 21.4% of those on computing trajectories had high science-related capital compared with 10% of all young people. Overall, more young people expressed a strong technology identity than was found for mathematics, science or engineering. However, as the chart below shows, identification with technology (e.g. seeing oneself and/or being seen by others as a 'tech person') was highly gendered, being espoused by 45% of men and 15% of women in our sample. There was a more even spread of technology identity across IMD and ethnicity, although a comparatively lower proportion of White students reported a strong technology identity.

The longitudinal analyses underlined how students' choices are shaped by the extent of fit between their identity and the field in question – that is, how far computing pathways were felt to be 'for people like me', or not. While both Josh and Gerrard started their joint degrees with good A levels, Josh fitted into his course, succeeded and secured a job in technology, whereas Gerrard had to resit the computing component of his first year and was uncertain whether he would be able, or would want, to work in computing in the future.

Gerrard's mathematical identity was stronger than his computing identity and he wondered if he might have been happier and more academically successful if he had taken a single honours degree in mathematics. But a lack of STEM-related cultural capital in the form of knowledge of the careers he could pursue with mathematics, combined with a working-class familial focus on being a wage earner, led him to see this as a selfish option, and therefore not for him.

The survey responses given by young people who had the requisite qualifications to have pursued computing but who chose otherwise also hinted at this perception of a potential mismatch between identity and computing. For instance: "Loved computing but programming was not for me" (Other ethnicity woman, IMD1).

A perceived lack of fit between femininity and the male/masculine culture of computing (across both education and industry) was often implicit, rather than explicit, in many young women's accounts (whereas it was often voiced explicitly in relation to engineering). For instance, some young women on the survey hinted that the reason they had not pursued computing was due to family discouragement or disapproval, although the reasons were not clearly articulated (e.g. "Because of my parents" – South Asian woman, IMD2).

The case study of Bethany exemplifies this notion through the feeling that she does not 'fit' with the dominant coder identity of her computing degree course ("I'm not a coder") and her reference to being "surprised" by the gender imbalance on the course, while also maintaining that this was not the primary cause of her withdrawal.

Case Study 3: Bethany is a White woman from a working-class background.She does not have a family history of university participation or working in computing. Age 17/18 she took A levels in English Literature, Sociology and Applied ICT. Her interest in pursuing computing first emerged around this time.

She started a computing degree but withdrew during the first year. She described being surprised, but not put off, by the gender imbalance on her degree course and explained that her main reason for withdrawing was because she felt ill-prepared for the course demands, lacking key skills and experiences. She also described feeling that she "did not fit" with the course and, in particular, did not have the right identity ("I'm not a coder"), which she felt was a requirement for doing well on the course, although coding experience was not among the degree entry criteria.

After leaving, she pursued a successful non-graduate career in retail. While she remained interested in STEM, she reflected at age 21/22: "I don't know if I'd want to work in that field now. Just don't think I'm smart enough to work in it".

Factor 3: Perceptions of computing jobs

As noted above, positive and negative perceptions of computing jobs and career prospects were given as reasons for pursuing, or not pursuing, a computing degree. Typical survey responses given by computing degree students included:

> *"Because it's where many [well-paying and secure] jobs are transitioning towards in the future" (White man, IMD5);*

> *"This industry is constantly growing and exciting. I also feel I can earn a lot of money having a job in this field" (White man, IMD1);*

> *"Technology is integrated into our everyday lives in one way or another, no matter what industry you are working in. It's an area which has helped achieve our biggest accomplishments and is constantly evolving. That's something I want to get involved with and pursue as a career path" (Chinese man, IMD5).*

In comparison, those who chose not to pursue computing tended to give less detailed reasons why they were not attracted to computing jobs, for instance:

> *"Not the job I wanted to be in" (White woman, IMD5);*

> *"I was never interested in pursuing a computing-based profession" (White man, IMD3).*

Several questioned the availability of jobs in the sector (e.g. "Not many available jobs" – Middle-Eastern woman, IMD1), including a couple of young people who described having tried to find work in computing, to no avail.

7. What do computing undergraduates say about their degree experiences?

Generally, computing degree students reported less positive views of their degree experiences compared with those taking other STEM degrees. For instance, they felt notably less prepared by A levels for degree study than their peers in other STEM disciplines, and were less likely to have felt comfortable and a sense of belonging on their courses.

Levels of satisfaction

Of those currently studying for a computing degree, 43% felt that the A levels they had taken had prepared them well for their course. **This was considerably lower than found in relation to other STEM degree areas,** where 59-61% of those in mathematics, chemistry and engineering felt well prepared for their courses by A levels.

65% of computing degree students agreed that if they could do it again, they would choose the same subject. This was comparable with students in STEM and high-status medicine areas (average 63%).

Just 20% of computing students felt their course was value for money – this was slightly lower than the average found among other STEM and high-status medicine students (28%). While there were no significant differences in responses by gender or IMD, Black and racially minoritised students were notably less likely (8%) to agree that their course had been good value for money, compared with 32% of White students.

Just over half (55%) of computing degree students said they felt comfortable and that they 'belonged' on their courses. This was notably lower than found among STEM and high-status medicine students overall (70%).

Concerns about completion

37% of computing students expressed worries about completing their degrees, the highest in all STEMM fields.

Across all subjects, students expressed similar reasons for these concerns, with academic issues paramount, alongside financial worries, health issues, the impact of COVID and, for a small number, caring responsibilities and/or social integration issues.

As a general pattern across all STEM areas, those from underrepresented groups – women, minoritised students, and students from low IMD backgrounds – were the most likely to express concerns.

Experiences of sexism on STEM degrees

Drawing on survey data from 798 STEMM students and 1,959 students doing other degrees on their experiences of sexism, women were significantly more likely than men to have experienced sexism in their educational setting during the past year. Women in STEM were significantly more likely than those in other fields to experience sexism in their educational setting.

Focusing on STEM and high-status medicine degrees, women in mathematics (3%) and biology (10%) were the least likely to report sexism and women in physics (50%) and engineering (30%) the most likely. 20% of women taking computing degrees said that they had experienced sexism in the past year.

Across the board, women most frequently attributed their experiences of sexism to their male peers.

Analysis of the longitudinal interview data showed that peer sexism usually involved gendered microaggressions, and everyday acts of disdain and disrespect, such as questioning women's academic legitimacy, ignoring or patronising them. As suggested in the wider literature, such experiences may reflect the discourses linking STEM with masculinity and broader inequalities between men and women.

Plans for after graduation

Of those young people in the ASPIRES sample who were studying for, or who had recently completed, a computing degree, most were planning to go into, or continue in, full-time work (73%). This was comparable with an average of 70% of all STEM students who were planning to enter the workforce. 14% of computing students were hoping to progress into postgraduate study.

The majority of computing students had either already progressed into STEM fields or anticipated doing so, with the largest proportion, 64%, planning on staying within the field. This was substantially more than the those planning on staying with chemistry (21%) but less than those planning on staying within engineering (82%). 13% of computing students/graduates were planning to go into a non-STEM field and 4% anticipated going into 'math-allied' work.

8. How can policy and practice support participation in computing?

In the UK, women are underrepresented throughout computing courses and employment. ASPIRES documents the scale of this underrepresentation, the impact of computing's masculine culture on young women, and the sexism faced by some women who pursue computing trajectories. Our findings also point to the importance of computing-related capital for growing interest in the subject and facilitating a successful computing trajectory.

Our findings suggest that there are limits to what can be done solely by seeking to change the views or aspirations of individual students without addressing systemic practices in computing education and culture at all levels, from school to higher education and beyond. Our recommendations fall into five categories.

Support young people's computing identities and capital over time and across contexts

To enable more young people to experience a 'wrap-around' of computing-related social, cultural and economic capital over time that can support their engineering interest and identity development, funders and policymakers might usefully:

- Review the balance of support offered for short vs. longer-term interventions and consider shifting towards longer-term interventions with key communities;
- Explore the potential to create a better connected, more comprehensive and coherent computing engagement 'ecosystem', in order to offer all young people clearer 'pathways' over time and across spaces that can enable and support computing trajectories. This could include mapping provision geographically and demographically to ensure equitable distribution and provision, and to support the establishment of both local and national engagement pathways (to enable young people to better access and navigate provision);
- Consider how to mitigate the inequities associated with self-referral models of careers education and outreach offers, and strategically consider how to reach those who could most benefit. Partnership working with other community organisations may be helpful in this respect;
- Support practitioners, teachers and educators to access and adopt pedagogical approaches and resources such as the Equity Compass and the (Primary) Science Capital Teaching Approach that can help increase understanding of the issues and scaffold critical professional reflection towards action. In particular, they may use such approaches to identify and implement ways to actively support and augment young people's computing identities and capital, and help young people to find meaningful connection with computing and see the relevance of computing learning to their current and future lives;
- Support family computing capital and enable more young people – particularly those from underrepresented backgrounds – to receive specific and sustained support to continue with computing from a trusted adult over time. This might enable computing routes to feel possible and desirable for more young people. Extracurricular activities can also usefully focus on supporting young people's identities (not just their coding skills) to enable more to feel like they fit into coding cultures – but these need to ensure that they centre issues of equity and inclusion and do not reproduce a 'traditional' (e.g. White, male) cultural ethos.

Challenge ideas of computing competence being based on 'natural talent'

To help more young people feel that they are 'clever enough' to continue with computing, funders and policymakers may find it useful to:

- Review the extent to which these ideas are reinforced and perpetuated by a range of common educational practices (such as pedagogy, attainment-based grouping practices, Gifted and Talented programmes, tiered examination entry) and develop action plans to address them at both strategic and operational levels, not only in computing but also in key 'feeder' subject areas, such as mathematics (e.g. providing professional development to enable educators to be aware of, and challenge, everyday practices which reinforce such ideas);
- Empower practitioners and those who support initial and continuing professional learning to draw on existing resources and approaches to (i) increase their understanding of how such ideas sustain unequal patterns of computing participation and damage many young people's relationships with the subject; (ii) help them to identify changes to their practice that can enable more young people to feel 'good at computing' by centring ideas of equity, broadening ideas about who/what counts and gets recognised as being 'good at computing' and using assets-based approaches (e.g. P/SCTA); and (iii) clearly communicate to others how ideas of 'natural brilliance/ability'; and the 'science/maths brain' are myths that hinder more inclusive computing participation;
- A level Mathematics acts as a gatekeeper to computing. As we say in the Mathematics Report, practices that divide learners – such as grouping by ability, Gifted and Talented programmes and tiered examination entry – offer recognition to a few, at the expense of the majority of young people. They are based on, and reinforce, the dominant idea that attainment and competence in mathematics (and computing) are the result of 'natural ability'. They conceal how uneven distributions of relevant capitals produce social patterns of mathematics (and computing) success, leading many to blame themselves for their failure.

Challenge peer sexism on computing degrees

To enable more young people – but specifically women – to experience a better 'fit' between their identities and computing, challenge sexist behaviours and cultures, and improve women's progression and retention, policymakers, funders and practitioners might usefully:

- Consider how they can support and encourage practitioners to understand, recognise and address sexist language and behaviours among students, particularly in areas such as engineering, computing and physics. It may be helpful to integrate this work with Athena SWAN departmental task groups;
- Support anti-sexism practice among HE staff and students, and in outreach work, by sharing and promoting resources such as the ASPIRES 'Step Up' anti-sexism ally poster and/or by engaging with wider anti-sexism initiatives aimed at tackling the sources of sexism. Practitioners can reflect and adapt their practice to be more inclusive using tools such as the Equity Compass;
- Encourage computing educators and employers to assertively call out sexism, rather than relying on young women to report it. Computing bodies can help by making it a priority to support them.

Support more equitable retention, belonging and transition on computing degrees

To support and enhance the experiences of those computing students who are less positive about their degree experiences, and to encourage increased retention in computing (particularly among young women), higher education policymakers, senior managers, professional societies and organisations concerned with equity in computing might usefully:

- Consider giving this issue greater policy consideration and prominence – both generally and specifically regarding the retention and progression of women computing students. It may be helpful to engage and coordinate with charities and initiatives that focus on supporting women, and underrepresented and first-generation students;
- Review degree entry criteria and/or what support is provided to 'level the playing field' between students with, and without, prior coding experience;
- Consider to how targeted support might be directed strategically to ensure it reaches those who could most benefit – not only in terms of supporting students directly, but also ensuring that staff are equipped to recognise the issue and address it through their own practice;
- Support practitioners to engage in critical professional reflection and professional development, with the goal of enhancing their understanding and action to improve retention and belonging among computing students.

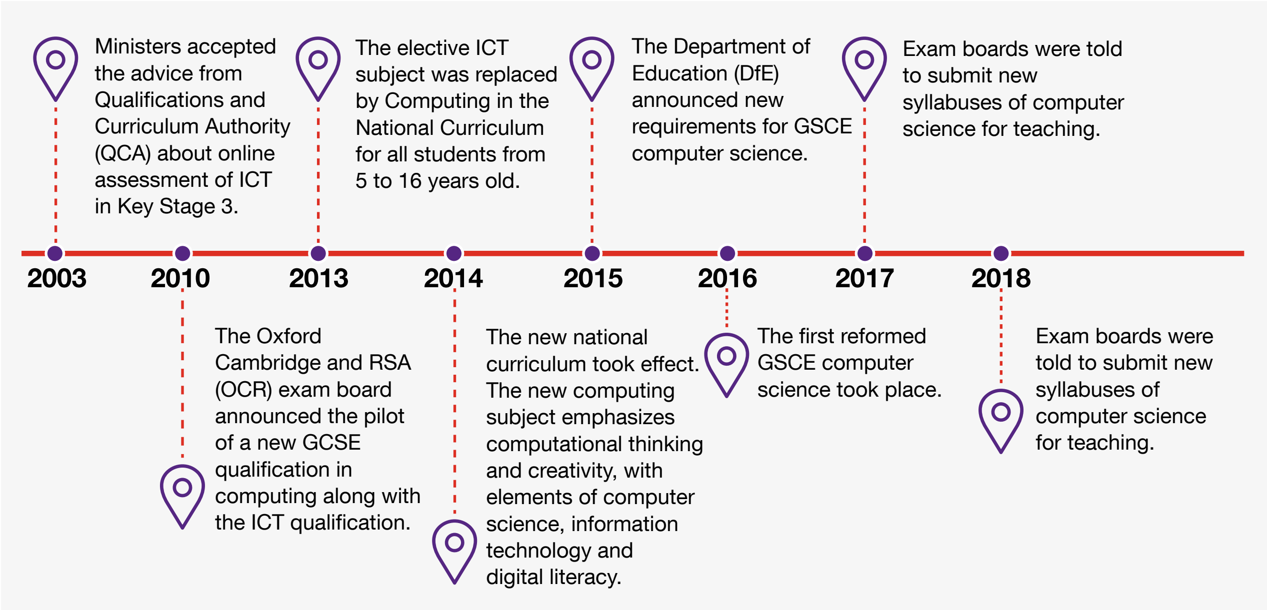
Facilitate greater access to key forms of social and cultural capital for young people from underrepresented communities, to support social mobility in computing and beyond

To create a more effective 'wrap-around' of support to build young people's computing-related capital over time, funders, policymakers, practitioners and those concerned with supporting more inclusive computing participation might usefully:

- Consider how they can best support young people from underrepresented communities to access key forms of social and cultural capital to support their computing trajectories. Funding longer-term interventions that foreground the generation of mutual trust and supportive relationships between young people and key adults may be particularly helpful, along with targeted measures to reduce the costs and risks of higher-level computing routes for young people from underrepresented communities;
- Support educators and practitioners to access and use tools and approaches such as the SCTA to help reflect on how they might best build supportive and equitable relationships with young people that also help redistribute valuable forms of capital (e.g. knowledge, experiences, social contacts, qualification routes). Explications and the principles of 'caring' pedagogy may also provide useful insights.

Overall, ASPIRES indicates a need for policy and practice, in STEM education generally and computing education specifically, to look beyond a narrow focus on attainment and on funnelling more young people through a 'STEM pipeline', to a broader focus on interventions to support more, and more diverse, young people in developing strong computing identities and to make computing-related capital available to all.

Appendix 1: Policy change related to computer science in England



References

1 In this report, we use the HESA terminology to refer to 'computing' at degree level, which includes degrees in: Computer Science, Information Systems, Software Engineering, Artificial Intelligence, and Others in Computing. For GCSE and A level qualifications, we use the National Statistics terminology of 'Computer Science' as per national A level and GCSE qualifications and results data.

2 e.g. Pein, C. (2018). *Live work work work die: A journey into the savage heart of silicon valley*. New York: Metropolitan Books. This tracks how technology, and specifically learning to code, was offered as a solution to the decline of manufacturing in the US and to those who lost jobs in the 2008 financial crisis. This also happened in the UK. Pein travels to Silicon Valley and uncovers a world of slum airbnb accommodation, exploitative jobs where employees happily work a few hours of unpaid overtime in exchange for a free meal, and thousands of people endure these conditions so they can repeatedly pitch their startups to venture capitalists, often paying for the privilege of doing so, until they burn out.

3 e.g. Visualwebz. (2023). Will AI take developers' jobs? Available at: https://seattlewebsitedesign.medium.com/will-ai-take-developers-jobs-24be45aa6c3; https://www.bcs.org/articles-opinion-and-research/will-ai-replace-software-engineers/ And in 2016, "Evans Data Corp., in a survey of 550 software developers, asked them about the most worrisome thing in their careers. A plurality, 29%, chose this answer: 'I and my development efforts are replaced by artificial intelligence'". Reported in: Thibodeau, P. (2016). *One in three developers fear A.I. will replace them*. Available at: https://www.computerworld.com/article/3041430/one-in-three-developers-fear-ai-will-replace-them.html

4 e.g. UK Government (2022). *UK Digital Strategy*: "Increasing the supply of digitally and tech enabled workers at all levels will be crucial for our long-term economic prosperity and is integral to unlocking productivity improvements across the economy… Improving the availability of digital skills not only unlocks the full economic potential of businesses, it helps individuals and opens up careers in interesting, sustainable, and well-paid jobs across the economy." Available at: https://www.gov.uk/government/publications/uks-digital-strategy/uk-digital-strategy

5 See: https://explore-education-statistics.service.gov.uk/methodology/key-stage-4-performance-methodology

6 The A level data in this section are from: 'A Level and other 16 to 18 results', available at: https://explore-education-statistics.service.gov.uk/find-statistics/a-level-and-other-16-to-18-results/2021-22. JCQ Annual Reports, 2022, available at: https://www.jcq.org.uk/examination-results/. Computer science as the subject name is used by National Statistics for GCSE and A Level data.

7 Data provided by the Higher Education Statistics Agency (HESA). Available via https://www.hesa.ac.uk/data-and-analysis/students. Note: HESA gender statistics allow only the responses: Male, Female, Other, and Unknown. In contrast, the ASPIRES data, discussed next, uses the options: Man, Woman, Non-binary, Other, and Prefer not to say. The computing degrees here include Computer Science, Software Engineering, Artificial Intelligence, and Others in Computing.

8 Computer science in 2015/16: Asian: 20.77%; Black: 9.14%. STEM in 2015/16: Asian: 16.61%; Black: 6.90%. Non-STEM in 2015/16: Asian: 12.56%; Black: 7.68%.

9 e.g. Margolis, J. and Fisher, A. (2002). *Unlocking the clubhouse: Women in computing*. Cambridge, MA: MIT Press; Eglash, R. (2002). Race, sex, and nerds: From black geeks to Asian American hipsters. *Social Text*, 20(2), 49-64; Rodriguez, S. and Lehman, K. (2017). Developing the next generation of diverse computer scientists: the need for enhanced, intersectional computing identity theory. *Computer Science Education*, 27(3-4), 229-247.

10 Antle, A. (2013). Research opportunities: Embodied child–computer interaction. *International Journal of Child-Computer Interaction*, 1(1), 30-36.

11 For example: Abbate, J. (2012). *Recoding gender: women's changing participation in computing*. Cambridge, MA: The MIT Press; Gupta, N. (2015). Rethinking the relationship between gender and technology: A study of the Indian example. *Work, employment and society*, 29(4), 661-672.

12 Bourdieu, P. (1977). *Outline of a Theory of Practice*. Cambridge: Cambridge University Press.

13 e.g. Reay, D., David, M. E., and Ball, S., J. (2005). *Degrees of choice: Social class, race and gender in higher education*. Stoke-on-Trent: Trentham Books; Walkerdine, V., Lucey, H., and Melody, J. (2001). *Growing up girl: Psychosocial explorations of gender and class*. Basingstoke: Palgrave.

14 Data was weighted to be representative, and analyses were performed using both weighted and unweighted data. Because weighting made no difference to the findings, the analyses referenced in this report use unweighted data. 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.

15 The wider sample was recruited on the basis that they lived in England, were born between 1st September 1998 and 31st August 1999, and were registered on the Open Electoral Roll. The total survey sample was not representative with regard to official government population estimates in England for 21-22-year-olds based on gender, ethnicity and Index of Multiple Deprivation (IMD) as it over-sampled populations of interest who tend to be underrepresented in STEM (namely women, minoritised communities and young people from lower IMD quintiles).

16 See Holmegaard, H. et al. (paper accepted, subject to corrections). Feeling the weight of the water: A longitudinal study of how capital and identity shape young people's computer science trajectories over time, age 10-21. *Computer Science Education*.

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