THE FUTURE OF COMPUTING EDUCATION

CONSIDERATIONS FOR POLICY, CURRICULUM AND PRACTICE

Findings from the Subject Choice, Attainment and Representation in Computing project (2021-2024)

Peter Kemp
Billy Wong
Jessica Hamer
Meggie Copsey-Blake

June 2024

King's College London
Nuffield Foundation
University of Reading

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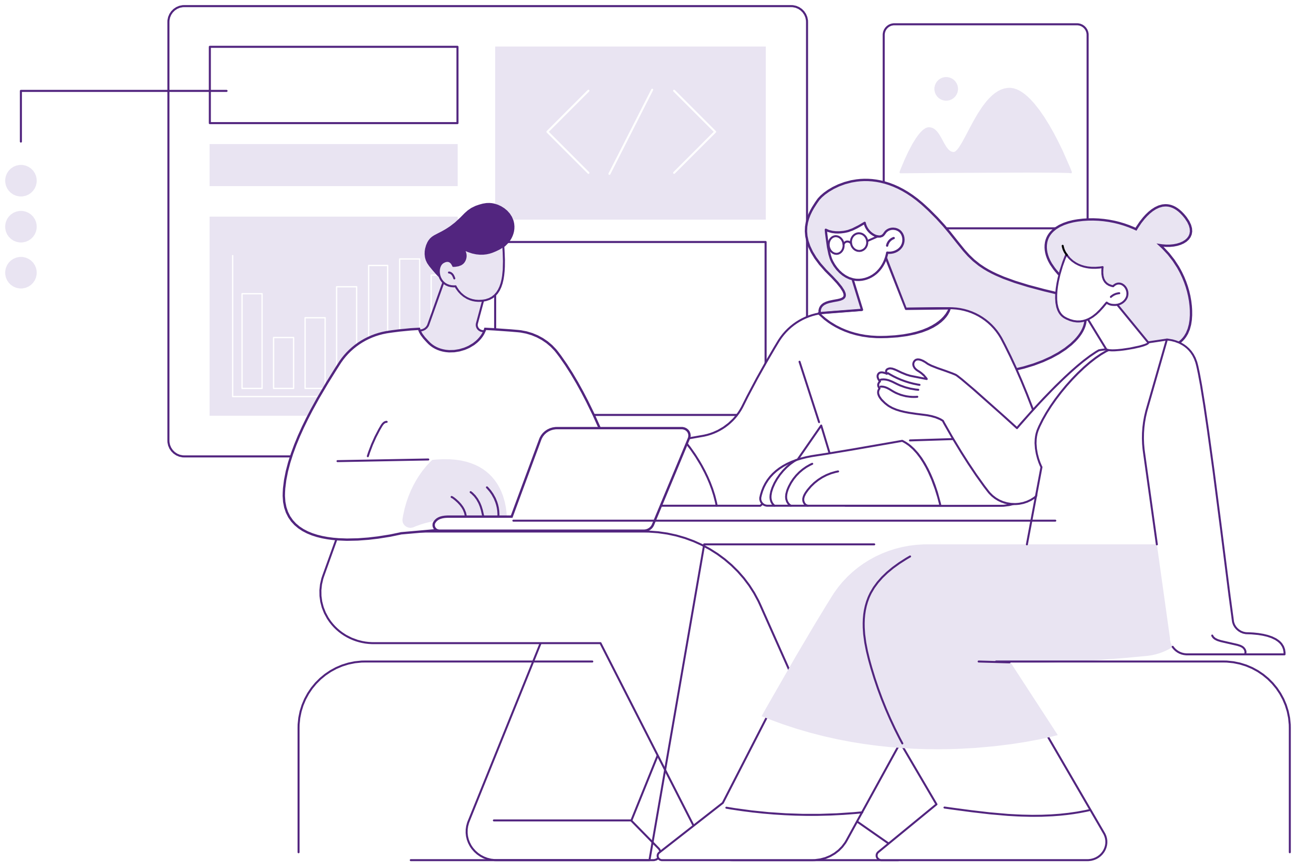

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EXECUTIVE SUMMARY

In today's digitally driven world, acquiring digital skills has become necessary for active participation in modern society. As England aims to establish itself as a 'science and technology superpower', the nurturing of digital skills amongst young people is crucial not only for personal empowerment but also for bolstering the nation's competitiveness in the global knowledge economy. Despite these ambitions, concerns persist regarding the low uptake of computing education. Gender disparities remain a pressing issue, with girls underrepresented, perpetuating gender imbalance in the digital domain and raising social justice concerns.

COMPUTING CURRICULUM CHANGES

The transition of England's computing education landscape in 2014 witnessed a notable shift from a broad information and communications technology (ICT) focus to a curriculum emphasising computer science. This transformation, marked by the introduction of the General Certificate of Secondary Education (GCSE) qualification in 'computer science,' aimed to elevate computer theory and programming skills as essential components of a rigorous subject. However, this shift has been accompanied by challenges, including a pronounced decline in the representation of girls in GCSE digital qualifications. In 2023, girls constituted only 21 % of the GCSE Computer Science cohort, compared to 43 % in 2015 in the previous ICT GCSE. Given it is ten years since the computing curriculum change and with technological advancements such as artificial intelligence (AI) changing the way we use computers, it is time to look again at the digital education offered in England.

THE SUBJECT CHOICE ATTAINMENT AND REPRESENTATION IN (SCARI) COMPUTING PROJECT

The Subject Choice, Attainment and Representation in (SCARI) Computing project (2021-2024), funded by the Nuffield Foundation, explores this shift in secondary computing education in England. Our data, comprising quantitative and qualitative insights from the National Pupil Database (NPD), School Workforce Census (SWC), an extensive student survey (n = 4,995), interviews with stakeholders (n = 45) and analysis of school documentation (n = 960 items), sheds light on the influences on female participation and students' attitudes towards computing. The schools involved in the research all offer GCSE Computer Science and represent some of the best-case scenarios in terms of computing provision in England. The project findings underscore significant challenges and highlight the imperative for targeted policy interventions.

CURRICULUM, CONTINUED PROFESSIONAL DEVELOPMENT AND WHOLE SCHOOL CHANGE

Interviews with teachers and school senior leaders revealed dissatisfaction with the GCSE Computer Science specification. Our survey revealed that of the young people who did not take the subject at GCSE, 74 % of girls reported that not enjoying computing was the reason why, contrasting with 53 % of boys. Moreover, 56 % of these same girls felt that GCSE Computer Science did not align with their career plans, in contrast to 39 % of boys. We found that at Key Stage 3 girls were significantly* more interested than boys in topics such as digital media, project work and presentation work, areas more akin to the previous ICT curriculum. Perceived relative difficulty in computing remains an issue for teachers, young people and their parents and carers.

* All references to "significant" in this report refer to statistical significance at the $P < .05$ level unless explicitly stated otherwise.

Many of the teachers interviewed expressed feeling unprepared to teach the current computing curriculum and commented on the variable quality and access to continuous professional development (CPD). Teachers and senior leaders in our study emphasised the importance of CPD to ensure equitable opportunities for students through both subject-specific training and CPD, with a focus on equality, diversity and inclusion (EDI) teaching and learning approaches. Our findings indicate that students who choose GCSE Computer Science are more likely to have supportive teachers who engage with their students. Teachers in schools with high uptakes of girls in GCSE Computer Science tend to build positive relationships with students and are often supported by effective EDI policies.

STEREOTYPES, JOBS AND INFORMAL LEARNING

Negative stereotypes surrounding computer scientists can deter young people from aspiring to a computing career. Pervasive stereotypes depict computer scientists as brainy and predominantly male, the latter attribution being significantly more likely to be perceived by girls than boys. Moreover, young people were more likely to identify the 'Big 5' tech entrepreneurs as the famous faces in computing, rather than a broader range of people and jobs.

This negative stereotyping is problematic, as career prospects motivate students to choose GCSE Computer Science, especially amongst girls (55 %). However, girls are 42 % less likely to aspire to be computer scientists compared to boys, even when they have chosen the subject at GCSE, indicating a need to broaden perceptions of computing careers. The girls we interviewed who have chosen GCSE Computer Science described a broader range of aspirations using digital skills, such as graphic design and theatre. Parental influence also plays a significant role, with parents and carers who are supportive and value computing being associated with an increased likelihood of their child aspiring to work as a computer scientist. Furthermore, digital making at home is also associated with increased GCSE Computer Science uptake for girls, emphasising the importance of promoting digital opportunities beyond the classroom. We found that schools that offer equitable opportunities for informal learning observe better uptake by girls of computing, but considerations around equity of access to these spaces needs to be carefully considered.

POLICY RECOMMENDATIONS

The SCARI Computing project makes six recommendations to address these challenges, encompassing curriculum reform, enhanced teacher training and professional development, fostering a supportive and inclusive school ecosystem, reframing the computing narrative, showcasing diverse digital opportunities and increasing access to informal digital making. By implementing these recommendations, policymakers, educators and stakeholders can work towards creating a more inclusive and equitable computing education system in England, supporting young people to develop essential digital skills and thrive in the digital age.

Please see kcl.ac.uk/scaricomputing for mini reports on teacher workforce, national computing provision, student demographics and subject comparability, and links to the journal articles and other outputs from this project.

RECOMMENDATIONS

1 REFORM THE COMPUTING CURRICULUM

A **Reform the GCSE provision for Computing:** Review the GCSE qualification space to ensure it covers a wider range of topics, appealing to a more diverse student population and the needs of society.

B **Review of relative difficulty:** Ofqual to look urgently at the relative difficulty of GCSE Computer Science compared to other subjects.

C **Explicitly widen the Key Stage 3 Computing Curriculum:** Place a greater emphasis on different areas of computing study, such as digital literacy, project work, digital media and data science.

D **An entitlement to a computing education for all students at Key Stage 4:** Expectation placed upon schools to provide a regular and broad computing education for all students.

2 PROMOTE AND ENHANCE TEACHER TRAINING AND PROFESSIONAL DEVELOPMENT

A **Support recruitment and retention of computing teachers:** Review the measures that support the recruitment and retention of computing teachers, including an increase in bursaries and the exploration of 'early career payments'.

B **School-level investment in staff professional development:** Teacher entitlement to self-defined CPD. Empower school senior leaders to invest in professional development, resources and time for teachers and leaders to support inclusive computing education and subject knowledge.

3 SUPPORT INCLUSIVE COMPUTING EDUCATION IN SCHOOLS

A **Foster inclusive learning environments:** Support the policies and structures to ensure that all computing classrooms promote a sense of belonging for young people.

B **Whole school approach to equity in computing:** Ensure school policies and strategies demonstrate a holistic and consistent approach to inclusion across the school, including CPD opportunities, pedagogy, learning resources, pastoral care, and acknowledging diverse contributions in computing and STEM fields.

4 REFRAME THE COMPUTING NARRATIVE

A **Reframe narratives surrounding computing:** Employers and organisations to share narratives of those working in computing that encompass a broader spectrum of individuals especially those working for social good, beyond tech entrepreneurs and historical figures.

B **Launch a sustainable national campaign:** A campaign aimed at showcasing diverse role models in computing, highlighting a variety of traits and skills beyond traditional stereotypes, especially relatable and contemporary role models, such as alumni and community members.

5 SHOWCASE DIVERSE DIGITAL OPPORTUNITIES

A **Improve subject-specific career guidance:** Ensure young people and their families and teachers have access to and understand the importance of computing education for a diversity of opportunities in computing and beyond.

B **Improve access to experiences of the workplace:** Enhance collaboration between employers (especially within the STEM sectors) and schools so that all young people have meaningful experiences of the workplace.

6 INCREASE ACCESS TO INFORMAL DIGITAL MAKING

A **Inclusive informal learning spaces:** Ensure access to informal learning spaces across the education system are supportive and inclusive for all young people and include a broad range of activities such as project work, digital media activities and programming.

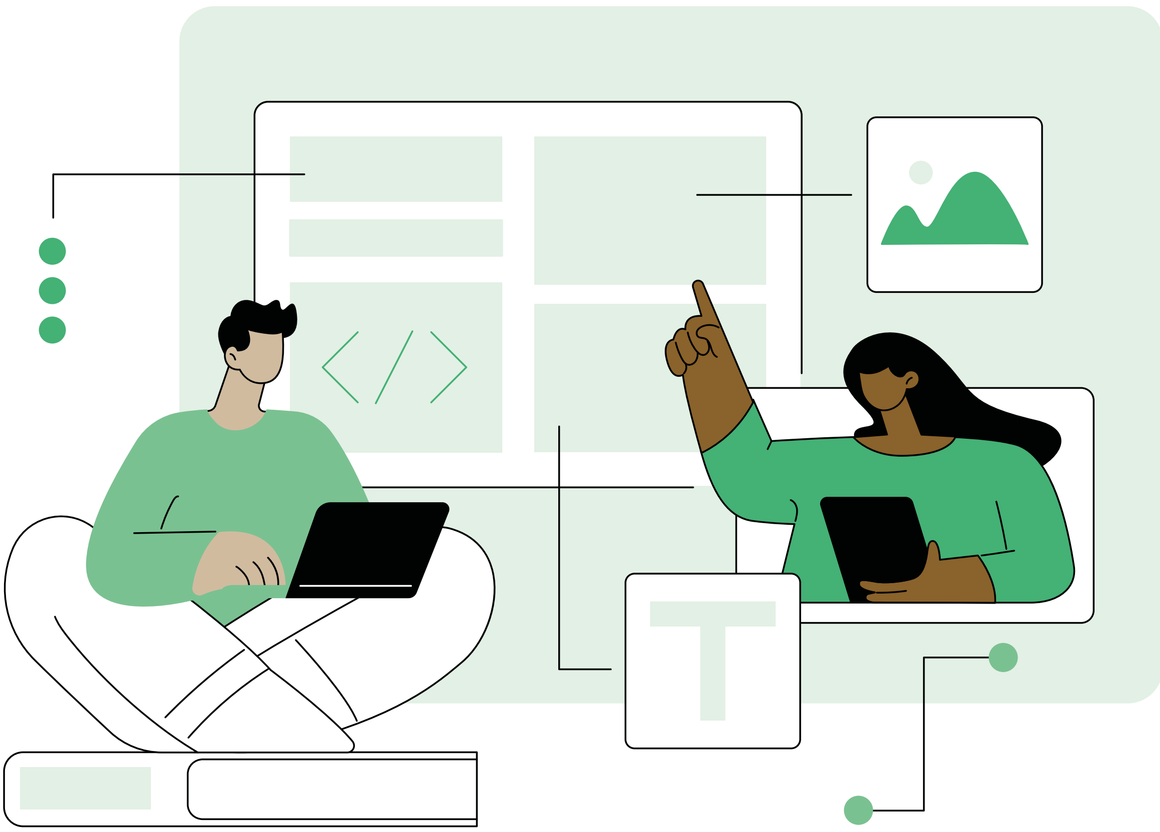
B **Coordinated efforts to ensure equity of access:** Schools and organisations recognise the challenges and work with teachers and families to ensure equity of access to digital devices and extracurricular activities that encourage digital making, using free and open-source resources where possible.

INTRODUCTION

As technology permeates every aspect of modern life, digital skills have evolved into a fundamental requirement for active participation in the digital age [1, 2, 3, 4]. The development of digital skills has taken on paramount importance as England strives to position itself as a "science and technology superpower" [5]. Ensuring that young people possess the skills to harness the potential of technology is not only essential for personal empowerment but also critical for securing England's position in the global knowledge economy [6].

However, in England and internationally, concerns have been raised about the low numbers of young people choosing computing; with particular concerns in England about the nature and scope of the compulsory computing curriculum [7]. Gender disparities persist, and a reservoir of untapped potential resides in a large proportion of the population [8, 9, 10]. Furthermore, the lack of women in computing may lead to heightened vulnerabilities and the dominance of men in shaping the modern world [11].

In 2014, England's computing education landscape transitioned from a broad Information and Communications Technology (ICT)† focus to a curriculum emphasising computer science theory and programming [12]. Central to this transformation was the introduction of the General Certificate of Secondary Education (GCSE) qualification in Computer Science, which replaced the traditional ICT GCSE and underscored coding and programming skills as essential components of a rigorous and intellectually stimulating subject [13, 14].



† See Annex 1 for definitions and key words used in this report.

This change extends beyond curriculum content to instructional focus, with a survey of 100 computing educators in England revealing an increased emphasis on “coding, programming, and digital making” within the contemporary computing curriculum. This change of emphasis has led to a reduction in attention to broader digital literacy and computing skills [15]. Furthermore, these curriculum changes appear to have contributed to increased gender disparity, with girls’ representation in the GCSE Computer Science cohort at 21 % in 2023 in England, compared to their 43 % representation in 2015 in the prior ICT GCSE [16, 17, 18, 19].

As we reflect on the past decade since the inclusion of computing in the national curriculum, it is evident that there have been substantial declines in the provision of essential computing skills and qualifications. These declines have particularly affected girls and women within our society. Now, more than ever, it is imperative to pause and critically examine how we can we address these challenges and ensure equitable access to quality computing education for all.

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THE SCARI COMPUTING PROJECT

The Subject Choice, Attainment, and Representation in (SCARI) Computing project (2021-2024) explores these shifts in secondary computing education in England. Our project seeks to understand the main predictors of the participation of girls in secondary school computing education (11 to 16 years) and how students’ views and attitudes in school-level computing influence their choices. Our data encompasses quantitative and qualitative data, collected from Department for Education (DfE) publicly available national datasets, the National Pupil Database (NPD) and the School Workforce Census (SWC); as well as a student survey (n = 4,995); and interviews with teachers (n = 15), senior leaders (n = 12), parents/carers (n = 8) and students (n = 10) from 15 co-educational state schools that had higher-than-average uptake of GCSE Computer Science in England. Five of these schools reported a high participation of girls choosing GCSE Computer Science (above 30 %), and we compared the data collected from these schools with the other 10 schools (which we call comparison schools). The findings in this report therefore represents some of the ‘best scenarios’ in terms of in-school opportunity for computing and computer science. Additionally, we analysed school documents (n = 960) from 40 schools including the surveyed schools. See Annex 2 for further details on the methodology.

With a focus on deciphering the factors shaping young people's choices in computing education, the SCARI Computing project provides insights into the motivations of students. These insights can inform strategic interventions by educators, parents, caregivers and policymakers aimed at harnessing the full potential of computing education, thereby fostering a more inclusive and diverse computing landscape and more digitally skilled future citizens.

THE CURRENT LANDSCAPE OF COMPUTING EDUCATION IN ENGLAND

Since the initial discussions to replace ICT with computing in 2012, the landscape of computing education has undergone dramatic changes. The number of students in the UK pursuing computer science first-degrees has increased from 14,000 to approximately 21,000 between 2013 and 2023 [20, 21]. A-level entries in computer science have seen a four-fold rise over the same period, reaching 18,306 students, with 57 % of providers now offering the A-level course. The GCSE in computer science has also become well-established, with 88,000 students taking the subject in 2023, and 80 % of non-selective state schools providing the course. GCSE Computer Science is now taught in a higher percentage of schools than was seen with GCSE ICT, which peaked at 43 % between 2012 and 2018. However, these successes have coincided with a general decline in computing and digital skills education at the secondary school level, particularly affecting girls, certain ethnic groups and students from underserved socioeconomic backgrounds.

In 2013, 71 % of students studied a digital qualification at Key Stage 4, but this figure dropped to just 28 % in 2023. While the iMedia qualification has provided some support, with girls making up 31 % of entries compared to 21 % for GCSE Computer Science in 2023, it has not yet reached the same level of participation as ICT and differs substantially in terms of content from the GCSE in Computer Science.

GIRLS CHOOSING GCSE COMPUTER SCIENCE

Since 2016, the percentage of female GCSE Computer Science students has remained around 20 %. This contrasts with the ICT GCSE which typically attracted more than 40 % of female students. For the A-level qualification, the representation of girls has more than doubled from 7 % in 2013 to 15 % in 2023. Our analysis of the National Pupil Database (NPD) shows that whilst white female students form the largest female group taking the GCSE, white female students had the lowest population representation of any ethnic group, with 4.5 % of this population taking computer science in 2020, compared to 16 % of Chinese female students, 11.2 % of Asian female students and 6.2 % of Black female students. Students receiving free school meals were also less likely to sit the GCSE with 4.6 % of this group taking the course, compared to 5.8% of female students not on free school meals. As discussed later, even though girls do better than boys in the GCSE, their outcomes were typically lower in the subject relative to their other GCSE's.

When looking at all computing related qualifications, 69 % of female students took an exam at Key Stage 4 in 2013, just before the curriculum change. This is a slightly lower figure than the 72 % of male students who took a qualification that year. These figures have dropped substantially, with 2020 data showing 17 % of female students taking any computing related qualification, against 39 % of male students (Figures 1 and 2). If the 2013 uptake had been maintained, roughly 160,000 additional girls would have taken a qualification in 2020. This low figure, combined with the data on the sharp decline in hours of computing taught, suggests that students not taking a qualification in 2023 were likely to be getting very little general computing education.

FIGURE 1: Computing-related exam entries between 2012 and 2023, "Other computing" includes a range of courses related to computer science, digital literacy and information technology [22].

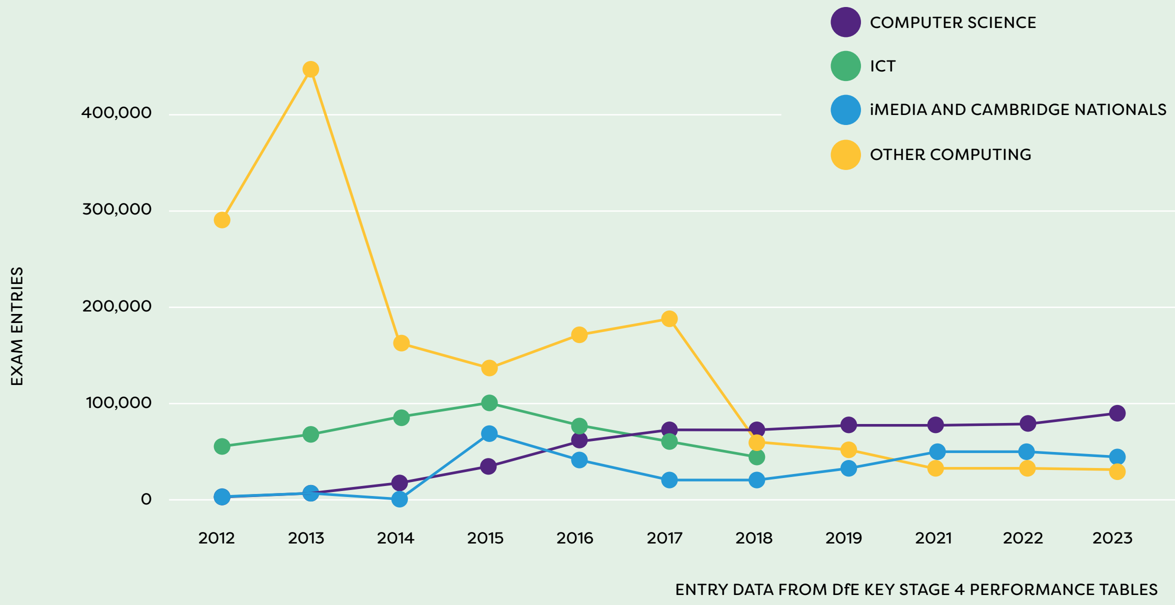
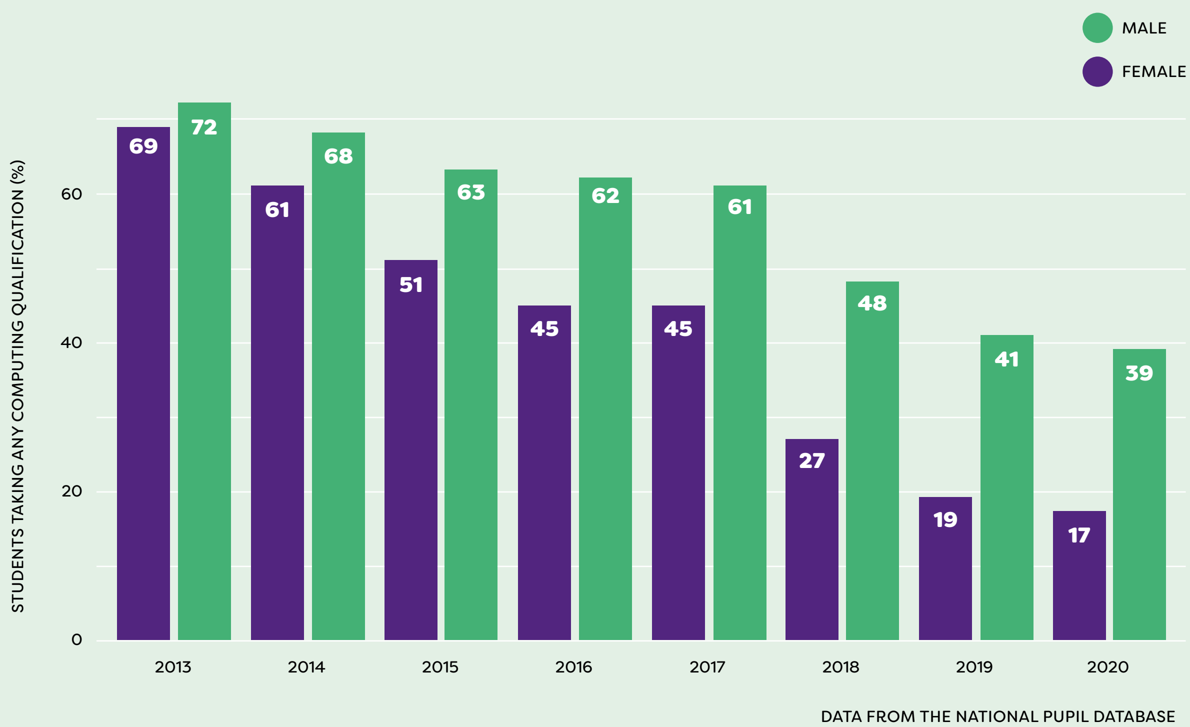


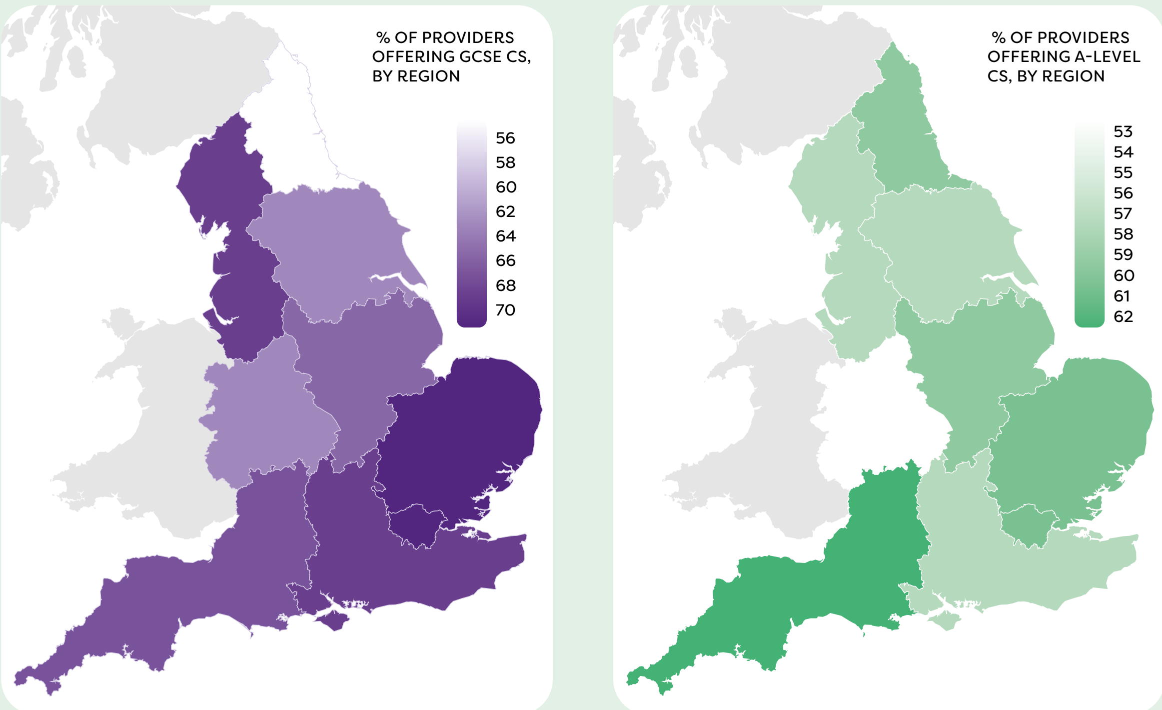
FIGURE 2: Exam entries for any computing qualification by gender of student between 2013 and 2020.



COMPUTING PROVISION

The increase in the number of secondary students taking GCSE Computer Science appears to have masked substantial decreases in numbers taking other computing-related qualifications and a reduction in the hours of general computing provision. Our study of School Workforce Census (SWC) data, which covers approximately 80 % of state schools overall, showed that taught computing hours across state schools declined by 28 % for Key Stage 3, 59 % for Key Stage 4 and 22 % for Key Stage 5 between 2010 and 2023. In 2022, 82 % of secondary schools had Key Stage 3 computing provision during the census period, a decrease from 91 % in 2010.

FIGURE 3: Regional access to GCSE Computer Science (3a) and A-level (3b). Entry data from DfE Key Stage 4&5 performance tables.



Regional disparities exist in access to the GCSE qualification with 71 % of schools in the East of England offering the subject, compared to just 56 % of schools in the North East. The pattern is different for A-level, with 62 % of schools in the South West offering the subject in 2023 compared to 53 % of those in the West Midlands. Schools in Slough saw 27 % of their students take the GCSE, compared to just 4 % of students in North East Lincolnshire and Sunderland. Intake for A-level is lower, with 8 % of students in Wokingham taking the exam, no provision at all in Knowsley and Thurrock, and fewer than 1 % of students taking the A-level in Middlesbrough, Sunderland, Barnsley, Gateshead and North East Lincolnshire. Urban schools have been consistently more likely to offer the subject than rural schools across GCSE and A-level.

Whilst most schools do now offer GCSE and A-level Computer Science, when the type of school is taken into consideration, provision varies substantially. Nearly 96 % of grammar schools offered the GCSE in 2023 compared to 80 % of non-selective state schools. For the A-level, 87 % of grammar schools offered the subject compared to 57 % of non-selective state schools. Schools serving the communities with the lowest uptake of free school meals (FSM) were found to be 60 % more likely to offer GCSE Computer Science than those with the highest uptake. For A-level, the picture was even starker with lowest uptake (FSM) schools 162 % more likely to offer the qualification.

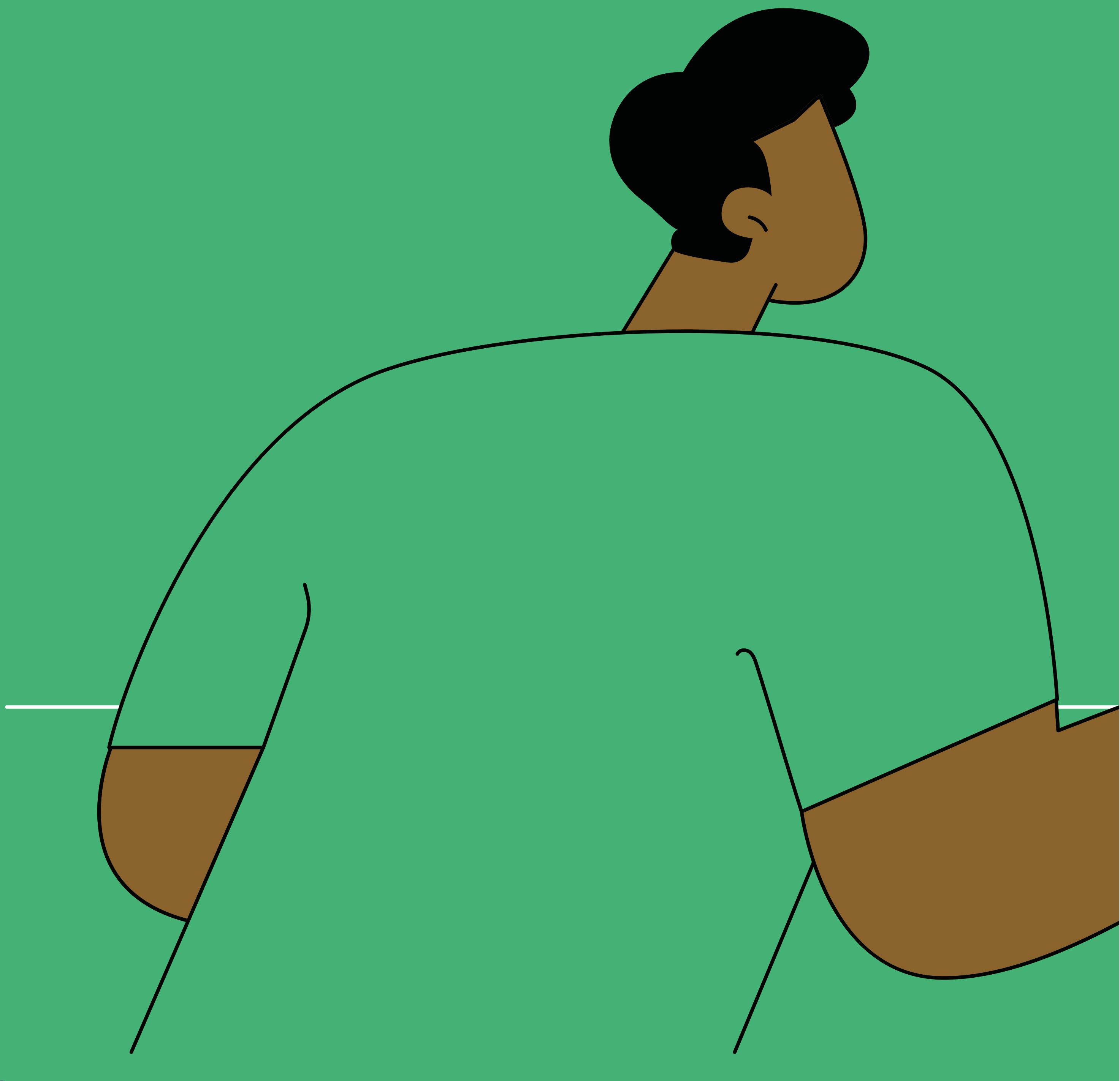
Analysis of the National Pupil Database also showed that at A-level, students with special educational needs (SEN) provision and taking at least one A-level were consistently more likely to take computer science than those without SEN. In 2020, 10 % of the SEN students with an Education, Health and Care (EHC) plan took the A-level Computer Science, compared to 4 % of their peers without an identified SEN. However, the overall number of students with SEN taking any A-level is very small and it remains unclear what kinds of special educational needs these students have.

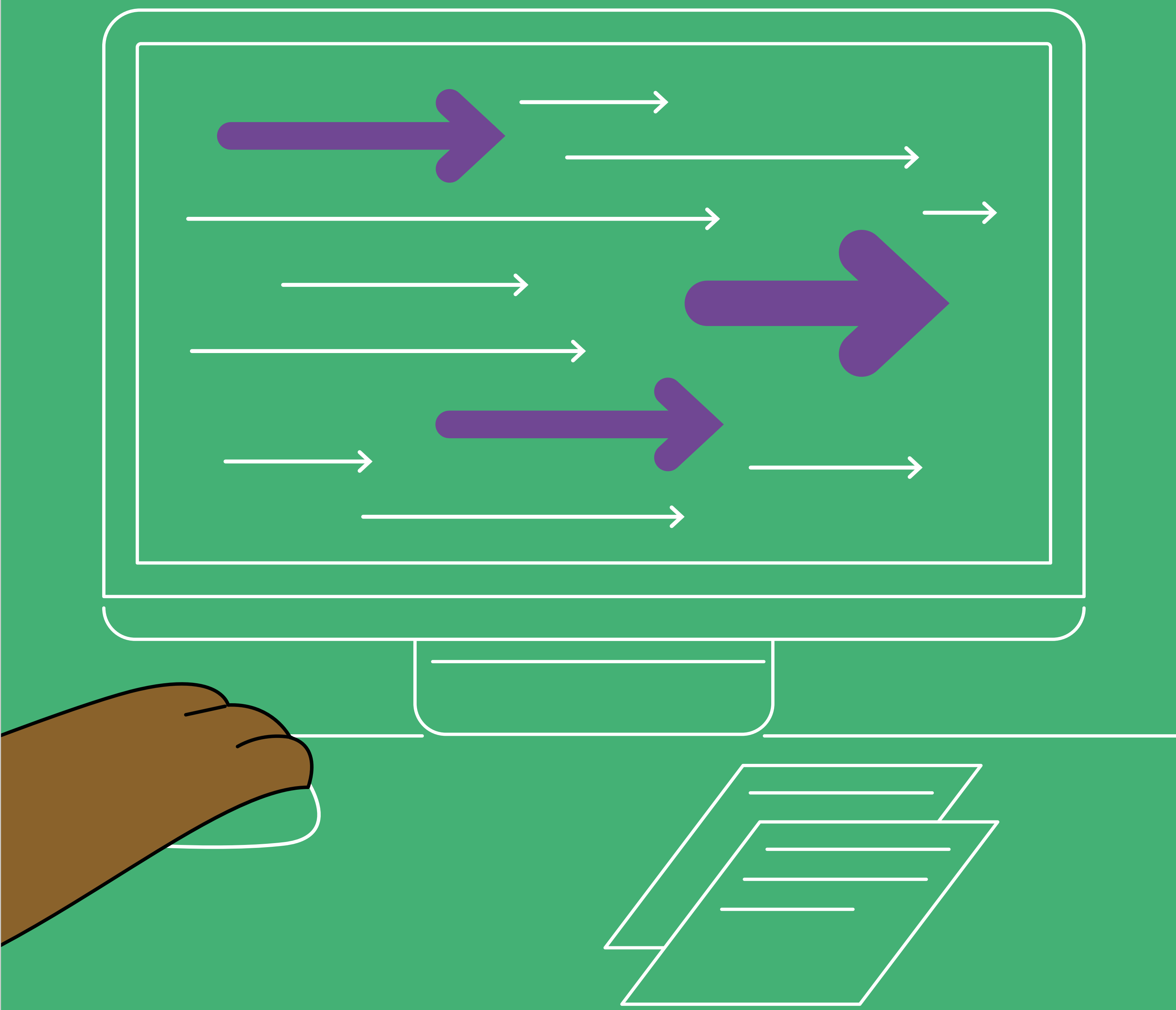
COMPUTING TEACHER RECRUITMENT AND WORKFORCE

Over the past decade, recruiting secondary school teachers has been challenging, with computing facing some of the lowest numbers taking up teacher training posts when compared to government targets [23]. This recruitment issue has coincided with a decline in the number of practising computing teachers and the overall number of hours of computing instruction. According to our analysis of the School Workforce Census, the number of computing teachers at Key Stages 3, 4 and 5 was 8,435 in 2022, down 31 % from 12,218 in 2011. This reduction parallels a decrease in computing hours taught, especially in Years 9, 10 and 11.

Within the computing teacher workforce, the percentage of women decreased marginally from 43 % to 41 % between 2010 and 2022, with women now making up 37 % of Key Stage 4 and 35 % of Key Stage 5 practitioners. Conversely, the percentage of computing teachers from minority ethnic backgrounds has increased from 19 % to 26 %, consistently higher than the overall minority ethnic teaching population, which was 20 % in 2022. Amongst experienced teachers with 11 years of classroom experience in 2020. and who had taught computing at some point in those 11 years, only 38 % had taught computing for each of the 11 years, compared to 72 % of mathematics teachers. Additionally in 2023, just 54 % of computing lessons were taught by teachers with computing degrees. This is much less than comparable teachers of other subjects such as mathematics (85 %), geography (87 %) and physics (72 %) [24].

EVIDENCE-BASED RECOMMENDATIONS FOR THE FUTURE OF COMPUTING





1

REFORM THE COMPUTING CURRICULUM

REVISE THE COMPUTING CURRICULUM TO MAKE IT MORE INCLUSIVE, ENGAGING AND RESPONSIVE TO THE DIVERSE INTERESTS AND NEEDS OF ALL STUDENTS.

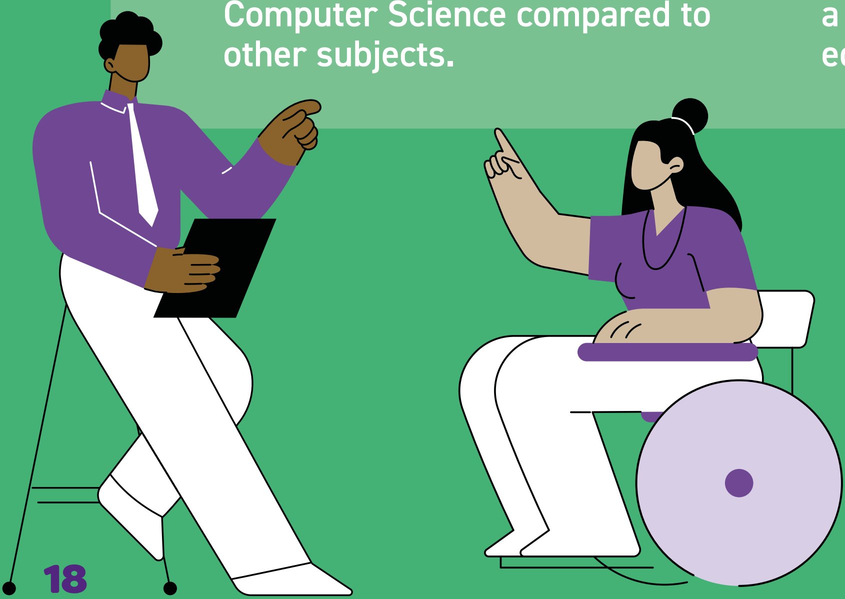
RECOMMENDATIONS

A **Reform the GCSE provision for Computing:** Review the GCSE qualification space to ensure it covers a wider range of topics, appealing to a more diverse student population and the needs of society.

B **Review of relative difficulty:** Ofqual to look urgently at the relative difficulty of GCSE Computer Science compared to other subjects.

C **Explicitly widen the Key Stage 3 Computing Curriculum:** Place a greater emphasis on different areas of computing study, such as digital literacy, project work, digital media and data science.

D **An entitlement to a computing education for all students at Key Stage 4:** Expectation placed upon schools to provide a regular and broad computing education for all students.



Our interviews with senior school leaders (n = 10/12) and teachers (n = 12/15) found that many consider GCSE Computer Science as unsuitable for the diverse needs of their student populations, highlighting the different interests and needs of students, particularly girls, and the need to teach digital literacy. Several teachers expressed a desire to see the development of a new broader GCSE qualification (n = 7/15). In interviews, girls did consider programming to be useful for their futures. However, the survey findings demonstrated that girls had significantly lower self-beliefs in computing and coding when compared to boys (see [25] for a description of self-beliefs and Annex 3 for a description of these two variables "coding attitudes" and "computing lesson"). Our interviews with parents, students and teachers raised concerns about the perceived difficulty of the exam subject. Teachers also raised concerns about the narrowness of the Key Stage 3 curriculum, as schools that were successful in engaging girls were more likely to integrate non-computer science exam topics into their provision. Additionally, girls were more likely to find non-computer science topics (e.g., project work) in computing at Key Stage 3 more interesting and less difficult than boys. In the sections below, we describe our curriculum-related findings from both our student survey, interviews with computing teachers and senior leaders and analysis of curriculum documents.

> **"We need a brand-new qualification at Key Stage 4 that is not called Computer Science or IT ... call it something else ... you could have sections that were programming based, but ... also sections where you did something ... more practical and creative, and more IT based ... if you have that medley ... you're much more likely to attract a broader range of people to it ... there needs to be a national conversation about it".**
>
> **Senior leader in a school with high participation of girls**

> **"I personally believe that removing ICT from the curriculum was a big mistake. I think it's a massively important thing that those children, our children, are taught those skills for how to use Microsoft Office... some kids don't know how to send an email, and I'm being serious there".**
>
> **Computing teacher in a comparison school**

PERSPECTIVES OF THE CURRENT GCSE CURRICULUM FOR COMPUTING

We found computing teachers and school senior leaders expressed dissatisfaction with the content of the GCSE Computer Science specification, which was often described as narrow and less responsive to the diverse interests, talents and needs of students.

Teachers and school leaders acknowledged a heavy focus on coding and mathematics in the computing curriculum, at the expense of core digital skills (such as the use of email and data handling), and how this may shape how students perceive the subject. They described a range of topics that interest girls, including digital literacy, thinking critically about computing in society, and creative topics, such as graphics design, animation and digital media. A broadening of the topics covered by the GCSE was seen as a potential solution to including more girls. These findings around interest are supported by our student survey and discussed later in this report.

Evidence indicates girls regularly outperform boys in educational outcomes including in GCSE Computer Science [26]. However, when we asked girls who had chosen the subject for their views of the current computing curriculum, they often demonstrated more negative computing attitudes, especially with regards to coding. This was further highlighted in our student survey which found that girls had significantly lower scores in their coding attitudes compared to boys, regardless of whether they had chosen the subject at GCSE [27].

Girls studying GCSE Computer Science acknowledged the relevance of coding skills for future careers, but tensions emerged between subjects of interest and those deemed advantageous for their futures. Some girls interviewed exhibited a strong interest in the societal and ethical dimensions of computing, showcasing a broader comprehension of its impact (n = 5/10). Girls also recognised the importance of digital literacy and data management skills for their future careers (n = 6/10). They appeared to enjoy these aspects of the curriculum and expressed enjoyment and aspirations in creative computing domains such as digital art, graphics, architecture and backstage theatre, areas that are less well covered by GCSE Computer Science [28].

PERCEPTIONS OF DIFFICULTY

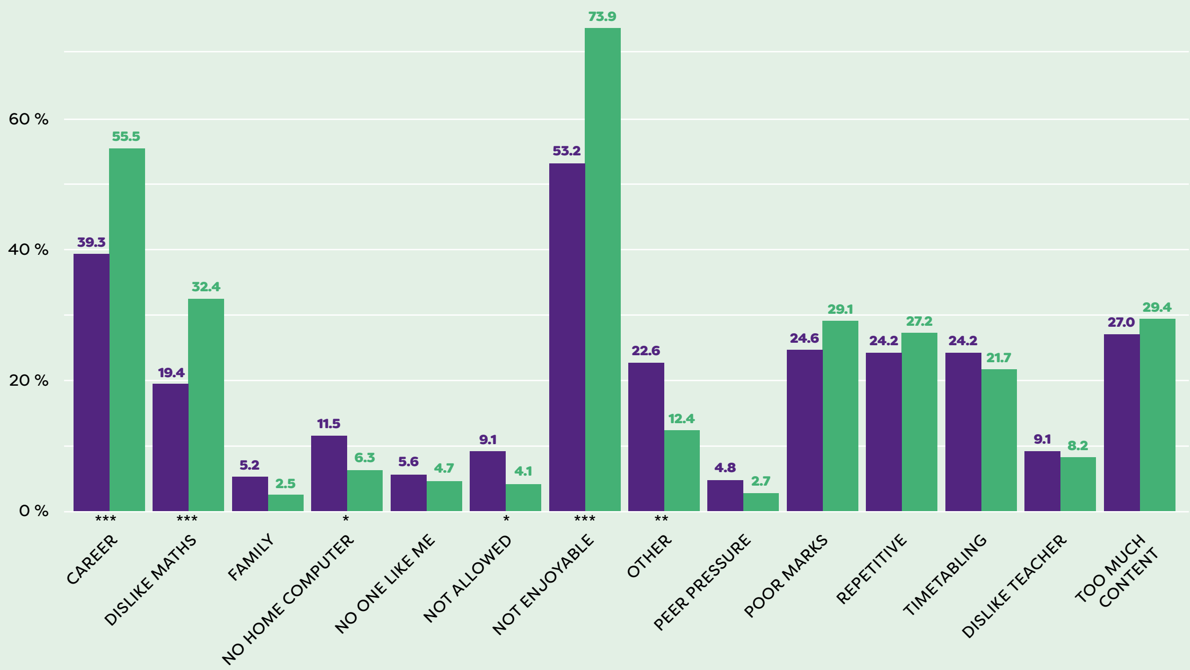
The perception of computer science being a difficult subject was shared by students, parents and teachers. This matches concerns raised by the British Computing Society with the English government's Office of Qualifications and Examinations Regulation

> **“People think, you have to be, like, really smart to take it.... it's sometimes not that enjoyable, people think ... you have to be, like, quite quick thinking and know it quite quickly to be able to do it. And know quite a lot of stuff around computing to understand it all”.**
>
> **Year 10 girl studying GCSE Computer Science**

(Ofqual) around the difficulty of the exam [29]. Ofqual's investigation into the difficulty of the GCSE is yet to conclude, more than two years after it started. Our analysis of the National Pupil Database supports these views of subject difficulty. In 2019, the last exam before the pandemic, GCSE Computer Science was one of the most difficult GCSEs, with the typical student achieving 0.72 of a grade less in the exam than the average grade of their other subjects. Girls taking the qualification typically achieved 1.11 of a grade less than their other subjects, with only GCSE Statistics having a greater difference. Using subject pair analysis, we found that only 6 % of girls and 7 % of boys got a higher grade in GCSE Computer Science than in GCSE Mathematics. Conversely, 74 % of boys and girls had a lower score in GCSE Computer Science compared to GCSE Mathematics.

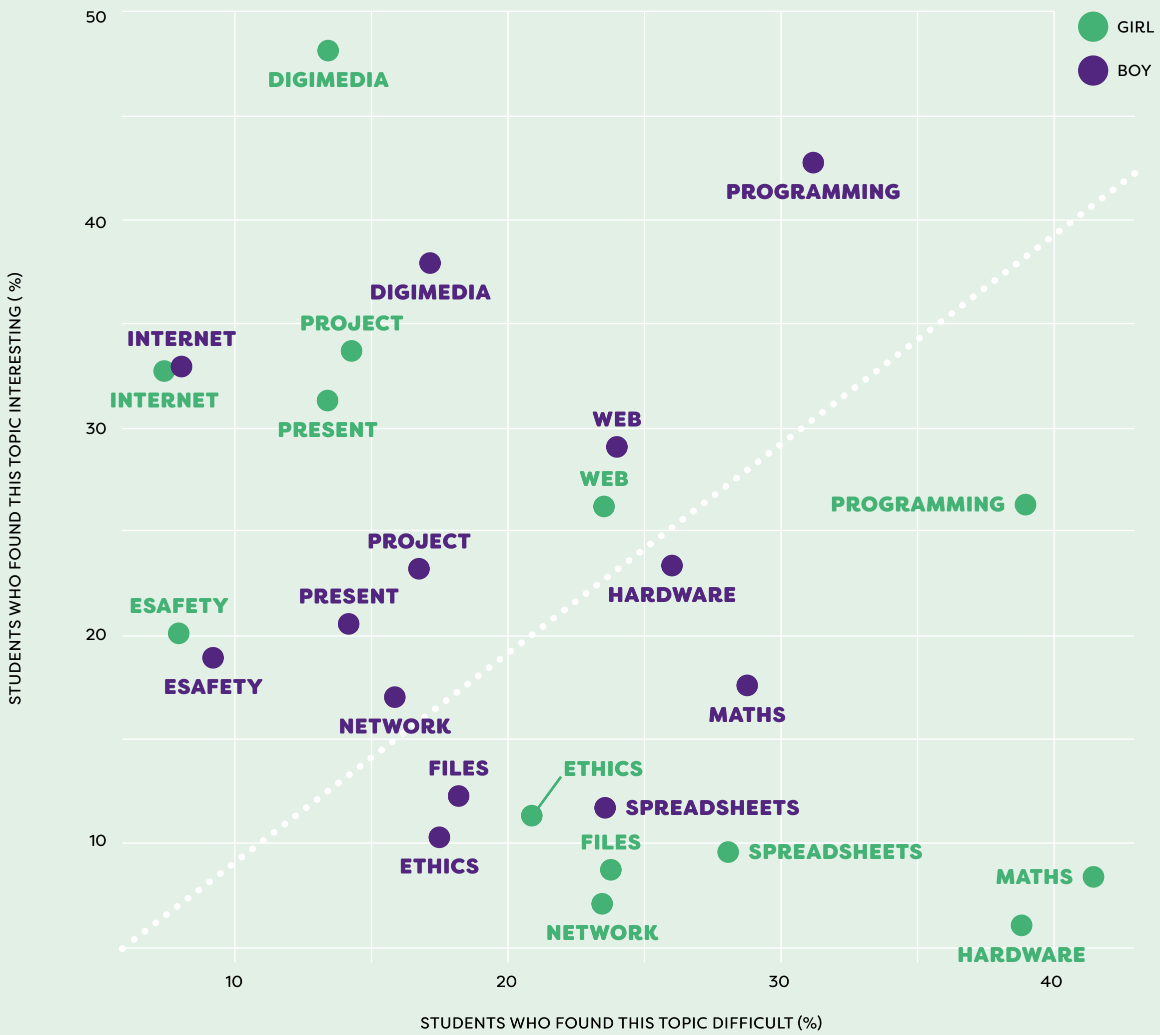
> **"So the end result means... some parents are fairly savvy about it, and they know that, 'Why should I get my daughter to do computer science if she did separate sciences and she's more likely to get a better grade? Not because of the quality of the teaching and not because she'll enjoy it less. But just because statistically, the grade boundaries are set up to give her a better chance of success in other subjects...' I find that really difficult".**
>
> **Computing teacher in a comparison school**

FIGURE 4: Reasons for not choosing GCSE Computer Science by gender. Boys *n*=252; Girls *n*=364. Statistical significance *** *P* < .001, ** *P* < .01, * *P* < .05.



SURVEY DATA FOR KEY STAGE 4 NON-GCSE COMPUTER SCIENCE STUDENTS

FIGURE 5: Curriculum areas of interest and perceived difficulty at Key Stage 3 for girls and boys. Girls *n* = 1,347; Boys *n* = 1,512.



SURVEY DATA FOR KEY STAGE 3

In our student survey (*n* = 4,995), 29 % of girls and 25 % of boys cited poor marks as a reason for not pursuing the GCSE (Figure 4). The interviewed students also mentioned that computing often seems inaccessible and is perceived as a subject only for "smart" students. Additionally, 59 % of the students taking GCSE Computer Science reported being in the top set for mathematics. Our interviews with computing teachers found that some schools reinforce the perception of difficulty by limiting access to GCSE Computer Science through computational thinking exams at the end of Key Stage 3 (*n* = 5/15). These findings suggest that addressing perceptions of difficulty, which shapes self-beliefs in computing ability and students' perceptions of the subject, could encourage more students to pursue GCSE Computer Science.

BROADENING THE KEY STAGE 3 CURRICULUM

The computing national curriculum document leaves the implementation and much of the content of the subject open to interpretation,

with the GCSE in Computer Science often driving what happens in Key Stage 3 [30]. Many teachers expressed concerns about the new curriculum when it was first introduced (n = 12/15). Teachers also suggested the curriculum can overlook essential aspects of computing, such as core digital literacy skills (n = 10/15), despite positive feedback regarding the general inclusion of computer science topics (n = 7/15). To address this, computing teachers in schools with high participation rates amongst girls all (n = 5/5) described integrating practical and creative computing topics, for example project work, digital media, and data science, into both Key Stage 3 and the GCSE Computer Science curricula. However, some teachers and school leaders also expressed concerns about the limited time allocated to Key Stage 3 computing, reporting that this affects how computing is perceived by students and staff, influencing its status in school strategies and priorities (n = 5/27).

At Key Stage 3, our student survey found that overall, girls were significantly more interested than boys in topics more akin to ICT courses, such as digital media, project work and presentation work. They were less likely to be interested in topics that are more akin to GCSE Computer Science, such as programming, hardware, mathematics and networking (Figure 5). Furthermore, girls were significantly more likely than boys to report finding certain computer science topics, such as hardware, mathematics, networking and programming, more difficult. The only area that girls perceived as significantly less difficult compared to boys was digital media.

AN ENTITLEMENT TO A COMPUTING EDUCATION FOR ALL STUDENTS AT KEY STAGE 4.

The percentage of girls taking a computing qualification at Key Stage 4 has decreased substantially since the introduction of the new curriculum, with just 17 % sitting an exam in 2020, compared to 39 % of boys (figure 2). This reduction has coincided with a general decline in the number of hours of taught computing at this Key Stage, which in 2022/23 sat at 41 % of its 2011/12 figure. It seems highly likely that many students, in particular girls, are no longer receiving regular computing education at school. Additionally, there is little evidence of substantial computing content being taught elsewhere in the curriculum for this age range.

2

PROMOTE AND ENHANCE TEACHER TRAINING AND PROFESSIONAL DEVELOPMENT

EMPOWERING TEACHERS TO CULTIVATE A DIVERSE AND DYNAMIC COMPUTING EDUCATION

RECOMMENDATIONS

A Support recruitment and retention of computing teachers: Review the measures that support the recruitment and retention of computing teachers, including an increase in bursaries and the exploration of 'early career payments'.

B School-level investment in staff professional development: Teacher entitlement to self-defined CPD. Empower school senior leaders to invest in professional development, resources and time for teachers and leaders to support inclusive computing education and subject knowledge.

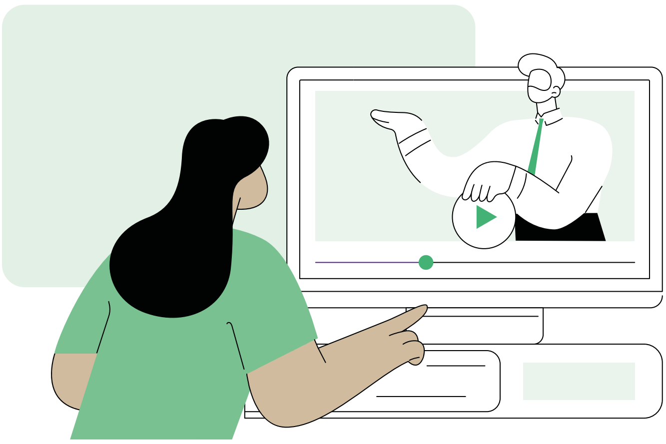
Our study confirmed that the role teachers play when it comes to subject choice is important. Through our student survey, we found that those young people who chose GCSE Computer Science were more than twice as likely to report having a supportive classroom teacher, who listens and takes an interest in their students (see Annex 3 Teacher Support). However, teachers are in short supply, with computing staff shortages being a major concern amongst senior leaders (n = 7/12). Despite national training programmes, our analysis of school workforce data shows substantial decreases in computing staff numbers across all key stages since the introduction of the computing curriculum. Computing teachers noted that the quality of and access to CPD since the 2014 curriculum change has been variable (n = 10/15).

Furthermore, interviews with computing teachers and senior school leaders highlight the importance of subject specific CPD, as well as training on inclusive teaching approaches for staff to effectively deliver a diverse range of computing topics and ensure equitable opportunities for all students. Supporting teacher capacity to engage effectively in CPD and to develop insights and strategies for inclusive practice is essential to support students with intersectional identities, particularly in computing education.

STAFFING AND TEACHER PREPAREDNESS FOR EFFECTIVE DELIVERY OF THE COMPUTING CURRICULUM

A shortage of subject-specialists combined with the perceived complexity of topics within the computing curriculum remains a critical issue for subject provision and was a common concern amongst school senior leaders in our research.

> **“I’d say most of the useful CPD within the department has come in the teachers’ own time through the National Centre for Computing Education (NCCE). So, I’ve encouraged all of the staff to attend the inclusive practice differentiation [course] and particularly how to adapt our practice to SEND and to widen participation, tackle the gender divide ... We’ve got a new Deputy Head who is in charge of CPD and she’s a breath of fresh air. She actually creates some time for departments to choose what we want to focus on”.**
>
> Computing teacher in a comparison school



> **“Computing has a place within the school ... [but] it isn’t ... necessarily central to the curriculum because we can’t reliably staff it”.**
>
> Senior leader in a comparison school

> **"You've got to have somebody who's got the skillset and knowledge to really make sure students get the best experience possible in computer science. You can't cut any corners with it. It wouldn't be worth it".**
>
> **Computing teacher in a school with high participation of girls**

The presence of teachers with the requisite subject-specific knowledge not only enhances the quality of education but could also help to alleviate existing barriers, particularly for girls, and has been evidenced in other subject areas such as physics [31]. Furthermore, recruitment of new computing teachers has been consistently below national targets and remains low, with research on improving computing teacher recruitment and retention suggesting that training bursaries should be maintained and increased over time, and that early career payments should be introduced for all new computing teachers to increase their likelihood of staying in the classroom [23].

Computing teachers and school leaders, especially those in comparison schools, also described challenges related to staff shortages, as well as varying levels of staff turnover within their computing departments and reliance on supply teachers (n = 8/27). This raises concerns about the retention of computing teachers, especially subject specialists. A lack of continuity may also negatively affect student-teacher relationships and sense of belonging, including the opportunity to develop positive computing self-beliefs amongst students. Additionally, computing teachers and school leaders described challenges related to school funding, which can limit resources and access to new technologies and equipment for the curriculum.

> **"When we want to try new things in the curriculum, it's ... confined by budget. Buying new tech to have in the classroom, robotics ... that's a challenge".**
>
> **Computing teacher in a comparison school**

Some computing teachers in our study reported that they felt there were issues with how the new curriculum was introduced when it came into effect in 2014, and suggested they and their colleagues were not adequately prepared with regards to subject knowledge to deliver the new curriculum (n = 7/15).

> **"I would probably say that when the new curriculum came into place, there were a lot of staff ...that were not trained, not prepared well enough for the new specifications. I would put on the top of the list [of priorities] is teachers are just not equipped to teach the subject well...".**
>
> **Computing teacher in a school with high participation of girls**

Furthermore, recent research found that whilst 81 % of teachers reported they had taught students that were better programmers than them, 48 % of teachers responded that they had received no initial teacher training on how to support exceptional young programmers [32].

THE CRUCIAL ROLE OF SENIOR LEADERSHIP SUPPORT IN ACCESSING CPD

Our research found that schools with a higher uptake of girls choosing GCSE Computer Science were more likely to report participating in "useful" CPD – not all CPD was considered useful by teachers, including the CPD provided by exam boards. These teachers reported independently seeking out CPD and building computing teacher networks in their own time rather than during directed time (*n* = 10/15). This suggests a culture of independent, self-taught learning is undertaken at the expense of personal time which may also be inequitable to those with other responsibilities. Furthermore, they felt well supported by senior leaders at their school to engage in CPD and develop inclusive practice in computing that fits in with broader school strategies around inclusion.

Many of the computing teachers we interviewed said they were aware of the Computing at Schools (CAS) network (*n* = 13/15) – a community of teachers, educators and industry professionals who share resources, events and news on teaching computing in schools. In a school with high participations of girls, a computing teacher had a community leadership role in CAS, and other teachers recounted benefiting from networking and resource-sharing at CAS conferences. However, time constraints and heavy workloads were cited by most of these teachers as hindering their ability to participate in professional development opportunities.

> **"Last year, I did ... the STEM facilitator course, and the school allowed me to go on that. I think they're very supportive. Even if they themselves can't provide it, then they will make sure we use ... different companies".**
>
> **Computing teacher in a school with high participation of girls**

3

SUPPORT INCLUSIVE COMPUTING EDUCATION IN SCHOOLS

BUILDING A LEARNING ENVIRONMENT THAT ENABLES ALL YOUNG PEOPLE TO FEEL SUPPORTED AND INCLUDED.

RECOMMENDATIONS

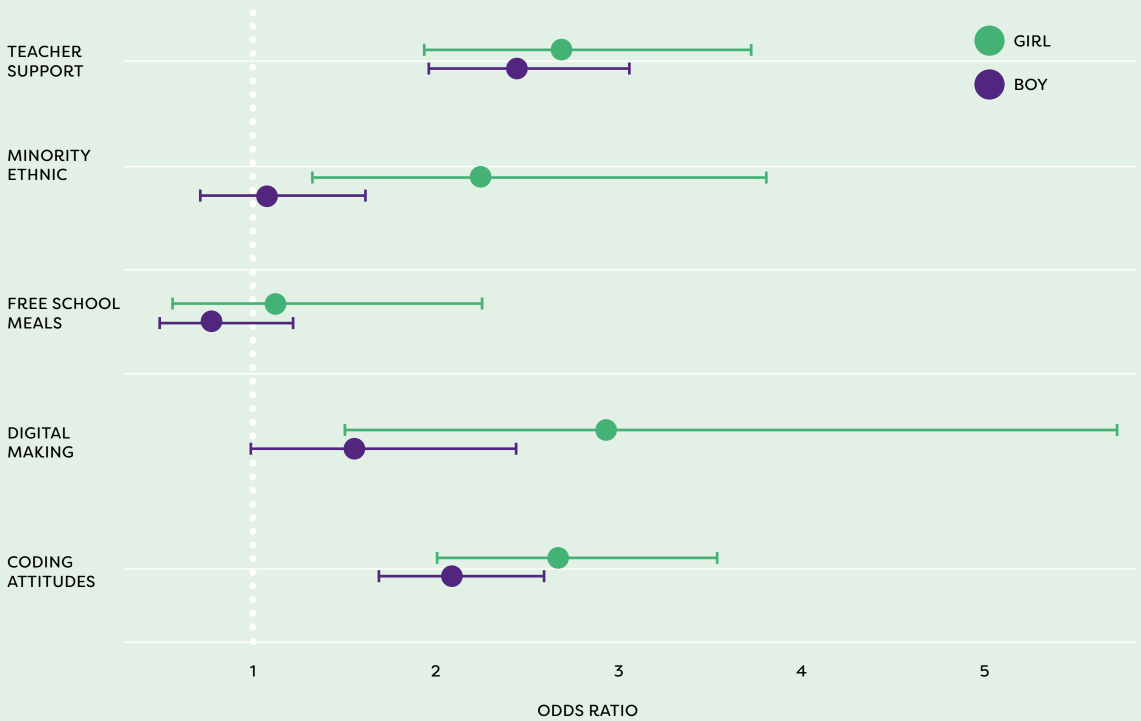
A **Foster inclusive learning environments:** Support the policies and structures to ensure that all computing classrooms promote a sense of belonging for young people.

B **Whole school approach to equity in computing:** Ensure school policies and strategies demonstrate a holistic and consistent approach to inclusion across the school, including CPD opportunities, pedagogy, learning resources, pastoral care, and acknowledging diverse contributions to computing and STEM fields.

Our research shows that students who took GCSE Computer Science were more than twice as likely to report having a teacher that uses strategies that support the building of self-beliefs (such as self-confidence) than their peers who did not choose the subject. Teacher support was one of the biggest predictors associated with GCSE Computer Science uptake, as identified from the student survey analysis. This highlights the pivotal role of supportive teaching practices and inclusive learning resources in nurturing students' self-beliefs and success in computing education.

These findings highlight that policies and structures, especially those related to training and professional development, are essential components for ensuring that all educators working in the computing classroom have capacity to cultivate an inclusive and supportive learning environment.

FIGURE 6: Factors associated with the uptake of GCSE Computer Science by gender. Logistic regression output from student survey data. Teacher support, Digital making and Coding attitudes are composite variables described in Annex 3. Free school meals (no-yes) and Minority ethnic (no-yes) are dichotomous. The reference level for Minority ethnic is White British and for Free school meals it is not being eligible for Free school meals. Boys *n* =700; Girls *n* =450. All variables except free school meals, and digital making and Minority ethnic for boys are statistically significant *P* < .05.



LOGISTIC REGRESSION OUTPUT FROM SURVEY DATA OF KEY STAGE 4 STUDENTS

STUDENT-CENTRED APPROACHES AND BUILDING RELATIONSHIPS

Interviews with teachers and senior leaders suggest those in schools with a high uptake of girls in GCSE Computer Science seem to adopt a targeted and dialogic approach to build positive relationships with students in computing, and respond to their needs and interests. For instance, teachers described having conversations with students to build their confidence in the subject, including girls and marginalised students.

> **"I don't want to put my hand up and ask this in case they'll think I'm dumb because I don't understand it. But then, like [Teacher name] will reiterate that there's no stupid questions".**
>
> **Year 10 girl studying GCSE Computer Science**

Interviews with girls who have chosen GCSE Computer Science also suggested that positive relationships with teachers, as well as the use of conversational approaches to learning, encourage students to contribute to class discussions and ask questions. These approaches include regular interactions with students to check understanding and offer support, identify their strengths and interests, and providing regular feedback during lessons. Additionally, teachers at three of the five schools with a high uptake of girls suggested encouraging students to take ownership of their learning direction and the topics that interest them. This may be either 'as a treat' in the curriculum, or through conversations with students and parents about areas where they may benefit from additional support or learning, and allowing that to steer extracurricular topics.

SUPPORTING IDENTITY AND BELONGING IN COMPUTING

According to the students we interviewed, girls may decide against a computing education due to the perceived masculine culture and dominance of boys in computing contexts. Research suggests misalignment between student identity and disciplinary culture can negatively affect retention and participation, even when attainment is high [33].

> **"You don't really see a lot of girls ... it's kind of like I don't want to be the only girl, because then it would be awkward".**
>
> **Year 10 girl studying GCSE Computer Science**

The GCSE Computer Science students we interviewed also talked about their lived experiences of intersectional inequalities, including those pertaining to gender, class and disability. This can lead to disparities in participation and outcomes, and perpetuate misconceptions that associate computing with 'cleverness', a subject 'for boys' or 'geniuses', and more geared towards the perceived innate talents of these students. Recent research suggests such stereotypes can impede participation in computing [10].

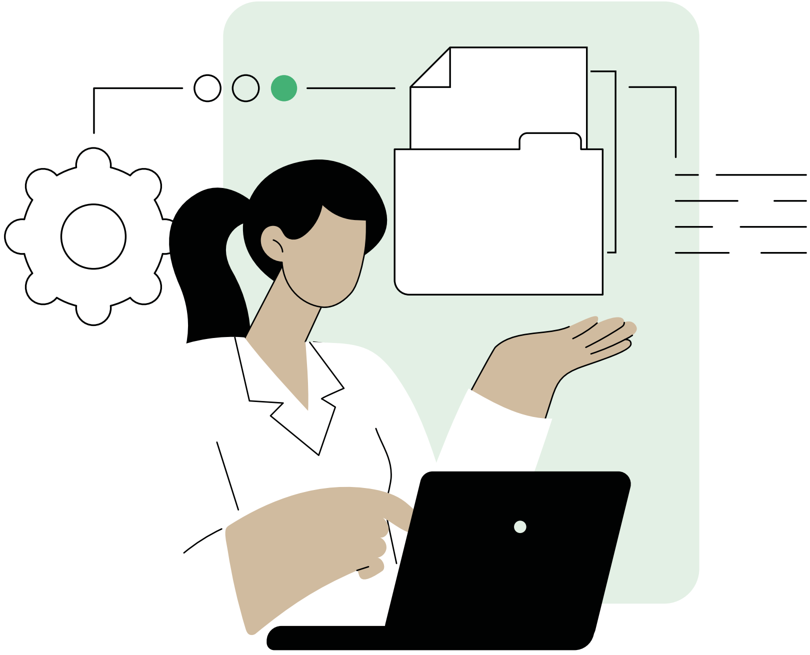
A teacher in a school with higher representation of girls in GCSE Computer Science also stressed the importance of introducing computer science concepts in Years 7 or 8, before students are thought to develop preconceptions about the subject, which tend to be more powerful as they get older and decide their options choices.

“I wish I was naturally good at it. Because I know some of my friends, they don’t really have to ... revise really hard and stuff, and that’s really admirable ... I wish I had the willpower to sit and focus ... my friend has a tutor for computer science, he spends a lot of time doing it. So that’s one thing I wish I like had”.

GCSE Computer Science student, girl, year 10

“When [students] are in Year 7 and 8, there is [are] not yet any preconceptions that computer science is for boys only, and it’s easier to get them interested there, and ... we introduced programming early enough for those reasons as well ... students in Year 7 and 8 ... respond a bit better, whereas it would be trickier to introduce that in Year 9 or 10”.

Computing teacher in a school with high participation of girls



GENDER INCLUSIVE PRACTICES TO SUPPORT SELF-BELIEFS IN THE COMPUTING CLASSROOM

Teachers and school leaders in schools that have engaged higher numbers of girls in GCSE Computer Science suggested a combination of gender inclusive practices and strategies to support the self-beliefs of students in the computing classroom (Table 1).

TABLE 1: Strategies to support the self-beliefs of students in the computing classroom, as identified from interviews with computing teachers [25].

Achievable tasks and positive feedback	Recognise the strengths, potentials and achievements of learners, such as setting achievable tasks and communicating positive feedback to highlight progress.
Balanced learning approaches	Find a balance between independent and collaborative learning during lessons.
Gender-inclusive resources and activities	Adapt learning resources and activities to be gender-inclusive and include real-life scenarios that are relatable to young people, especially underrepresented groups.
Active dialogue and safe environment	Engage learners in active dialogue and feedback, and adapt collaborative tasks so young people feel safe to contribute to discussions.
Pastoral care	Support students with pastoral care to develop their self-beliefs in computing, such as personalised support, regular feedback and acknowledgement, and positive reinforcement in computing contexts.

WHOLE-SCHOOL INCLUSIVE POLICIES TO IMPROVE EQUITY IN COMPUTING EDUCATION

Interviews conducted with computing teachers and senior leaders revealed that four out of the five schools which had achieved a greater success in increasing the number of girls taking GCSE Computer Science typically had effective, school-wide EDI policies. Additionally, these schools tended to have senior leaders and colleagues in other subject areas who possessed a deep understanding of and appreciation for computing. In these schools, teachers exhibited holistic approaches to promoting gender inclusivity in computing education. Specifically, these schools tended to have resources highlighting their EDI initiatives, policies and resources to challenge gender stereotypes, such as webpages, presentation slides and newsletters.

> **“Our ethos as a school is “belief, belong, care” ... which ties very much into our equality, inclusivity, diversity ... We do a lot of work with the students around it... we think that we’re probably further along the journey than some other schools in embracing ... these issues. We have a gender-neutral uniform as well”.**
>
> **Senior Leader in a school with high participation of girls**

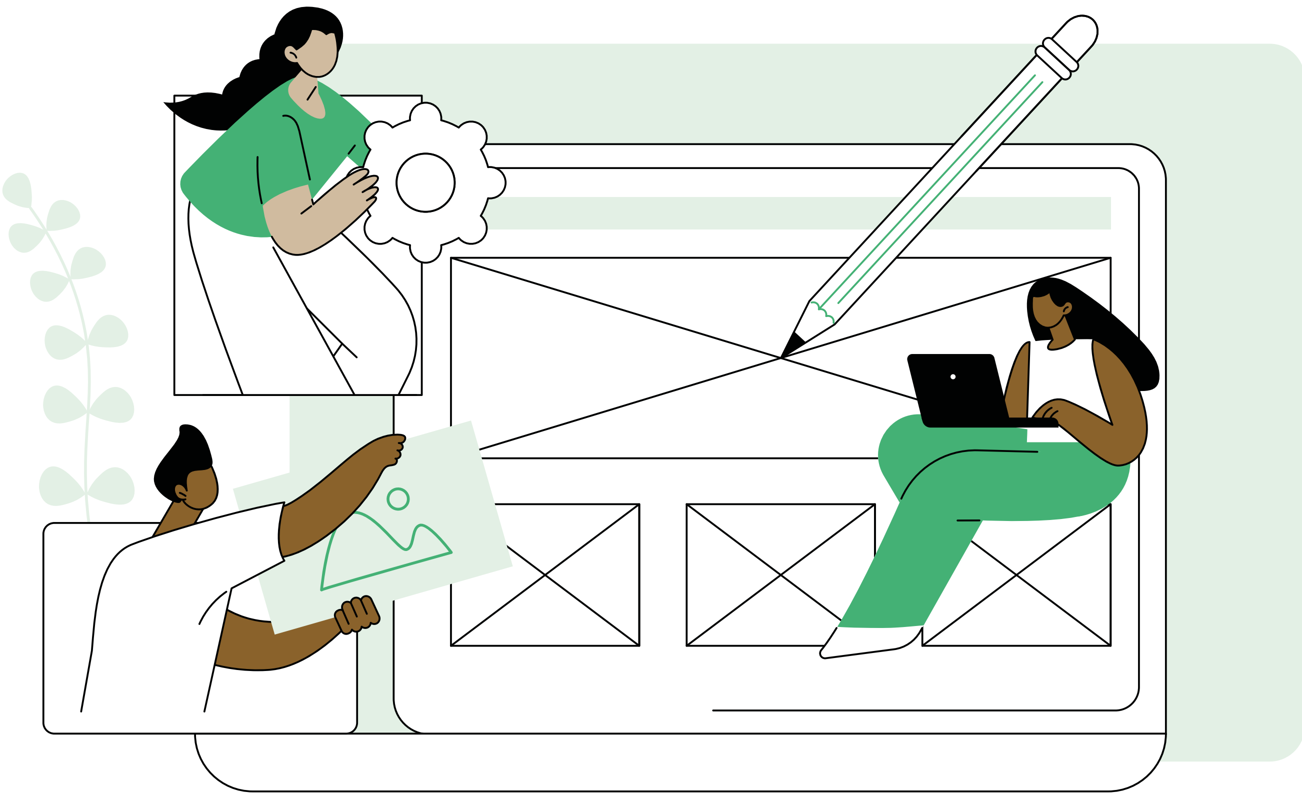
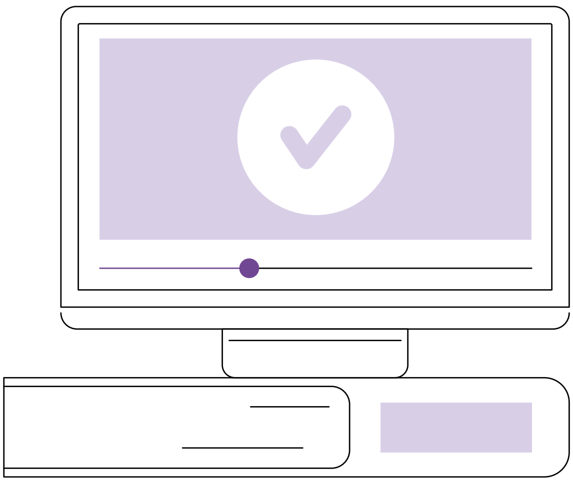


TABLE 2: Summary of school-wide EDI policies from a school with high participation of girls.

Policy	Adapt policies and communications with the school community to promote EDI and different opportunities for underrepresented groups.
Pastoral	Counter stereotypes and sociocultural norms, such as providing students with support networks and improving visibility of underrepresented groups.
Curriculum design	Adapt the curriculum to respond to student diversity, 'tell different stories' and acknowledge knowledges and contributions of underrepresented groups to challenge stereotypes.
Micro	Showcase role models and achievements in departments, including posters and visual aids, to promote the achievements of people with diverse gender identities, ethnicities and backgrounds.
Pastoral care	Support students with pastoral care to develop their self-beliefs in computing, such as personalised support, regular feedback and acknowledgement, and positive reinforcement in computing contexts.

A senior leader in a school with a high participation of girls described their school-wide EDI policy across multiple dimensions and levels, as summarised in Table 2 above.



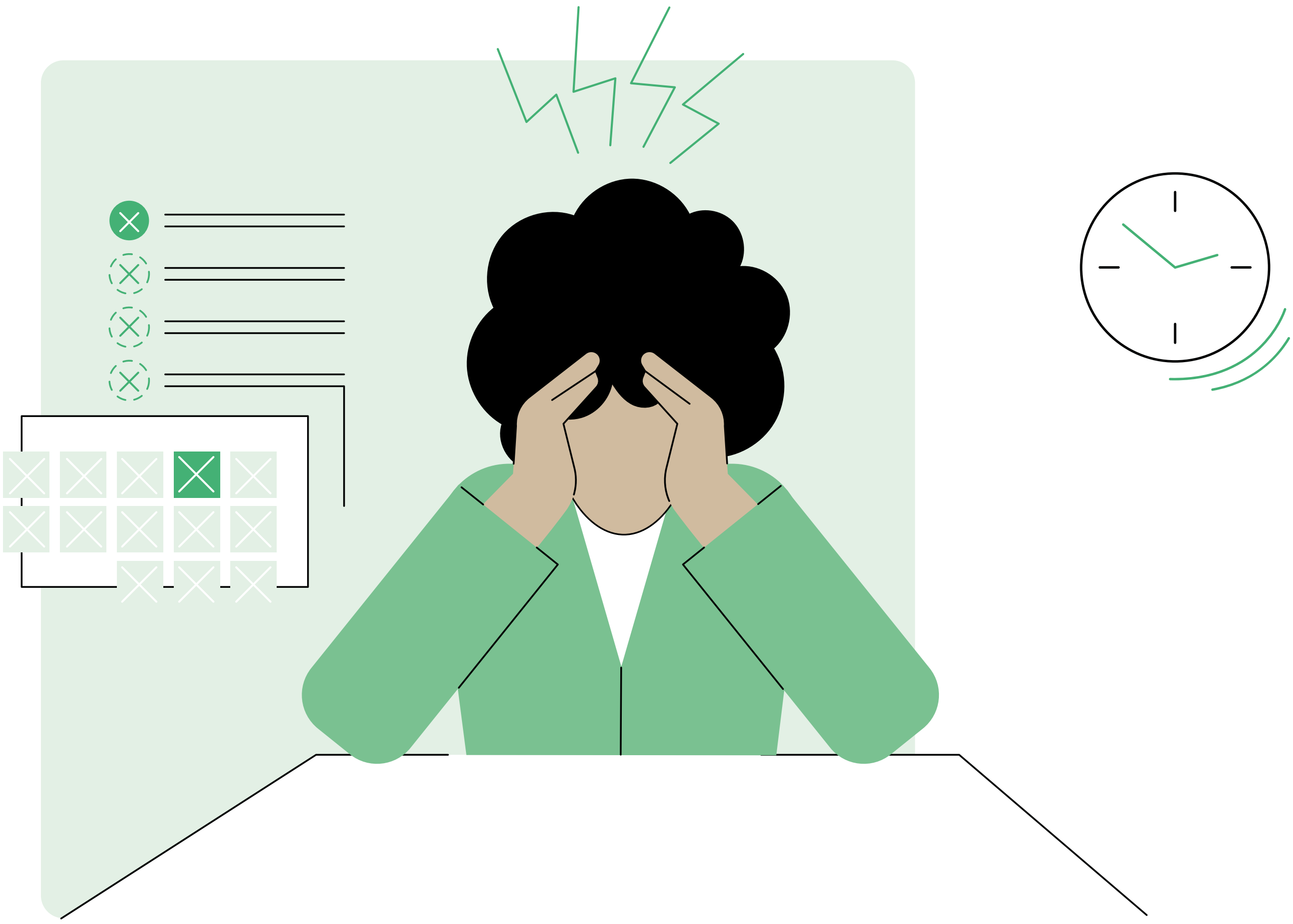
Schools with a greater uptake of girls described challenging gender discrimination in computing contexts through broader school-wide strategies, demonstrating the social importance of a computing education. This includes year-group assemblies, values days and student campaigns, incorporating topics such as online allyship, identifying misinformation, supporting local communities, and keeping each other safe. Teachers also described tailoring inclusive strategies to computing contexts, such as positive postcards home and appointing girls as student leaders.

Schools with higher numbers of girls participating in GCSE Computer Science demonstrated a combination of inclusive policies and practices, that aim to improve attitudes towards gender diversity in computing education. These schools tend to frame computing as an inclusive subject that is accessible and achievable for all students, especially girls.

Elsewhere, concerns have been raised about the impact of Key Stage 4 'option blocks' on girls choosing to take GCSE Computer Science. For example, schools might ask students to select only one GCSE from an option block of computer science and three other subjects [34]. Some teachers raised concerns about this during interviews (*n* = 5/15):

> **"Computing competes with ... Religious Studies, Drama, Art, Music ... So, it's ... the more creative subjects we were put with".**
>
> **Computing Teacher in a school with a high participation of girls**

Additionally, the student survey found that timetabling issues were given by 22 % of girls and 24 % of boys, as a reason for not taking the GCSE. Overall, there was no statistical difference between the genders. Whilst timetabling issues appear to influence student uptake of GCSE Computer Science, they do so to a smaller extent compared to other reasons given for subject choice.



4

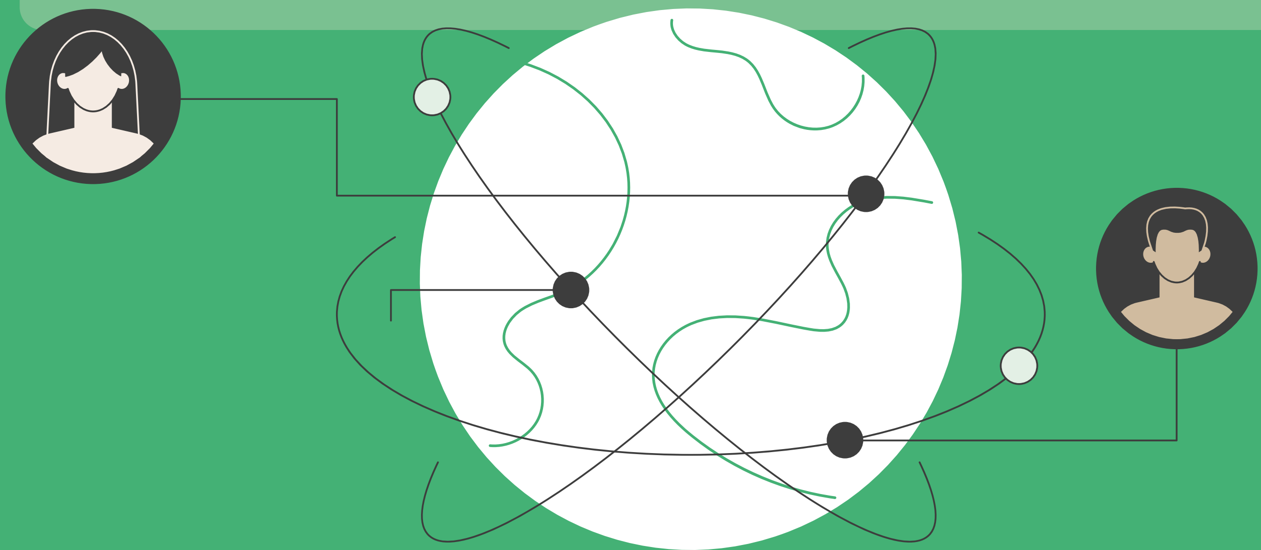
REFRAME THE COMPUTING NARRATIVE

LOCAL AND NATIONAL LONG-TERM INITIATIVES TO DISMANTLE TRADITIONAL NARRATIVES IN COMPUTING.

RECOMMENDATIONS

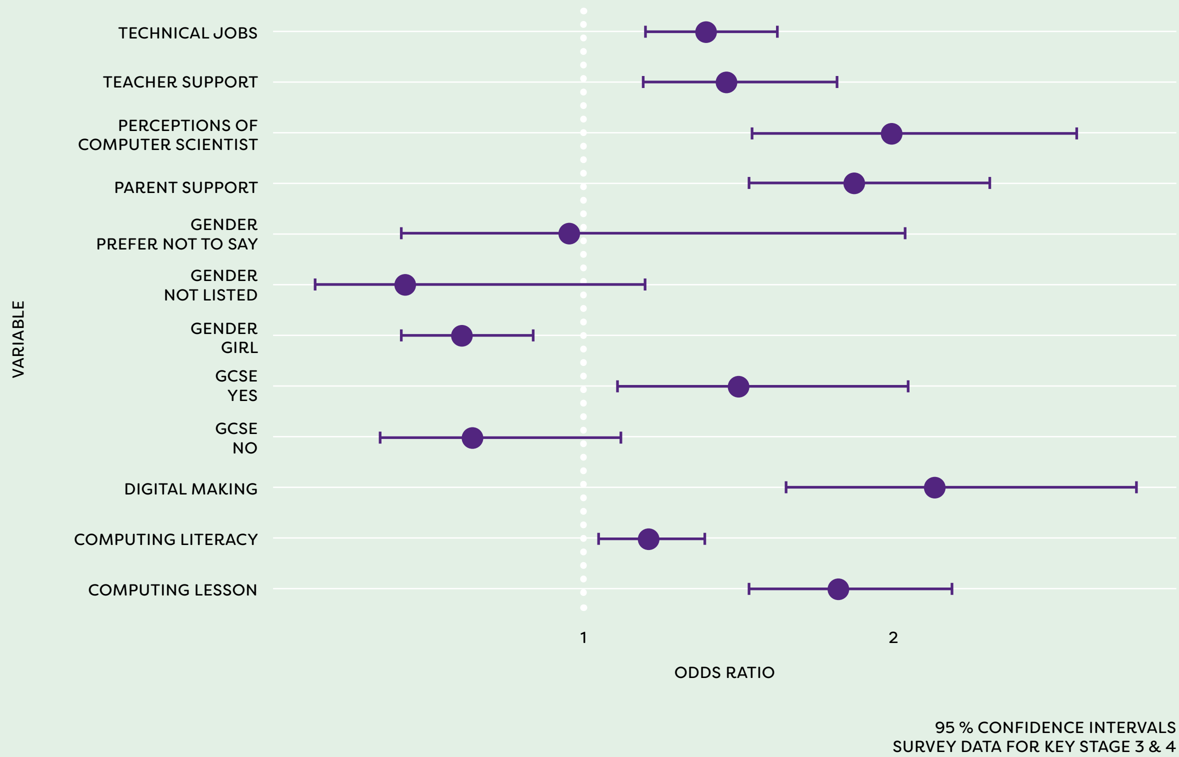
A Reframe narratives surrounding computing: Employers and organisations to share narratives of those working in computing that encompass a broader spectrum of individuals, especially those working for social good, beyond tech entrepreneurs and historical figures.

B Launch a sustainable national campaign: A campaign aimed at showcasing diverse role models in computing, highlighting a variety of traits and skills beyond traditional stereotypes, especially relatable and contemporary role models, such as alumni and community members.



Our research has highlighted the role stereotypes play in creating barriers that deter young people from underrepresented groups from pursuing careers in computing, which has implications for computing curriculum design, classroom practice and wider society. Our student survey of almost 5,000 young people found that having a negative and stereotypical view of computer scientists made young people 39 % less likely to want to be a computer scientist. These stereotypes include perceiving computer science as predominantly for 'highly intelligent but socially awkward individuals. However, positive perceptions of computer scientists and the recognition of the value of computing to society are associated with a young person having positive self-beliefs in their coding ability – which in turn increases the odds of continuation in the subject [27].

FIGURE 7: Variables associated with having positive coding attitudes from multiple logistic regression analysis. Bars show 95 % confidence intervals. Students *n* = 1,949. Reference level for gender is boys and reference level for GCSE is those students who have not yet chosen, i.e. those in Key Stage 3. All variables, except Gender: not listed / prefer not to say and students not taking GCSE Computer Science are statistically significant $P < .05$. Bars indicate 95 % confidence intervals See Annex 3 for description of variables.

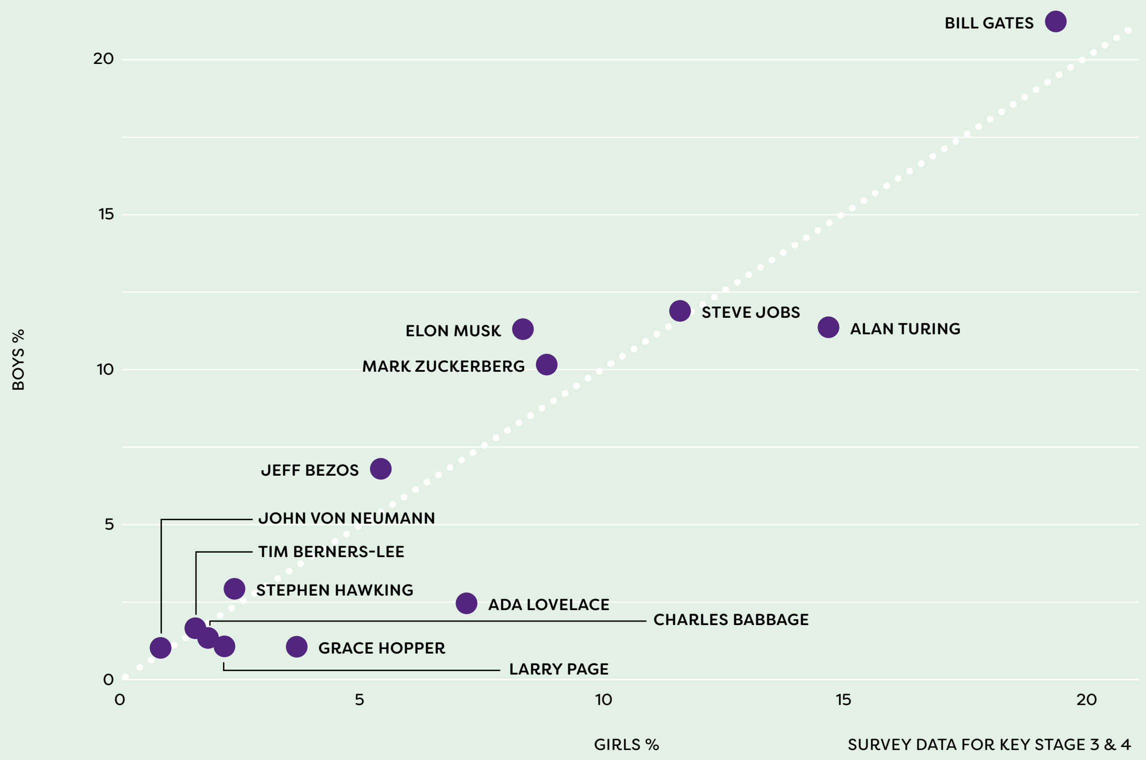


THE CONTEMPORARY COMPUTING NARRATIVE

Amongst those surveyed, the brainy stereotype emerged as the most pervasive perception associated with computer scientists, with 67 % of young people in agreement, showing no significant difference between genders. Girls were significantly more likely to agree that computer scientists are men (39 %) compared to boys (32 %). While the association of computer scientists with masculinity is observed more amongst girls, the brainy stereotype remains predominant across genders, potentially excluding individuals who do not identify with this narrow characterisation. Furthermore, our analysis revealed that students pursuing GCSE Computer Science or aspiring to computing careers were significantly more likely to perceive themselves as more 'academic' and 'independent' than their counterparts who did not choose the subject. According to respondents, the ideal student in computer science is predominantly perceived as smart and clever, constituting 35 % of all mentions (n = 2,606). However, our data also indicates a wide range of desirable characteristics in computing, including being knowledgeable and interested (19 %), determined and hardworking (18 %), kind and helpful (12 %), creative (5 %), independent (5 %), confident (3 %), and collaborative (3 %) [35]. This recognition of diverse attributes beyond mere academic prowess is promising, indicating a more inclusive understanding of who can excel in computing disciplines.

FIGURE 8: Top 10 famous faces of computing according to students:
Top row (L-R) Bill Gates*, Alan Turing, Steve Jobs*, Elon Musk*, Mark Zuckerberg*
Bottom row (L-R), Jeff Bezos*, Ada Lovelace, Stephen Hawking, Grace Hopper, Charles Babbage (*the Big 5). Image sources on page 66.

FIGURE 9: The famous faces in computing for students who completed our survey. Boy *n*=1,108; Girl *n*=578



THE FAMOUS FACES OF COMPUTING

> **“I think the most important thing is that we have a selection of role models that everybody can see themselves in ... we’ve tried to not go for the big five”.**
>
> **Computing secondary school teacher**

From our student survey, we found that when students were asked to name three famous computing people, white male tech entrepreneurs, the “Big 5”, were amongst the most common figures mentioned. Furthermore, girls were three times more likely to name a famous female figure in computing compared to boys. It is especially concerning that all the contemporary famous faces of computing are tech entrepreneurs, with the high-ranking women on the list, Grace Hopper and Ada Lovelace, long since deceased.

These findings suggest a need for policies that counter these stereotypes, celebrate the success of diverse people and expand access to computing education for underrepresented groups. In particular, the lack of diversity amongst famous figures in computing, particularly the underrepresentation of women from minority ethnic backgrounds, and inventors who are not entrepreneurs, underscores the need for curriculum reform that promotes greater inclusivity and representation [36]. Furthermore, the narrative surrounding computing needs to be broadened beyond the spotlight on tech entrepreneurs, to highlight the invaluable contributions of diverse computing people in all fields tackling pressing local and global challenges such as sustainability, the impact of artificial intelligence and freedom to information. Given that difference in career aspirations is one of the main reasons given by girls for not choosing the GCSE, a wider range of role models from different disciplines are needed.

STRATEGIES TO COUNTER STEREOTYPES IN COMPUTING

Drawing on interviews with teachers and school leaders, and analysis of school documents, wall displays and websites, we found the following strategies described in Table 3 were used by schools involved in this project to counter stereotypes in computing education.

TABLE 3: Strategies identified from interviews with teachers and students that attempt to counter stereotypes in computing. Examples of comments made by interviewees also included.

Improve visibilities of relatable role models in computing, to demonstrate different career paths and support student belonging. This includes greater representations of school alumni who have progressed to post-16 computing or careers, such as on school wall displays, and inviting school alumni to give talks and share their experiences with students.	**"We've got pictures of ex-students up on the wall … with 'I'm a computer scientist', 'I'm an engineer', and we've got all these different faces … the most important thing is that we have a selection of role models that everybody can see themselves in, and that there is somebody who looks like you or talks like you or has an opinion like you that you can relate to."** Computing teacher in a school with high participation of girls in GCSE Computer Science
Support students in accessing opportunities to meet and engage with relatable role models to improve how they perceive and identify with the subject. The focus on relatability may encourage more girls to develop an intelligible identity in computing and explore the range of opportunities linked to a computing education.	**When I went to the university for work experience to do computer science. There was a girl who was one of the students who are helping people out … I think she won some sort of award because I was looking on the Twitter of the university … So, seeing her made me feel like, you know, maybe it is possible."** GCSE Computer Science student, girl, year 9

Regularly **acknowledge the contributions of women** in computing to counter masculine associations and stereotypes. This includes increased visual representations of women on classroom wall displays, and resources depicting women in computing careers on the school website.	**"On our careers page ... I deliberately use videos and images of women ... in computing ... of different cultures and backgrounds, ... ages, and doing different things ... in cybersecurity ... women in technology and medicine ... so the images they receive are not all men."** Computing teacher in a school with a high participation of girls
Adapt lesson plans and learning materials to **mitigate competitive cultures,** such as in gaming contexts, to challenge stereotypes and masculine cultures, and ensure the safety of girls in the classroom.	**"I think a lot of the boys do gaming and I think the girls do as well. But I do think probably more boys do, and I think they're more vocal about it and they're quite competitive ... girls can be a bit intimidated by that."** Computing teacher in a school with a high participation of girls

These strategies support a more inclusive and supportive environment in computing education. By increasing the visibility of relatable role models, particularly through school alumni and women in computing, and by adapting learning materials to foster a safer and more welcoming atmosphere, schools can effectively counteract stereotypes and encourage more girls to pursue computing. These efforts may help students to see themselves in computing roles, thereby broadening their career aspirations and promoting greater diversity in the field.

5

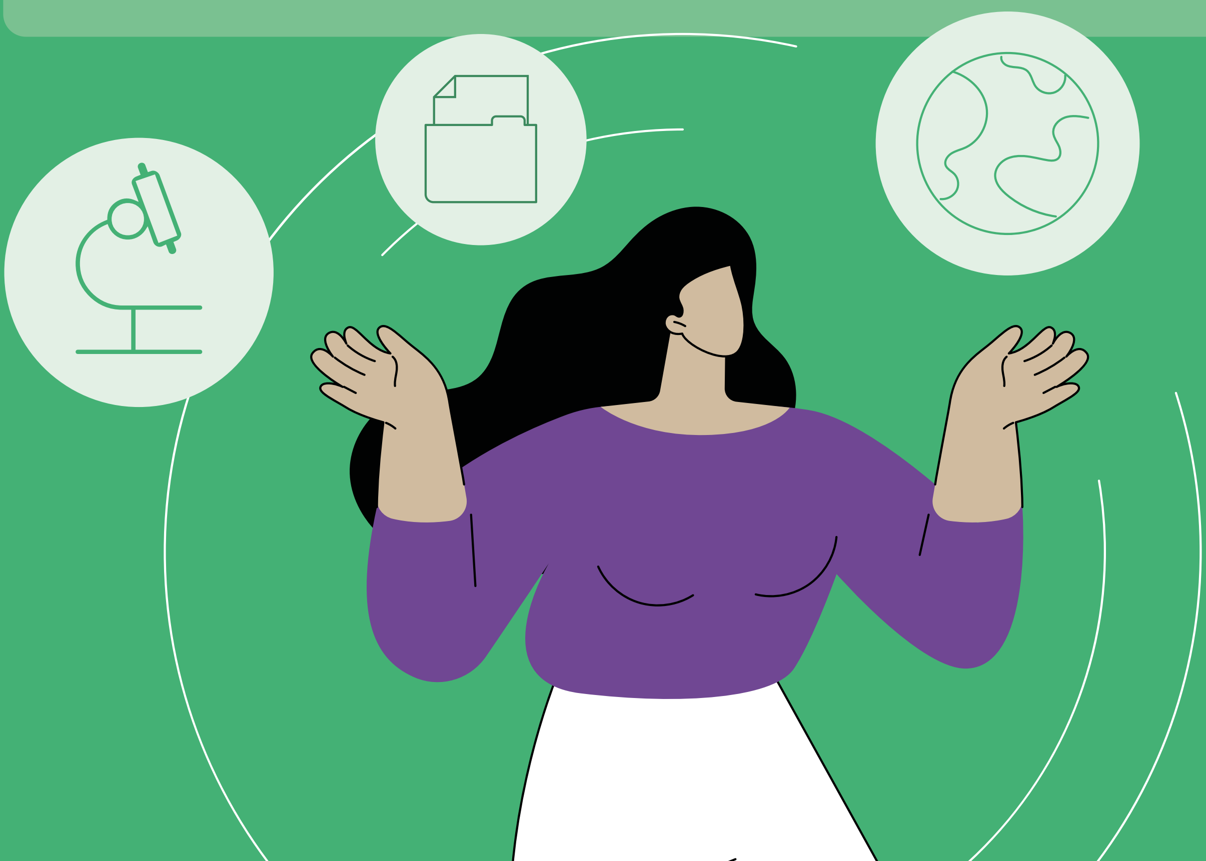
SHOWCASE DIVERSE DIGITAL OPPORTUNITIES

OPENING DOORS TO OPPORTUNITIES AND JOBS THAT USE COMPUTING SKILLS.

RECOMMENDATIONS

A **Improve subject-specific career guidance:** Ensure young people and their families and teachers have access to and understand the importance of computing education for a diversity of opportunities in computing and beyond.

B **Improve access to experiences of the workplace:** Enhance collaboration between employers (especially within the STEM sectors) and schools so that all young people have meaningful experiences of the workplace.

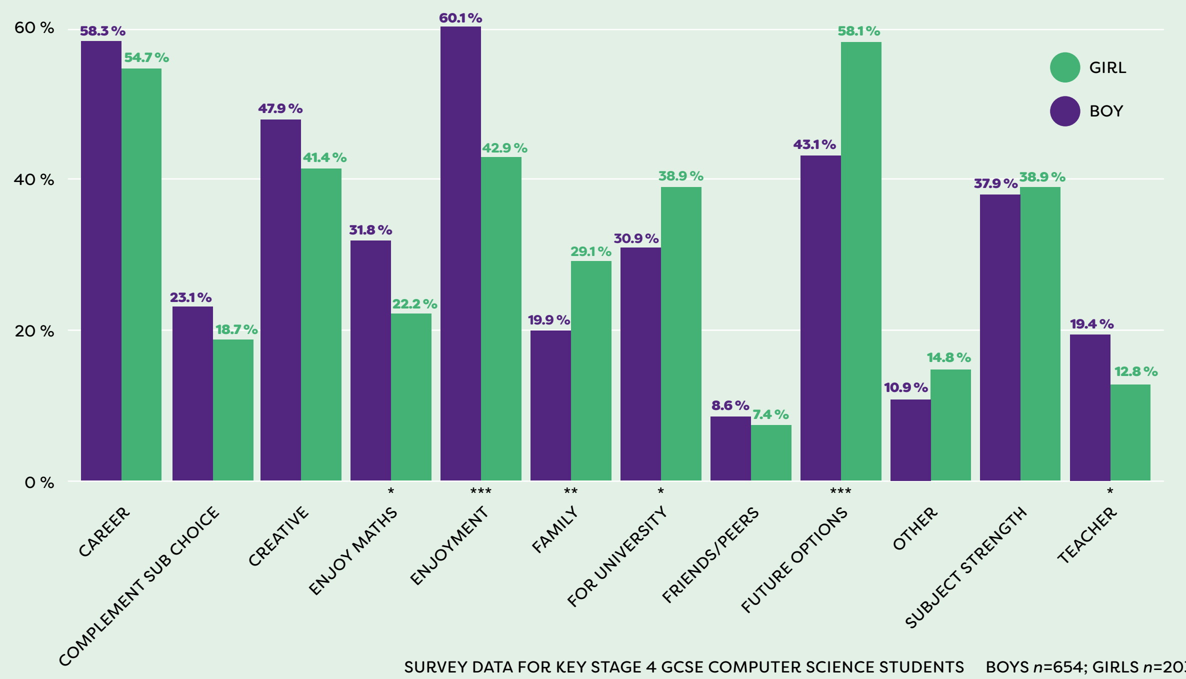


Our research found that aspirations to work in computing are associated with factors such as gender, ethnicity, parental influence, teacher support and coding confidence. Career aspirations heavily influence student decisions about taking the GCSE, with girls more likely to say the course will keep their future options open. Our interviews with girls who are taking computer science indicates many appear to have knowledge of a wide range of careers related to the subject (n = 8/10). The promotion of diverse computing careers was a key part of curricula in schools with a higher uptake of girls and was present in communications with parents in these providers. However, even girls taking GCSE Computer Science are 42 % less likely to aspire to be a computer scientist compared to boys [28].

NOT JUST A COMPUTER SCIENTIST: THE IMPORTANCE OF SUBJECT-SPECIFIC CAREERS GUIDANCE

Young people choose GCSE Computer Science for a variety of reasons and career aspirations is a significant motivator, with no significant difference between girls (55 %) and boys (58 %). Notably, girls were significantly more likely to say that choosing GCSE Computer Science kept their career options open (58 %, compared to 43 % of boys), while boys were more likely to choose it because they enjoy it (60 %, compared to 43 % of girls). Similarly, amongst those students who had chosen not to take the GCSE, 56 % of girls stated that Computer Science does not fit in with their

FIGURE 10: Reasons for choosing GCSE Computer Science by gender. Statistical significance *** $P < .001$, ** $P < .01$, * $P < .05$.



SURVEY DATA FOR KEY STAGE 4 GCSE COMPUTER SCIENCE STUDENTS BOYS n=654; GIRLS n=203 career aspirations, significantly higher than the 39 % of boys who gave that response. The top 5 subjects identified by young people (regardless of gender) as being “useful for getting a good job” were: Mathematics, English, Science, Computer Science and Modern Foreign Languages.

The survey found that parents and carers valuing jobs in computing was associated with a 61 % increase in their child aspiring to work as a computer scientist. Furthermore, young people feeling like they belong in the computing classroom was associated with a 53 % increase in aspiration to be a computer scientist. This suggests that equipping teachers and families with knowledge about digital job opportunities and the importance of digital skills can empower them to provide meaningful

> **“I’m very interested in like, backstage theatre. And sort of lighting and sound area of that. So, I think computing definitely helps me in that area”.**
>
> **Year 10 girl studying GCSE Computer Science**

guidance and support young people as they explore their career options.

Those aspiring to be computer scientists were significantly more likely to consider themselves to be academic, modest, cooperative, independent, and determined. Additionally, aspirations for other technical jobs, such as becoming a network engineer or electrician, are significantly higher amongst students with more positive attitudes towards their coding abilities. However, our data reveals a gender disparity in coding attitude, with girls overall having a significantly less positive attitude towards

FIGURE 11: A collage of school documents showcasing diverse digital opportunities in schools with high participations of girls in GCSE Computer Science.

coding than boys, regardless of whether they have chosen GCSE Computer Science.

In our survey, boys were found to be more likely to aspire to a wider range of jobs in computing than girls, the only digital job that girls were more likely to aspire to was digital art [28]. Our interviews with girls taking GCSE Computer Science indicate aspirations spanning diverse sectors, recognising the versatile skills the subject develops in computing. To address this, we must ensure that young people, their families, and educators are aware of the breadth of opportunities stemming from choosing computing.

Our analysis of school documents including curriculum maps, newsletters and careers information pages on school websites found schools with a higher proportion of girls in GCSE Computer Science included clear links between the skills developed through Key Stage 3 computing and GCSE Computer Science. This included a range of computing topics and careers that may appeal to a more diverse range of students (Figure 11 and Annex 4). Skills such as problem solving, critical thinking, creativity and teamwork, and linking these to careers such as software development, graphics design, cybersecurity, game development and AI were emphasised. Additionally, these schools appeared to showcase diverse digital opportunities through extracurricular provision, including coding and animation clubs, university visits and inviting relatable role models in computing to speak to students about their experiences.


January 2022 Newsletter

[redacted] Computing Celebrations

Back in October some brave students chose to enter a national scratch coding competition. We are delighted to announce that for a second year running a student from [redacted] has been chosen as a winner. A very big well done to [redacted] for her impressive entry – we hope you enjoy your Divoom Pixoo Max.

They have recently been learning about the concept of Dancheong in Korea and produce their own artistic creations following the guidance.

Design Your OWN: Haunted House

Emerging technologies

Online Kindness

Being brave, strong and kind is equally important online as in

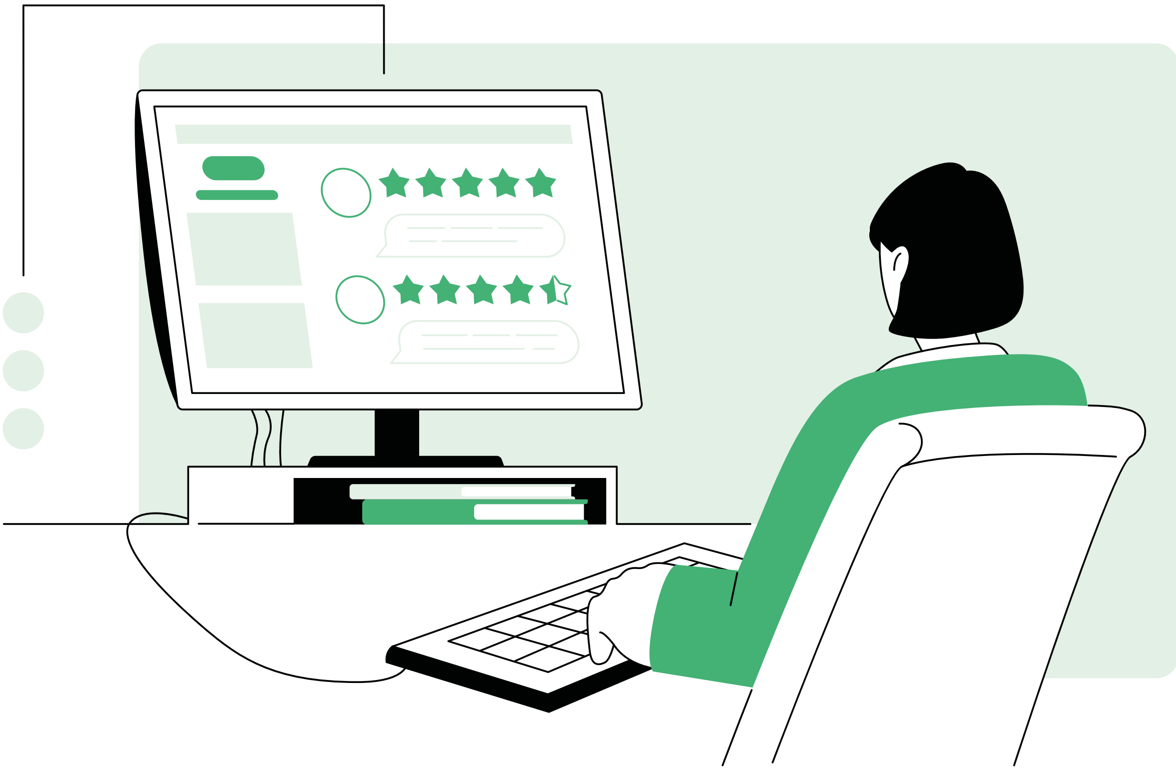
> **"She's got no experience of those sorts of professions ... because we couldn't find anywhere that would give her that suitable experience".**
>
> **Parent of student taking GCSE Computer Science**

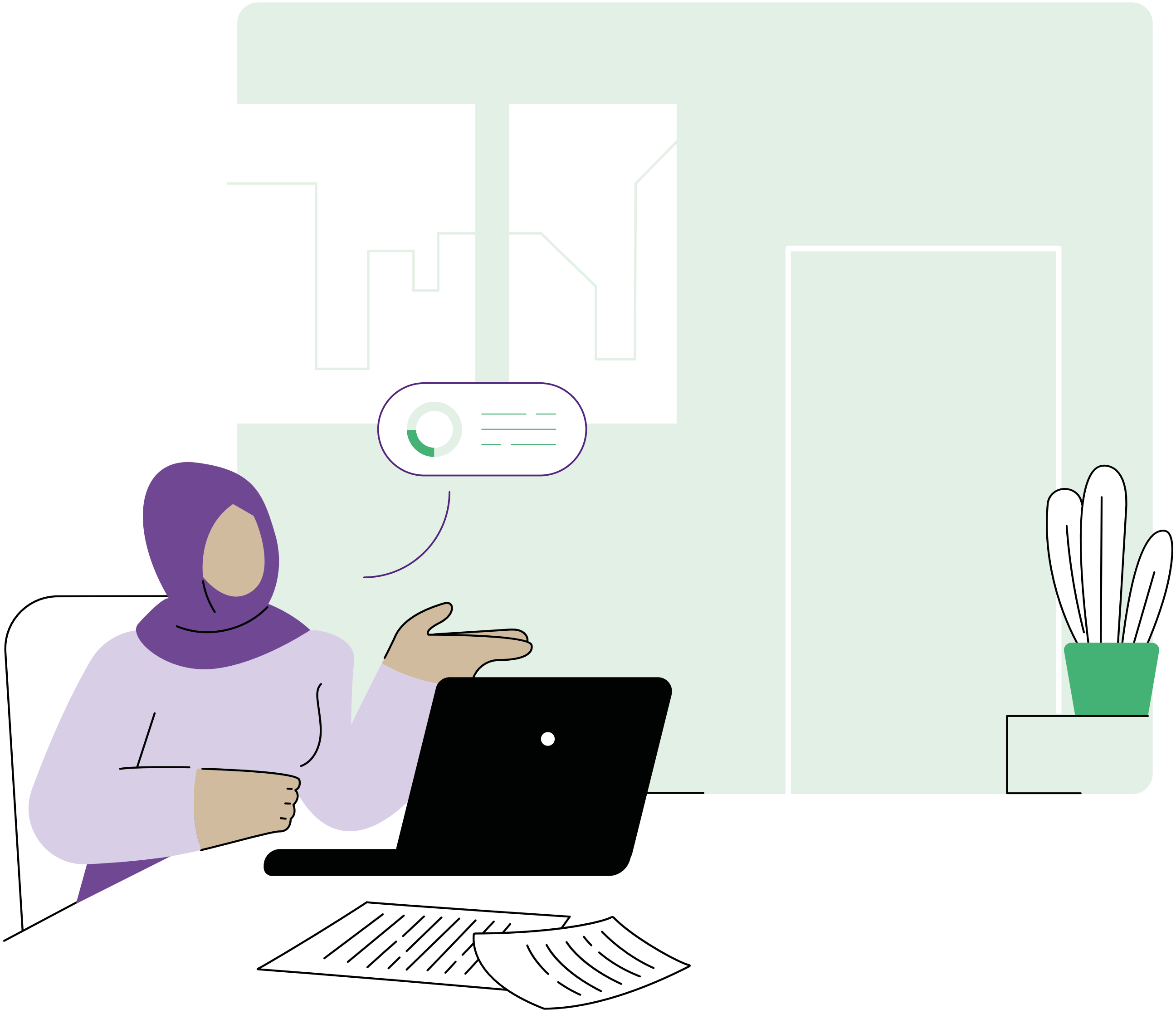
It is essential to convey that many jobs utilise the skills developed in computing, not just within the tech sector. This comprehensive understanding can be an enabler for young people to explore diverse career paths and foster greater inclusivity in the field of computing.

FOSTERING COLLABORATION BETWEEN EMPLOYERS, SCHOOLS AND THE FAMILY TO ENSURE EQUITY OF ACCESS TO WORKPLACE EXPERIENCES

The influence of family in subject choice and career advice is well recognised [19]. Our interviews with parents also highlighted this, with parents of young people studying GCSE Computer Science believing that it would provide their child with a competitive edge in the workplace (n = 4/8). Although, while young people often discuss their options with their parents or carers, older siblings working or studying in computing also seemed to have an influence (n = 2/8).

Enhancing collaboration between schools and employers is key to ensuring that young people have equitable access to work experience opportunities. A recurring theme in our interviews was the challenge some parents face in supporting their child to find meaningful exposure to the workplace. Families with connections in the computing or tech sector had greater capacity to help their children access valuable work experience opportunities. Whilst the onus should not be on parents to find these opportunities, this "Computing





Capital" can shape whether young people can benefit from such opportunities. Exposure to these opportunities could potentially pave the way for a career in computing, as inequities in access are likely to be linked to broader structural inequalities in society [37]. Student perceptions of computing careers play a pivotal role in shaping their educational choices and aspirations. Strengthening collaboration amongst schools, employers and families is crucial for improving access to valuable work experience opportunities for young people from a diverse range of backgrounds.

Enhancing collaboration between schools and employers is key to ensuring that young people have equitable access to work experience opportunities.

6

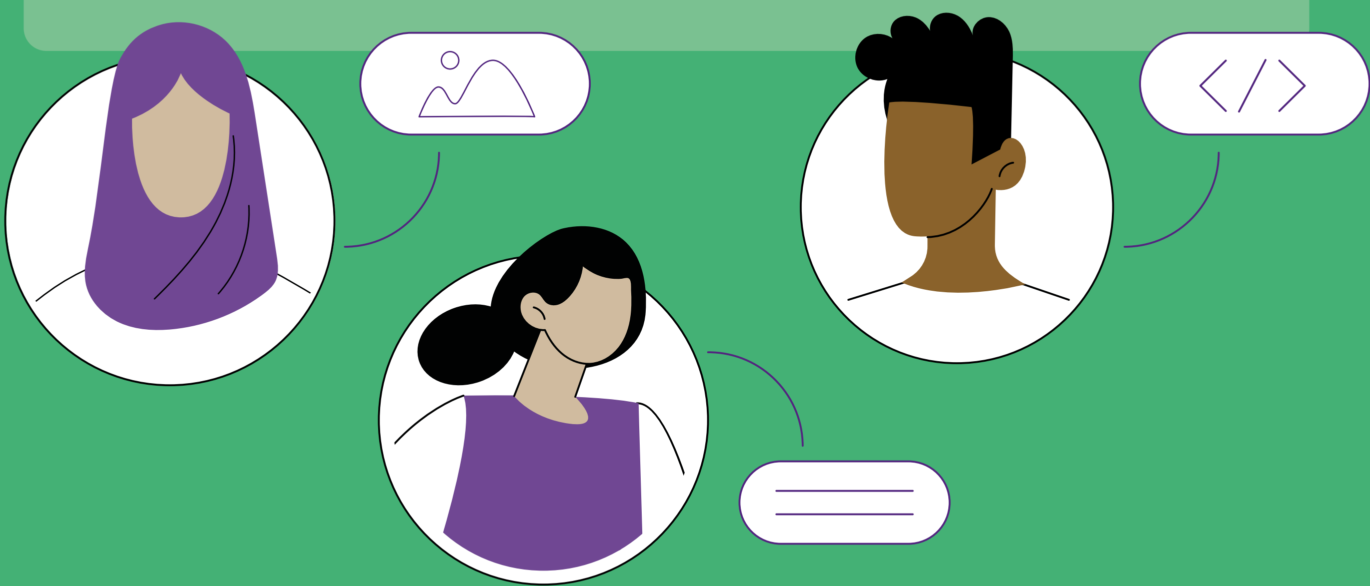
INCREASE ACCESS TO INFORMAL DIGITAL MAKING

IMPROVE SUPPORT FOR FAMILIES AND SCHOOLS TO ENSURE EQUITY OF ACCESS TO INFORMAL LEARNING OPPORTUNITIES.

RECOMMENDATIONS

A **Inclusive informal learning spaces:** Ensure access to informal learning spaces across the education system are supportive and inclusive for all young people, and include a broad range of activities such as project work, digital media activities and programming.

B **Coordinated efforts to ensure equity of access:** Schools and organisations recognise the challenges, and work with teachers and families to ensure equity of access to digital devices and extracurricular activities that encourage digital making, using free and open-source resources where possible.



Schools with a high participation of girls described having a diverse range of extracurricular digital making opportunities that matched student interests. Additionally, the digital making composite variable (Figure 6) was associated with girls taking GCSE Computer Science, but not for boys.

However, while computing in informal settings such as clubs, events and the home offers invaluable opportunities for hands-on learning, skill development and potential for increasing the computing self-beliefs of young people, findings from previous research in this area has indicated limited impact [37, 38].

> **"There is a wealth of extracurricular clubs in computing ... robotics, Javascript, Python Club, Gaming Club ... it's about trying to...catch as many people in your net as possible. When she's got them, they do keep coming back. So, offering something for everybody would be another piece of advice that I'd offer to other schools trying to grow their computer science provision".**
>
> **Senior leader in a school with high participation of girls**

SCHOOLS THAT OFFER EQUITABLE OPPORTUNITIES FOR INFORMAL LEARNING HAVE A BETTER UPTAKE OF COMPUTING BY GIRLS

The teachers and school leaders interviewed in our research emphasised the significance of extracurricular provision in fostering relationships with students and promoting an inclusive computing curriculum. All five schools with a high uptake of computing by girls offered a range of extracurricular clubs in computing, from robotics to gaming, aimed at engaging diverse interests. These activities were considered by teachers and senior leaders to be instrumental in attracting students and maintaining their participation, contributing to the overall growth of computer science provision in the school.

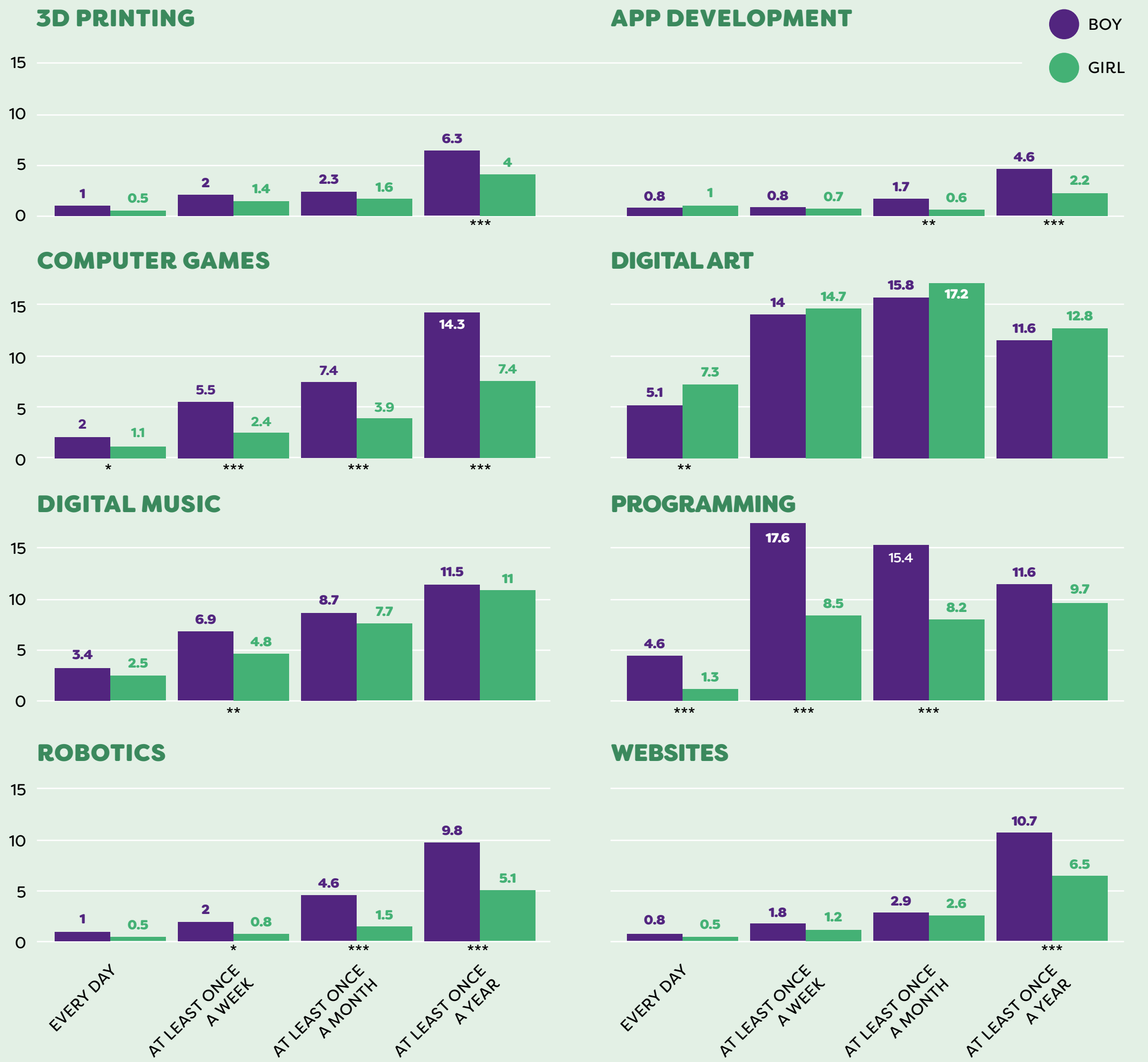
Teachers and school leaders in schools with a high participation of girls in GCSE Computer Science highlighted the importance of empowering students to take ownership of their learning direction during extracurricular activities. They encouraged students to express their preferences and interests, allowing these to shape the content of extracurricular activities. By tailoring to student needs and interests, they fostered a sense of agency and motivation. Additionally, teachers and school leaders in schools with a high uptake of computing by girls reported that student experiences and opportunities related to extracurricular computing activities were often publicly showcased, such as through social media platforms and newsletters. This includes information about employer outreach programmes, industry trips and university visits, thereby broadening students' and their families' awareness of computing career paths.

DIGITAL MAKING AT HOME

Digital making at home was associated with an almost three-fold increase in GCSE Computer Science uptake for girls, but not for boys (Figure 5). Our findings also found an association between the time a young person spends doing practical computing activities outside of school, such as building mobile apps or building websites, and how positive they feel in their ability to code [25].

When looking at a limited range of digital making activities, there are large gender differences in the types of activities that happen outside school contexts. Digital art was the only area of computing where girls were significantly more likely to be active every day than boys. Most concerning is programming and coding, given the importance of this area in the GCSE and curriculum, as boys were three and a half times more likely than girls to be doing this activity daily. Most students participated in one or more of these digital making activities outside of school at least once a year, with boys (74 %) significantly more likely to be doing so than girls (68 %).

FIGURE 12: Digital making activities in own time by gender %.
Boys *n*=1,039-2,394; Girls *n*=861-1,817. Statistical significance *** $P < .001$, ** $P < .01$, * $P < .05$



Activity	Frequency	Boy	Girl	Significance
3D Printing	Every day	1	0.5	
3D Printing	At least once a week	2	1.4	
3D Printing	At least once a month	2.3	1.6	
3D Printing	At least once a year	6.3	4	***
App Development	Every day	0.8	1	
App Development	At least once a week	0.8	0.7	
App Development	At least once a month	1.7	0.6	**
App Development	At least once a year	4.6	2.2	***
Computer Games	Every day	2	1.1	*
Computer Games	At least once a week	5.5	2.4	***
Computer Games	At least once a month	7.4	3.9	***
Computer Games	At least once a year	14.3	7.4	***
Digital Art	Every day	5.1	7.3	**
Digital Art	At least once a week	14	14.7	
Digital Art	At least once a month	15.8	17.2	
Digital Art	At least once a year	11.6	12.8	
Digital Music	Every day	3.4	2.5	
Digital Music	At least once a week	6.9	4.8	**
Digital Music	At least once a month	8.7	7.7	
Digital Music	At least once a year	11.5	11	
Programming	Every day	4.6	1.3	***
Programming	At least once a week	17.6	8.5	***
Programming	At least once a month	15.4	8.2	***
Programming	At least once a year	11.6	9.7	
Robotics	Every day	1	0.5	
Robotics	At least once a week	2	0.8	*
Robotics	At least once a month	4.6	1.5	***
Robotics	At least once a year	9.8	5.1	***
Websites	Every day	0.8	0.5	
Websites	At least once a week	1.8	1.2	
Websites	At least once a month	2.9	2.6	
Websites	At least once a year	10.7	6.5	***

SURVEY DATA FOR KEY STAGE 3 & 4 STUDENTS

> **"It was organised by [a national organisation] ... they did talks about how they got into technology and about their businesses. Students went round to each ... of these various women talking about their careers ... and they could ask questions. That was amazing. We had such good feedback from parents about that ... We have a local company to us ... they come in and do a Girls in Computing Day in Year Eight ... she came in, talked about her story, did things with them about micro bits and ... designing code ... There's not enough [of these opportunities]".**
>
> **Computing Teacher in a school with high participation of girls**

Our qualitative research indicates the importance of access to computing resources in informal settings, including opportunities to attend extracurricular computing events. Our interviews with teachers and school leaders indicated that this access depends on teacher capacity, and can be limited by staff shortages, as well as the resources available in the school, which are constrained by budget. Schools with closer proximity to organisation outreach programmes were also more likely to engage in these opportunities, such as through collaborations between schools and local employers. Given our sample likely represents the "best case scenario" in terms of computing resources (i.e., with schools equipped to have at least two GCSE Computer Science classes per year), access to school-based informal learning initiatives for young people is likely to be patchy at best.

> **"We have a computer science club on Mondays, which is more aimed at Key Stage three students. We also offer some ... coding opportunities .... But I wouldn't say there are as many as I'd ... like to do, but I think that's just to do with the amount of staff we've got. We're stretched quite thin, unfortunately".**
>
> **Computing Teacher in a comparison school**

Previous research shows that for numerous reasons, including economic, social and geographic, access to digital resources at home is not equitable.

Furthermore, 15 % of secondary age young people in the United Kingdom do not have access to a laptop or desktop at home, and 21 % do not have access to home broadband [40]. To counteract this, schools and educational systems must take proactive measures to ensure greater access and engagement for all students. This necessitates a multifaceted approach, including promoting community partnerships, providing subsidies or loan programmes for necessary equipment, and implementing culturally relevant curricula. Additionally, fostering collaboration between schools and families is crucial for tailoring initiatives to local needs and contexts, thus empowering students with the tools they need to thrive in an increasingly digital world.

CLOSING REMARKS

This report offers a comprehensive analysis of the current state of computing education in England, shedding light on both the challenges and opportunities inherent in the pursuit of a more inclusive and effective education system for young people. The findings underscore the critical importance of collaborative efforts to navigate the complexities and potentials of subject choice, attainment and representation of young people in computing education and wider society.

Moving forward, the implementation of the six recommendations outlined in this report necessitates a concerted commitment from policymakers, educators, employers and other relevant parties. This collective endeavour is essential to realise the overarching objective of empowering all young people with the digital skills to thrive in an increasingly technology-driven society, especially with the rapid development of AI in everyday life. By adopting measures aimed at broadening the computing curriculum, enriching professional development avenues for educators, challenging entrenched stereotypes, ensuring an inclusive computing classroom, highlighting the career opportunities and expanding access to informal digital learning, real progress can be made towards fostering a more equitable and diverse computing subject and workforce.

The journey towards a more inclusive computing education system demands a methodical and collaborative approach, grounded in empirical evidence and informed by best practice. By embracing this approach, we can aspire to create a future where every individual can leverage technology creatively and critically, and effectively contribute to society.

Peter Kemp
Billy Wong
Jessica Hamer
Meggie Copsey-Blake

AREAS FOR FURTHER RESEARCH

We have identified the following areas meriting further research:

- Comparing the relative difficulty of computing topics – pedagogies to address perceptions and experiences.
- Computing teacher recruitment, retention and career progression, especially in relation to accessing CPD.
- The inclusion of digital skills across other subject areas.
- Exploring family / home support with computing, including the role siblings play in subject choice.
- Better understanding of curriculum design and evaluation of individual computing topics.
- Examining the computing narratives being presented in school, focusing on how they go beyond discussions around business and industry.
- Identifying what schools, parents and carers, students, and employers, including those beyond tech firms, believe should be included in the computing curriculum.
- Understanding the learning pathways for students to access computing related degrees.
- The impact of computing in primary schools, both formal and informal learning.
- Exploring the perceptions and experiences of gender identity in computing.
- Better understanding the state of non-exam provision at Key Stage 4 and the effect on digital skills for the future.
- Researching the experiences in computing of students with special educational needs and disabilities.

ANNEX 1

GLOSSARY

Term	Meaning
Advanced-level (A-Level)	Academic qualifications typically taken by students in England aged 16 to 18.
British Computing Society (BCS)	A professional body and learned society that represents those working in the field of computing in the United Kingdom.
Comparison School	Schools with at least 2 classes per year entering the GCSE Computer Science qualification and exam cohorts with less than 30 % girls.
Computer science	The study of computers and computational systems, including their principles, theories, algorithms, programming languages, hardware, software, and applications. It encompasses both theoretical and practical aspects of computing, focusing on understanding how computers work and how they can be used to solve problems and perform tasks.
Computing at School (CAS)	CAS supports teachers in understanding and teaching computer science, offering hubs for collaboration and training. It advocates for computer science in the National Curriculum, and partners with government and educational institutions to promote its importance.
General Certificate in Secondary Education (GCSE)	An academic qualification awarded in a specified subject, generally taken by secondary school students aged 14-16. GCSEs cover a wide range of subjects, including computer science.
Information and Communications Technology GCSE (ICT GCSE)	The ICT GCSE was designed to provide students with a broad understanding of information technology and its applications, as well as practical skills in using ICT tools and systems effectively.

Term	Meaning
Key Stage 3 / 4 / 5	In the education systems of England, Wales, and Northern Ireland, the term "Key Stages" refers to specific phases of a child's education, each covering a range of school years. Typically, Key Stage 3 are aged 11-14, Key Stage 4 are aged 14-16 and Key Stage 5 are aged 16-18.
National Centre for Computing Education (NCCE)	The NCCE is a UK-based organisation established to support the teaching of computing in schools. It was founded in 2018 as part of the government's commitment to improve computing education and increase the number of young people studying computer science.
National Pupil Database (NPD)	The NPD is a collection of data maintained by the Department for Education (DfE) in the United Kingdom. It contains information on pupils attending schools and educational institutions.
Ofqual	The Office of Qualifications and Examinations Regulation. It is the non-ministerial government department responsible for regulating qualifications, exams, and assessments in England
School with high participation of girls	Schools with at least 2 classes per year entering the GCSE Computer Science qualification and with the cohorts having at least 30 % girls.
School Workforce Census (SWC)	The School Workforce Census is an annual data collection exercise conducted by the Department for Education (DfE) in the United Kingdom. It gathers information about the workforce in state schools and educational institutions across England.
Secondary school	In England, a secondary school is an educational institution that provides education to students typically between the ages of 11 and 16 or 18, depending on the structure of the school.

ANNEX 2

METHODOLOGY

The SCARI Computing project employed a mixed methodology to explore the main predictors of female participation in secondary school computing education, and how students' views and attitudes in school-level computing influence their choices. National data sets, including the School Workforce Census and National Pupil Database, were utilised to examine patterns in national-level data. Additionally, 15 co-educational, non-selective, state-funded schools in England offering GCSE Computer Science were selected as partner schools. While these partner schools were not representative of the national population, they reflect institutions demonstrating amongst the current "best scenario provision" of computer science uptake in England as they were amongst the few schools offering two classes of GCSE Computer Science. Moreover, five of these schools exhibited a higher-than-average proportion of girls enrolled in GCSE Computer Science (more than 30 %, the national average in 2023 was 21 %). The 10 other schools had at least two classes per year entering the GCSE Computer Science qualification and exam cohorts with less than 30 % girls, which we have called comparison schools.

STUDENT SURVEY

The student survey, conducted online between June 2021 and March 2022, involved 4,995 students in Years 7 to 11, which are those students aged 11 to 16 years (see [28] for the background characteristics of survey respondents). Drawing on extensive background literature, the survey comprised 244 items, with pre-validated scales and novel elements addressing pertinent aspects such as attitudes to computing, job aspirations and family support. Details of composite variables identified through exploratory factor analysis are described in Annex 3.

DOCUMENT ANALYSIS

Document analysis encompassed 960 items from 40 schools, including partner schools and 'average' schools (with an uptake of 18 % students in Years 10 and 11 choosing GCSE Computer Science). For a direct comparison between school groups, we lowered the requirements for schools with a high participation of girls to 25 % and over. Data were collected from various online sources such as school homepages, curriculum documents, and teacher resources, totalling 876 items from school webpages and 84 items directly from teachers. A thematic approach was employed to analyse the data, involving iterative coding and themes refinement.

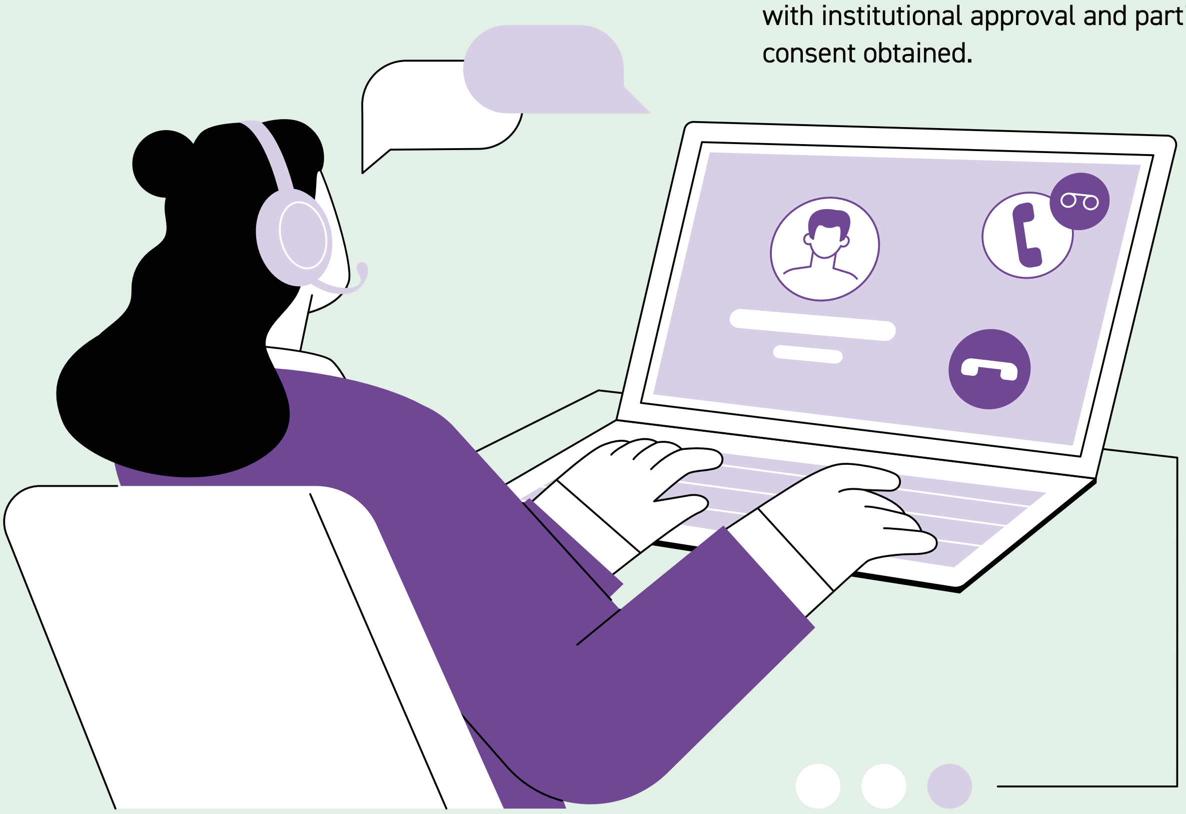
INTERVIEWS

In total, 45 semi-structured interviews were conducted. Teacher and school senior leader interviews consisted of online interviews lasting 45 minutes each, conducted between September 2021 and March 2022. These interviews, comprising 15 computing teachers and 12 senior leaders from partner schools, addressed various aspects of computing education, including perceptions of gender, equity, and career guidance. Additionally, 10 girls studying GCSE Computer Science and eight of their parents were also interviewed online.

NATIONAL DATA SETS

Parts of this work was produced using statistical data from the Office of National Statistics (ONS). The use of the ONS statistical data in this work does not imply the endorsement of the ONS in relation to the interpretation or analysis of the statistical data. This work uses research data sets which may not exactly reproduce National Statistics aggregates. Permission was obtained from the Department for Education to access the National Pupil Database and School Workforce Census; these datasets were analysed separately. Data spanning from 2010 to 2022 were utilised to analyse computing provision and outcomes over time, employing predictive models and regression analyses to explore factors influencing computing uptake and achievement. Additionally, open Department for Education datasets were used to create descriptive statistics on overall computing provision.

The methodology adhered to ethical guidelines, with institutional approval and participant consent obtained.



ANNEX 3

DEVELOPMENT OF COMPOSITE VARIABLES

Exploratory factor analysis of the student survey identified the following 12 composite variables. These were used for subsequent analysis, including in regression models.

Composite variable	Item
1) Teacher support	• My computing teacher listens to what students think. • My computing teacher believes that mistakes are OK as long as we are learning. • My computing teacher treats all students the same regardless of their computing ability. • I like my computing teacher. • My computing teacher is enthusiastic about computing. • My computing teacher is interested in me as a person.
2) Coding attitudes	• I want to use coding to be more creative in my future jobs. • I would like to use coding to make something new. • Using code will be important in my future jobs. • If I learn coding, then I can improve things that people use every day. • I am interested in what makes computer programs work.
3) Computing lesson	• I am good at computing. • I learn things quickly in computing lessons. • I am better at computing than my classmates. • I understand everything in computer lessons.
4) Perceptions of computer scientists	People who work in computer science • ....do valuable work. • ...make a difference. • ...are brainy. • ...make a lot of money. • ...have to be creative in their work. • ...are respected by people in this country.

5) Computing and society	• Computers make the world a better place. • Computers are a force for good. • Computers make the world a safer place. • Computers help to strengthen my relationships with others. • Computer companies or firms can be trusted.
6) Parent support	• My parents/carers would be happy if I became an IT professional in the future. • My parents/carers would be happy if I became a computer scientist in the future. • My parents/carers think computing or IT is interesting. • My parents/carers think it is important for me to learn computing or IT.
7) Stereotypes	People who work in computer science • ...are odd. • ...are geeks. • ...don't have many other interests. • ...spend most of their time working by themselves. • ...are usually men.
8) Digital making	In my spare time I • ... make websites. • ...make phone Apps. • ...make computer games. • ...3D printing. • ... digital music creation. • ... Programming/Coding.
9) Computing literacy	In my spare time I • .... read about computing or IT online. • ... read about computing or IT on social media. • ...read a book, magazine or newspaper about computing or IT.
10) Technical jobs	I would like to be an • ... engineer • ... electrician, plumber, builder, or in a trade • ... network engineer • ... tech entrepreneur
11) Creative jobs	I would like to be an... • ... artist, musician, actor or dancer, or in the arts • ... digital artist • ... designer
12) Professional jobs	I would like to be a • ... doctor • ... lawyer • ... other scientist

ANNEX 4

SCHOOL DOCUMENTATION

	Year 9 – Cycle A	Year 9 – Cycle B
What do we teach?	**What are computers?** How computers work and store data with a focus on data representation.	**Algorithms and Programming.** Recapping Algorithms and Python.
How does this meet the National curriculum?	This unit meets points 1 and 2 of the national curriculum's aims. Students recap the components of a computer, how data is represented and begin to learn simple Boolean logic with its uses in programming. They will carry out similar operations on binary numbers (points 4, 5 and 6 of KS3 NC content).	This unit meets point 1 one of the national curriculum's aims: students keep developing their understanding and application of fundamental principles of computer science, including logic and algorithms. Students continue to analyse, write and evaluate solutions to a range of problems (point 1, 2 and 3 of KS3 NC content).
Why does this knowledge matter?	This unit further recaps students' understanding on hardware and software (essential computer components). It has strong links with cross curricula subjects, especially mathematics and it prepares students well for the number unit covered at GCSE.	The European Commission urges people to learn coding and warns that a lack of coding skills could lead to Europe facing skills shortage by 2020. This topic continues to develop such skills, developing logical thinking and creativity.
Why do we teach in this sequence?	This knowledge continues to build and develop their understanding of what makes up a computer, which should make new content more accessible. This also helps prepare them for the next cycle.	Previously students have learnt the basics of programming. This is continuously developed, challenging students further and helping prepare for the GCSE requirements. They can also apply knowledge from cycle A.
What career links are made?	• Several jobs use computers, but this unit could be particularly useful for technicians, network and system administrators, engineer. • Careers requiring the use of problem solving, logical, critical thinking and analytical skills.	• Careers in Software development, game design, programming, app and web development. • Careers requiring critical thinking, resilience, team work, design and analysis skills.

Example of a Key Stage 3 computing curriculum map for Year 9 in a school with a high participation of girls in GCSE Computer Science.

Year 9 – Cycle C	**Year 9 – Cycle D**
Digital Citizenship. Being responsible citizens, recapping cyber security threats, prevention and introducing legislation.	Software Project – Advanced Algorithms and Python Programming Continuing to develop previous knowledge, looking at sorting algorithms and introducing machine learning.
This unit meets point 4 of the national curriculum's aims: this unit continues to ensure that students are responsible, competent, confident and creative users of information and communication technology (point 9 of KS3 NC content).	This unit also meets 1 and 2 as well as point 3 of the national curriculum's aims: evaluating and applying information technology and thinking analytically to solve problems. Students will be able to undertake creative projects which involves collecting and analysing data to meet the needs of known users (points 7, 8, 9 of KS3 NC content).
Last year the GDPR replaced the Data Protection Act and as of February 2019, it was revealed that GDPR breaches and fines have already topped over 10,000 in the UK. This unit continues to internet safety, with a greater focus on personal data and the different legislation students must be aware of.	Typically, companies use just a fraction of the data they collect and store. This unit allows us to explore and appreciate the analysis of data and its practical applications. Per PWC, 'AI will contribute $15.7 trillion dollars to the global economy by 2030'. With the increasing dependence on technology it seems particularly relevant to develop students' understanding and appreciation of these real life applications.
This cycle allows students to demonstrate and build on skills and knowledge previously taught. It introduces some concepts ready for Cycle D and for the GCSE.	This unit allows for consolidation and further development of programming skills taught. It further prepares and allows for a smooth transition for the algorithm and programming content taught at GCSE.
• Careers in security, or law enforcement, teaching, business. All users in personal and professional lives must be aware of the risks of computers. • Careers requiring public speaking, team work, presentation and leadership skills.	• Several careers will analyse and retrieve data, such as jobs in retail, business, recruitment and schools. • Careers requiring critical thinking, problem solving skills and data analysis, manipulation and presentation. • Careers using AI/Machine learning.

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Image sources
Figure 8: Top 10 famous faces

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