System upgrade required

Creating opportunities in computing education

THE ROYAL SOCIETY

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Introduction

As technology rapidly evolves, advanced digital skills are increasingly in demand from the UK workforce. The number of jobs in the technology sector is rising, particularly in areas such as artificial intelligence (AI) and software development, and organisations hoping to grow and remain competitive in the future rely on a workforce that is equipped to fill these roles[1]. However, employers in these sectors are reporting a lack of relevant skills in applicants. In 2022, 44% of employers across England identified digital skills as an area that required significant development[2].

The UK's digital skills gap is estimated to cost the UK economy £63 billion per year and, without remedial action, is expected to widen in the future. This will result in a workforce ill-equipped to meet the demands of the digital age[3]. In addition to the specific and specialised skills gaps that need addressing, all citizens require a basic level of digital literacy in a world where computing and technology are ubiquitous in daily life.

Only 48% of students leave full-time education with the digital skills needed and employers cite lack of talent as the biggest constraining factor to their growth[4]. Too few young people gain qualifications in computing subjects to meet the demands for digital skills, and the computing workforce does not reflect our diverse society.

In 2023, only 21% of UK IT specialists were women. Women and girls play a critical role in science and technology communities, and it is therefore important to ensure opportunities to study computing are open to girls and students from a broad range of backgrounds. This change will help meet the UK's skills need, to drive innovation and creativity whilst also enabling all young people to pursue fulfilling and potentially lucrative careers.

The number of students taking computing qualifications at secondary level is low, and disproportionately so for females, representing a lost opportunity and exacerbating the UK's skills gap. Only around 15% of young people in England choose GCSE Computer Science each year, and within these entries boys outnumber girls by four to one. The number of entries for digital/computing GCSEs declined steeply following the introduction of GCSE Computer Science in 2012 and the termination of GCSE Information and Communication Technology (ICT) in 2019. Overall, there has been a 34% decline in entries across ICT and Computer Science GCSEs since 2015 (Figure 1a)[5].

The popularity of A level Computer Science has grown recently (Figure 1b), but participation in the subject stays considerably lower than other A level STEM subjects and it has the lowest proportion of female entries at just 18%. In 2022/23, 6% of students taking A levels chose A level Computer Science while participation in other STEM subjects (including biology, chemistry, physics and mathematics) was at least more than double and up to 30%[6].

1 World Economic Forum. 2023. Future of Jobs Report. See https://www3.weforum.org/docs/WEF_Future_of_Jobs_2023.pdf (accessed 6 November 2024).

2 DfE 2023. Employer Skills Survey 2022. https://assets.publishing.service.gov.uk/media/672a2743094e4e60c466d160/Employer_Skills_Survey_2022_research_report__Nov_2024_.pdf (accessed 14 March 2024).

3 DCMS. 2022. UK Digital Strategy. https://www.gov.uk/government/publications/uks-digital-strategy/uk-digital-strategy#s3 (accessed 31 October 2024).

4 *Ibid*.

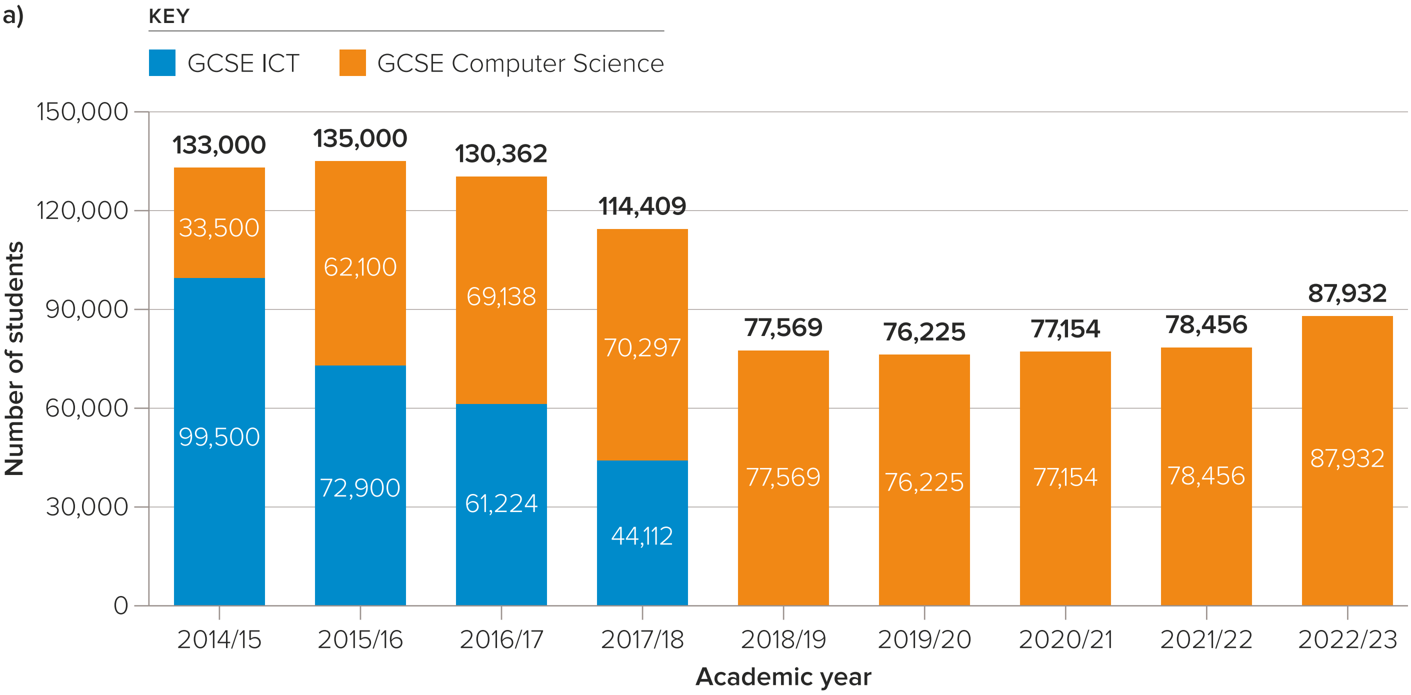
5 DfE. 2024a. Key Stage 4 Performance. See Key stage 4 performance, Academic year 2022/23 – Explore education statistics – GOV.UK (accessed 18 November 2024).

6 DfE. 2024b. A level and other 16 to 18 Results. See https://explore-education-statistics.service.gov.uk/find-statistics/a-level-and-other-16-to-18-results (accessed 23 October 2024).

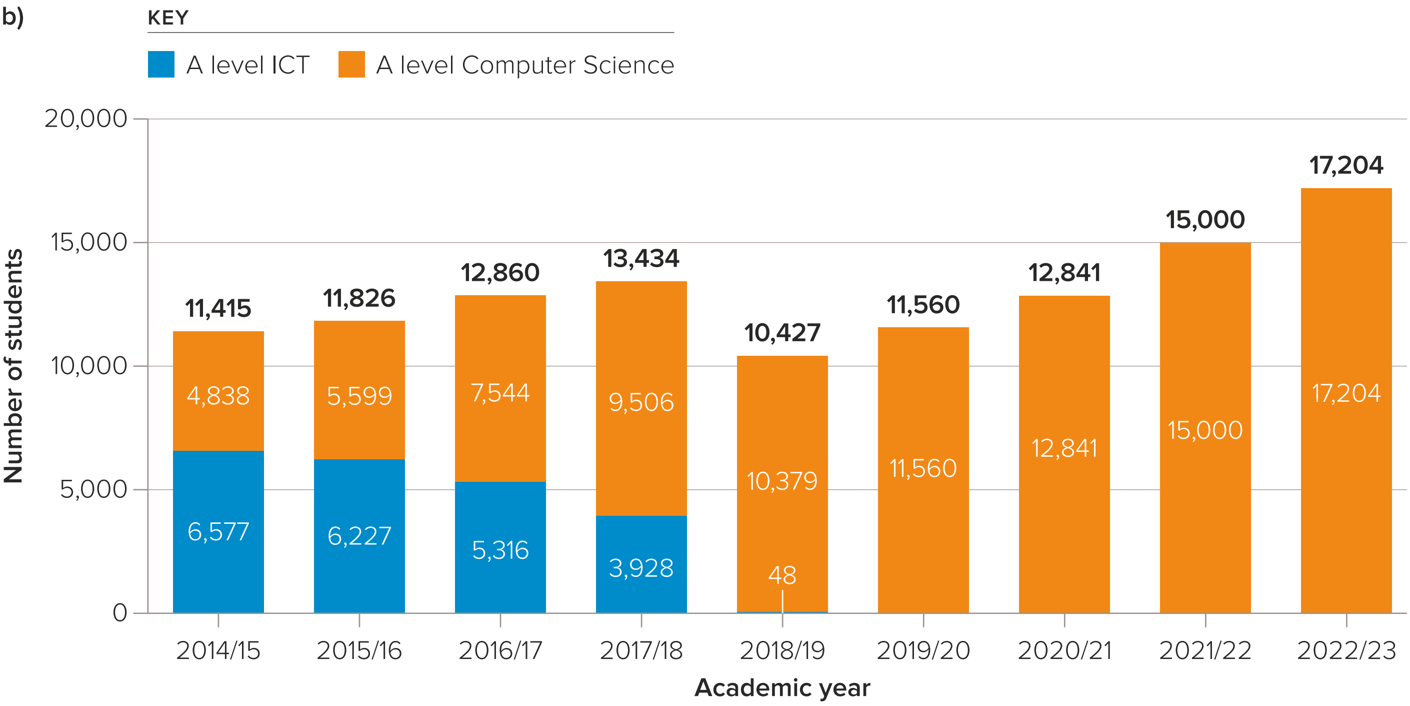
FIGURE 1

Uptake of computing qualifications (ICT and Computer Science) at both GCSE and A level between 2014 and 2023[7].

a)



b)



7 DfE, Subject entry level data https://explore-education-statistics.service.gov.uk/data-catalogue/data-set/c4059865-4a4b-48ea-bd94-394b8bb6bdb2 (accessed 19 August 2025).

Participation through vocational and technical routes in computing is considerably lower than academic routes, and gender imbalance issues persist. In the recently introduced T level qualifications, only 12% of students taking digital pathways were female[8] and only 32% of ICT apprenticeship leavers were female compared to 50% of apprenticeship leavers in total[9].

In contrast, computing undergraduate degrees (including computer science, information systems, software engineering, artificial intelligence and others) were consistently the third most popular degree subject between 2015 and 2022, but only 1 in 4 computing degree students were female[10]. Ethnic minority students and students from low socio-economic backgrounds are well represented on computing degree courses, relative to other STEM subjects, and these figures have been stable over time. However, the completion rates for students from the most deprived Index of Multiple Deprivation (IMD) quintile are low. Some 10% of students from this quintile left their computing degree in their first year compared to just 5% in the least deprived quintile[11].

Rates of degree non-completion in computing are the highest compared with all students across both STEM and non-STEM subjects. 7.7% of computing undergraduates withdrew from their degree within their first year – more than double the percentage recorded among mathematical sciences students[12]. This is a cause for concern.

In 2022, the UK government committed to encouraging the uptake of GCSE and A level Computer Science in England to fill the economy's skills gap[13]. More recently, the DfE's Curriculum and Assessment Review, due to report in autumn 2025, specifically seeks to recommend curriculum change that "reflects the issues and diversities of our society, ensuring all children and young people are represented"[14]. In addition, the 2024 Autumn Budget highlighted investment in the Government's growth mission which aims to address place-based inequalities in economic performance and the need to address skills challenges across the country[15].

8 DfE. 2024c. Provisional T Level Results. See https://explore-education-statistics.service.gov.uk/find-statistics/provisional-t-level-results (accessed 18 November 2024).

9 DfE. 2024d. Apprenticeships. https://explore-education-statistics.service.gov.uk/find-statistics/apprenticeships (accessed 18 November 2024).

10 HESA. 2024. HE student enrolments by CAH level 1 subject, sex, entrant marker, level of study, mode of study and country of HE provider. See https://www.hesa.ac.uk/data-and-analysis/sb269/figure-13 (accessed 18 September 2024)

11 Archer, L., DeWitt, J., Godec, S., Henderson, M., Holmegaard, H., Liu, Q., Macleod, E., Mendick, H., Moote, J. & Watson, E. 2023. ASPIRES3: Computing. UCL. https://discovery.ucl.ac.uk/id/eprint/10182299/1/ASPIRES3%20Computing.pdf (accessed 18 November 2024).

12 HESA. 2022. Non-continuation: UK Performance Indicators. See https://www.hesa.ac.uk/data-and-analysis/performance-indicators/non-continuation (accessed 23 October 2024).

13 DCMS. 2022. UK Digital Strategy. https://www.gov.uk/government/publications/uks-digital-strategy/uk-digital-strategy#s3 (accessed 31 October 2024).

14 DfE. 2024e. Curriculum and Assessment Review. https://www.gov.uk/government/groups/curriculum-and-assessment-review (accessed 18 November 2024).

15 HM Treasury. 2024. Autumn Budget 2024. See https://www.gov.uk/government/publications/autumn-budget-2024/autumn-budget-2024-html#rebuilding-britain-1 (accessed 18 November 2024).

These examples provide further impetus to widen access to computing education through policy interventions that are targeted towards underrepresented groups, including girls and young people from areas of socio-economic deprivation. The Covid-19 pandemic and its aftermath have worsened existing inequalities and reinforced the need to shape education to engage all students across the country. In 2024, in recognition of the importance of skills, the Government launched Skills England to address the needs of the UK and to "kickstart economic growth" including "providing strategic oversight of the post-16 skills system"[16].

Computing education in England suffers from uneven provision and lack of suitably qualified subject specific teachers, as well as significant barriers for underrepresented groups to participate in the subject at GCSE and beyond. There are persistent problems with old and inadequate computing equipment available in schools and colleges, requiring investment from Government and involvement with equipment recycling schemes.

Reform is urgently needed to the way computing and digital literacy is taught and approached. Targeted policy interventions in computing education and careers guidance should be introduced, using approaches informed by an understanding of different students' values, attitudes and experiences.

The Royal Society has commissioned a series of research studies to provide insight into the decision-making of young people from groups that are currently underrepresented in computing education, and the factors that contribute to their decision-making around choosing whether to study the subject.

This report is a summary of these research studies, combined with findings from other recently published work. It highlights key themes common across the findings and the significant barriers which exist to participation in computing education. There are a number of overarching recommendations needed to support a skilled and inclusive workforce for the benefit of individuals and future economic growth.

16 DfE. 2024f. Skills England to transform opportunities and drive growth. See https://www.gov.uk/government/news/skills-england-to-transform-opportunities-and-drive-growth (accessed 18 November 2024).

Recommendations

RECOMMENDATION 1

Recognising the importance of computing for all

Government and devolved administrations should ensure the profile and status of computing education is elevated to reflect its importance as part of a broad, balanced and connected education, as well as its important links with mathematics and data, science and creative subjects.

RECOMMENDATION 2

Invest in infrastructure to remove barriers to access

During the next spending review period, the Government should restore the c.£100m funding it committed during the previous parliament to ensure that the 1.5 million school-age children in the UK have access to devices and a suitable broadband connection.

RECOMMENDATION 3

Review qualifications and assessment options

Implementation of any recommendations following the publication of the Curriculum and Assessment Review in England must ensure that the computing curriculum and the qualifications available are suitable for all learners and pathways.

RECOMMENDATION 4

Update curriculum, flexibly, to create more opportunities

In implementing the recommendations of the Curriculum and Assessment Review, the Department for Education (DfE) should ensure that special attention is paid to aspects of the current curriculum and qualifications which would most encourage participation from currently underrepresented groups. This includes increasing creative opportunities; more team and practical work; more relevance to different backgrounds; more opportunities for students from low socioeconomic backgrounds to develop computing capital; and more representative role models within curriculum content.

RECOMMENDATION 5

Support specialist teaching through professional development

Teacher recruitment in computing remains at a critically low level against DfE's own targets, with only 37% of the recruitment target met according to NFER's 2024/25 Teacher Labour Market survey. Government must invest significant financial resource into improving these figures given their commitment to recruiting 6500 teachers into 'key subjects'. The Society recommends the Government follows the National Audit Office's advice to publish recruitment plans for the 6,500 new teachers, and detail how this will address critical shortages across computing subjects.

Gender

Nine in ten girls leave school without IT skills or a computing qualification.

At present, only 20% of GCSE Computer Science students are female[17, 18]. This imbalance expands further between key stages 4 and 5, making A level Computer Science the most gender-imbalanced subject of all the STEM fields (Figure 2)[19]. Data on vocational and technical qualifications (VTQs) in computing show similar levels of gender disparity, but much lower uptake overall compared to GCSEs and A levels[20, 21]. BCS, The Chartered Institute for IT, notes that nine in ten girls leave school without IT skills or a computing qualification[22]. Male dominance continues at degree level, where only 25% of computing students are female. At the current rate of uptake, it would take over 30 years to reach gender parity in this subject[23].

The overwhelming gender disparity in the computing field may create challenges for female participation, and the extent to which women and girls see computing as fitting with their identity and future career aspirations. With concerns of a computing sector skills gap in the UK, the gender imbalance contributes to a significant loss of economic opportunity, prosperity and diversity. It is important that the creators of technology shaping the modern world reflect the communities and individuals it serves[24].

17 DfE. 2024a. Key Stage 4 Performance. See Key stage 4 performance, Academic year 2022/23 – Explore education statistics – GOV.UK (accessed 18 November 2024).

18 Hamlyn, B., Brownstein, L., Shepherd, A., Stammers, J. & Lemon, C. 2024. Science Education Tracker 2023. See https://royalsociety.org/-/media/policy/projects/science-education-tracker/science-education-tracker-2023.pdf 9 (accessed 18 September 2024).

19 DfE. 2024b. A level and other 16 to 18 Results. See https://explore-education-statistics.service.gov.uk/find-statistics/a-level-and-other-16-to-18-results (accessed 23 October 2024).

20 DfE. 2024a. Key Stage 4 Performance. See Key stage 4 performance, Academic year 2022/23 – Explore education statistics – GOV.UK (accessed 18 November 2024).

21 DfE. 2024b. A level and other 16 to 18 Results. See https://explore-education-statistics.service.gov.uk/find-statistics/a-level-and-other-16-to-18-results (accessed 23 October 2024).

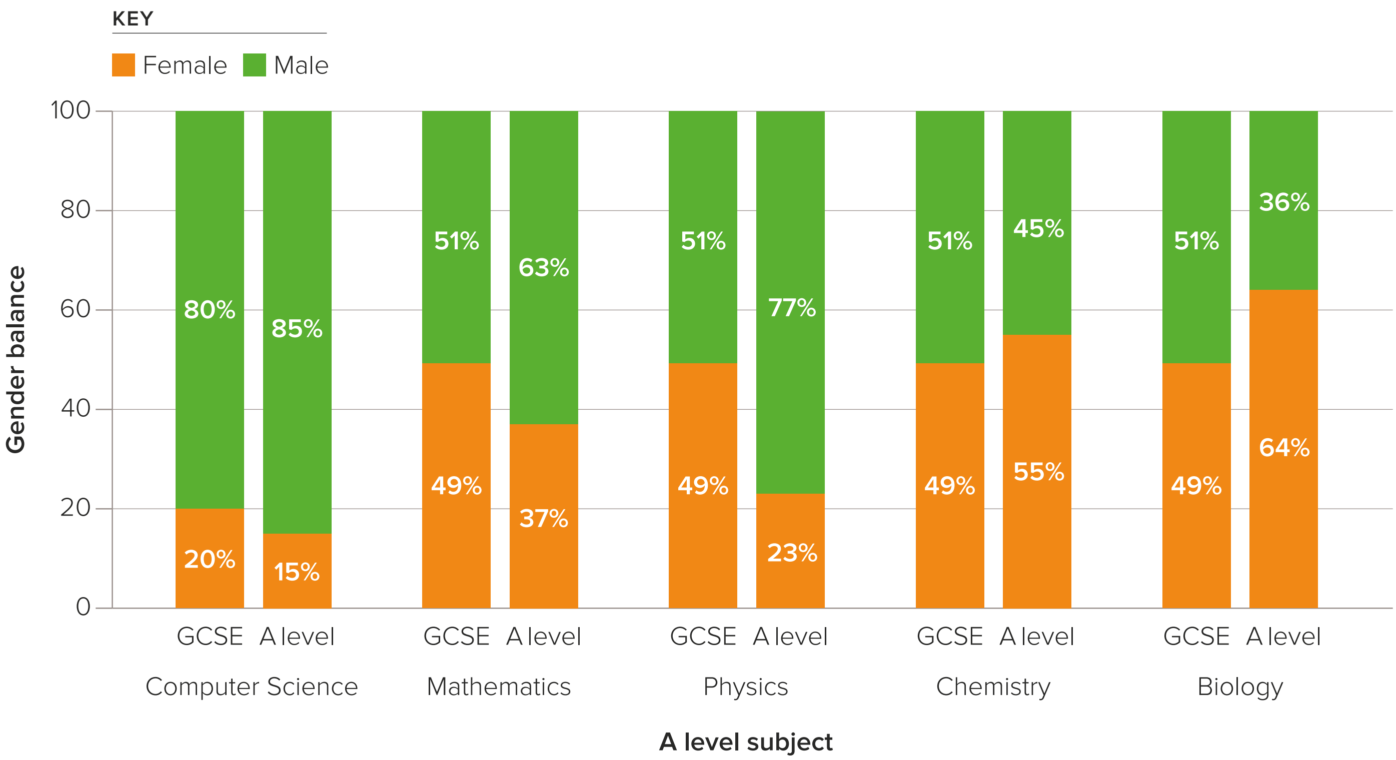
22 BCS. 2021. BCS Landscape Review: Computing Qualifications in the UK. See https://www.bcs.org/media/8665/landscape-review-computing-report.pdf (accessed 24 October 2024).

23 HESA. 2024. HE student enrolments by CAH level 1 subject, sex, entrant marker, level of study, mode of study and country of HE provider. See https://www.hesa.ac.uk/data-and-analysis/sb269/figure-13 (accessed 18 September 2024).

24 Vitores, A. & Gil-Juarez, A. 2016. The trouble with 'women in computing': a critical examination of the deployment of research on the gender gap in computer science. Journal of Gender Studies, 25(6), 666-80. https://doi.org/10.1080/09589236.2015.1087309

FIGURE 2

Gender balance of each major STEM subject at A level, for all qualification entries in England, 2022 – 2023 (data from DfE, 2024b)[25].



25 DfE. 2024b. A level and other 16 to 18 Results. See https://explore-education-statistics.service.gov.uk/find-statistics/a-level-and-other-16-to-18-results (accessed 23 October 2024).

Why don't girls enjoy computing?

A survey of 11 – 19 year olds across the UK found the most popular reason girls choose not to study computing qualifications is because they dislike computing. Girls enjoy computing significantly less than boys (Figure 3)[26] and the gap between female and male interest in computer science has widened since 2019[27]. Even among those who were considering or had chosen computing, girls were less likely to say that they enjoyed it and more likely to say nothing had encouraged them to choose the subject[28, 29]. Across Europe, the UK has the lowest percentage of girls interested in computer science subjects. This highlights the need for changes to the delivery of computing education in the UK[30].

Multiple research studies have found that girls prefer the creative and people-focused elements of computing such as digital media, graphic design and animation – areas that are less well covered by current specifications of GCSE Computer Science[31, 32]. A broadening of the topics included in computing GCSE, with less emphasis on the technical elements (eg coding, mathematics) and increased coverage of digital media and other creative aspects, could make the curriculum more appealing to girls[33].

Alternatively, the BCS has recommended that the Government should introduce a new GCSE in Applied Computing to create space for technical, digital and creative areas of study, which was backed by a House of Lords Education for 11 – 16-year-olds Committee in 2023[34]. In the classroom, creativity can be integrated through open-ended assignments, and interactive hands-on elements can be used to show the relevance of computing and coding to digital media, which could increase girls' motivation and engagement with computing education[35].

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26 Chrysalis. 2024. Representation in Computing Education.

27 Hamlyn, B., Brownstein, L., Shepherd, A., Stammers, J. & Lemon, C. 2024. Science Education Tracker 2023. See https://royalsociety.org/-/media/policy/projects/science-education-tracker/science-education-tracker-2023.pdf 9 (accessed 18 September 2024).

28 Chrysalis. 2024. Representation in Computing Education.

29 Hamlyn, B., Brownstein, L., Shepherd, A., Stammers, J. & Lemon, C. 2024. Science Education Tracker 2023. See https://royalsociety.org/-/media/policy/projects/science-education-tracker/science-education-tracker-2023.pdf 9 (accessed 18 September 2024).

30 Google. 2023. Breaking Barriers. See https://services.google.com/fh/files/misc/breaking_barriers_europe_report.pdf (accessed 19 September 2024).

31 *Ibid*.

32 Kemp, P., Wong, B., Hamer, J. & Copsey-Blake, M. 2024. The future of computing education: considerations for policy, curriculum and practice. King's College London. See https://www.kcl.ac.uk/ecs/assets/kcl-scari-computing.pdf (accessed 23 September 2024).

33 *Ibid*.

34 BCS. 2023. House of Lords Committee backs BCS call for reform of computing qualifications for 14-16-year-olds. See https://www.bcs.org/articles-opinion-and-research/house-of-lords-committee-backs-bcs-call-for-reform-of-computing-qualifications-for-14-16-year-olds/ (accessed 5 November 2024).

35 Sharmin, S. 2021. Creativity in CS1: a literature review. ACM Transactions on Computing Education, 22(2), 1-26. https://doi.org/10.1145/3459995

The role of confidence

Despite consistently outperforming their male peers at GCSE and A level Computer Science[36], girls who have chosen to study computing qualifications are less likely to say that they are 'good' at the subject compared with boys[37, 38]. Girls typically perform worse in Computer Science compared to their other GCSE qualifications[39]. A perception that computing is 'not for them' could lead to a lack of confidence in girls resulting in less engagement in the subject[40]. Due to the strong dominance of males in computing contexts beyond school, and STEM more broadly where women represent just 29% of the workforce[41], computing has a perceived masculine culture. Girls are less likely to see people like them in computing fields and so more likely to feel that they don't belong there. The stereotype that computing is a subject 'for boys' can affect girls' confidence and make it harder to aspire to a career in technology[42]. Research has shown that misalignment between student identity and the culture of a subject field can negatively affect student retention and participation rates, even when attainment is high[43].

Some students who are predicted lower grades overall may decide not to study computing at GCSE and beyond due to their lack of confidence, or the perception of the subject's difficulty. GCSE and A level Computer Science are regarded as a 'difficult' option among students, teachers and parents, which is only suitable for the 'cleverest' students, notably those who are 'naturally talented' in mathematics. This belief reduces the number of people pursuing it, especially girls, who are less likely than boys to see themselves as 'clever', which could lead to further entrenchment of gender stereotypes about intellectual ability in STEM subjects[44]. Significantly more girls than boys describe themselves as not being good enough at computing or mathematics to choose computing qualifications[45].

Significantly more girls than boys describe themselves as not being good enough at computing or mathematics to choose computing qualifications (Figure 1; Chrysalis, 2024).

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36 Across all schools in England in the school year 2022/23, 56% of girls achieved a grade 9 – 5 in GCSE computer science compared to 47% of boys and 70% of girls achieved a grade A*-C in A level computer science compared to 64.9% of boys. See: Explore our statistics and data – Explore education statistics – GOV.UK

37 Chrysalis. 2024. Representation in Computing Education.

38 Hamlyn, B., Brownstein, L., Shepherd, A., Stammers, J. & Lemon, C. 2024. Science Education Tracker 2023. See https://royalsociety.org/-/media/policy/projects/science-education-tracker/science-education-tracker-2023.pdf 9 (accessed 18 September 2024).

39 DfE. 2024a. Key Stage 4 Performance. See Key stage 4 performance, Academic year 2022/23 – Explore education statistics – GOV.UK (accessed 18 November 2024).

40 Chrysalis. 2024. Representation in Computing Education.

41 Equality Hub. 2023. More women to be supported back into STEM jobs in Government backed training. See https://www.gov.uk/government/news/more-women-to-be-supported-back-into-stem-jobs-in-government-backed-training (accessed 19 September 2024).

42 Archer, L., & Tomei, A. 2013. 'What influences participation in science and mathematics?': A briefing paper from the Targeted Initiative on Science and Mathematics Education (TISME). See https://kclpure.kcl.ac.uk/ws/portalfiles/portal/64435093/TISME_briefing_paper_March_2013.pdf (accessed 19 November 2024).

43 Wong, B., Chiu, Y.T., Murray, O.M., Horsburgh, J. & Copsey-Blake, M. 2022. 'Biology is easy, physics is hard': student perceptions of the ideal and the typical student across STEM higher education. International Studies in Sociology of Education, 32(1), 118-139. https://doi.org/10.1080/09620214.2022.2122532

44 Chrysalis. 2024. Representation in Computing Education.

45 *Ibid*.

Often, STEM subjects are stereotyped as male domains, which could lead to girls underestimating their own ability or potential[46, 47]. There is extensive evidence to suggest that young people making subject choices at a relatively early age (as is the case in England) increases gender segregation[48, 49].

The computing curriculum should prioritise the visibility and diversity of role models, giving students examples of the variety of people and their impact in the world of computing, digital and data. As well as having more female role models, it is important that they are relatable and representative of students from diverse backgrounds. Peer role models, such as older students who are studying computing, and female computing teachers, can be more effective than accomplished, but less relatable, role models in public life[50]. Without role models, girls are often faced with examples of STEM professionals, in the media for example, that don't align with their identity[51].

In all-girls schools, rates of participation in computing courses are much higher than in mixed gender schools[52], which suggests being in mixed-gender settings could potentially be a barrier to girls' participation in computing. Peer and teacher support in schools is crucial for building girls' confidence in learning, especially given that 40% of girls believe that it is harder for women to get ahead in computing than men because of obstacles such as gender bias, lack of awareness of career opportunities, and lower exposure and encouragement to computing from a young age[53]. Teachers who build positive relationships with students in computing through conversational approaches to learning seem to have a positive effect on GCSE Computer Science uptake rates[54], and girls are more likely to take advice from their teachers about which subject to choose to study[55]. Girls could benefit from increased support and encouragement to pursue technology related subjects and courses.

46 Archer, L., & Tomei, A. 2013. 'What influences participation in science and mathematics?': A briefing paper from the Targeted Initiative on Science and Mathematics Education (TISME). See https://kclpure.kcl.ac.uk/ws/portalfiles/portal/64435093/TISME_briefing_paper_March_2013.pdf (accessed 19 November 2024).

47 Eccles, J. S. 2015. Gendered socialization of STEM interests in the family. International Journal of Gender, Science and Technology, 7(2), 116-132. https://genderandset.open.ac.uk/index.php/genderandset/article/view/419

48 Hendersen M., Sullivan, A., Anders, J. & Moulton, V. 2017. Social class, gender and ethnic differences in subjects taken at age 14. The Curriculum Journal, 29(3), 298-318. https://doi.org/10.1080/09585176.2017.1406810

49 Anders, J., Hendersen, M., Moulton, V. & Sullivan, A. 2018. The role of schools in explaining individuals' subject choices at age 14. Oxford Review of Education, 44(1), 75-93. https://doi.org/10.1080/03054985.2018.1409973

50 Szlávi, A. 2021. Barriers, role models, and diversity: women in IT. Central-European Journal of New Technologies in Research, Education and Practice, 3(3), 20-7. https://doi.org/10.36427/CEJNTREP.3.3.2582

51 Archer, L., DeWitt, J., Godec, S., Henderson, M., Holmegaard, H., Liu, Q., Macleod, E., Mendick, H., Moote, J., Watson, E. 2023. ASPIRES 3 Summary Report: Computing. UCL. See https://discovery.ucl.ac.uk/id/eprint/10182299/1/ASPIRES3%20Computing.pdf (accessed 19 September 2024).

52 The Royal Society. 2017. After the reboot: computing education in UK schools. See https://royalsociety.org/~/media/policy/projects/computing-education/computing-education-report.pdf (accessed 9 October 2024).

53 Chrysalis. 2024. Representation in Computing Education.

54 Kemp, P., Wong, B., Hamer, J. & Copsey-Blake, M. 2024. The future of computing education: considerations for policy, curriculum and practice. King's College London. See https://www.kcl.ac.uk/ecs/assets/kcl-scari-computing.pdf (accessed 23 September 2024).

55 Chrysalis. 2024. Representation in Computing Education.

Career opportunities for girls

Research commissioned by The Royal Society that categorised young people (aged 11 – 18) based on their attitudes to education and computing found 'education enthusiasts' were significantly more likely to be female than other genders. This group of students enjoys school, are high achievers, and are interested in computing, meaning computing could be a fulfilling career option for them. When surveyed however, they often see other subjects as more central to their chosen career and further study (Figure 3)[56]. Demonstrating that computing is interesting and worthwhile for their future could lead to an increase in the study of computing among this group[57].

Before age 18, girls are more likely than boys to have some idea about their future career, but they are less informed about computing careers, particularly the types of jobs that computing qualifications can lead to[58]. Furthermore, they are less interested than boys and non-binary young people in finding out about careers in computing and often see computing jobs as 'boring' (Figure 3)[59], meaning they may miss out on fulfilling and often well-rewarded career opportunities. Research shows only 28% of girls aspire to work in the 'technology industry' compared to 60% of boys[60].

Studies have found that girls' dream jobs tend to be ones aligned with their own identity, and only 8% of girls think computer science fits with their future self[61]. By understanding the career attributes that girls look for, the computing curriculum and wider career advice and guidance could be better tailored to support the growth of women in computer science.

Girls prioritise having a job that helps other people[62, 63], however, they aren't necessarily aware of the importance of computing skills to their desired roles. Computing literacy and digital skills is important in a range of careers outside of the traditional 'tech' sector, including throughout health and social care, in roles across education, in government and legal professions, and across the charity sector. A third of girls who chose not to study computing said it was not needed for their intended future career[64]. Therefore, promotion of varied careers within the computing curriculum, including non-specialist roles and emphasising having digital literacy, is essential to ensure girls are aware of the breadth of opportunities available to them after studying computing[65].

28% of girls aspire to work in the 'technology industry' compared to 60% of boys.

56 DJS. 2021. Diversity in Computing Education.

57 *Ibid*,

58 Chrysalis. 2024. Representation in Computing Education.

59 *Ibid*.

60 DJS. 2021. Diversity in Computing Education.

61 Google. 2023. Breaking Barriers. See https://services.google.com/fh/files/misc/breaking_barriers_europe_report.pdf (accessed 19 September 2024).

62 DJS. 2021. Diversity in Computing Education.

63 Chrysalis. 2024. Representation in Computing Education.

64 *Ibid*,

65 Kemp, P., Wong, B., Hamer, J. & Copsey-Blake, M. 2024. The future of computing education: considerations for policy, curriculum and practice. King's College London. See https://www.kcl.ac.uk/ecs/assets/kcl-scari-computing.pdf (accessed 23 September 2024).

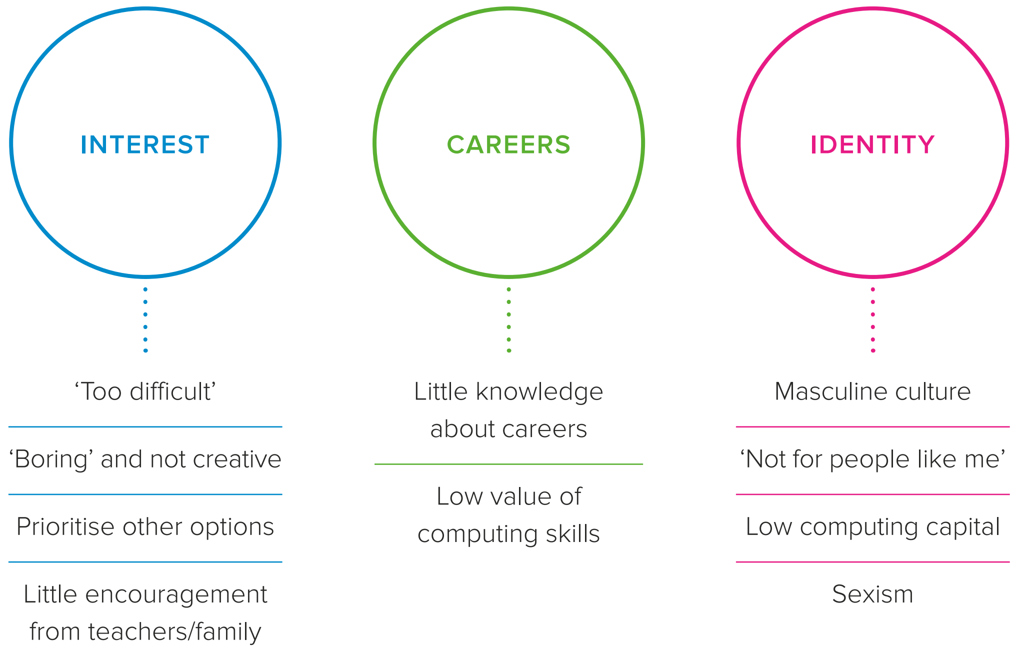
STEM initiatives including computing education

Organisations, projects, and initiatives that support women in STEM are essential for encouraging more girls to study and pursue careers in STEM and supporting women to thrive in STEM careers. This in turn makes STEM fields inclusive of and attractive to women and girls, which has long-term benefits in reducing the skills gap and boosting the economy.

For example, Ada Lovelace Day celebrated annually has initiated hundreds of events to be held worldwide that highlight the achievements of women in STEM fields, giving them a platform and inspiring future female scientists[66]. However, multiple organisations, including Ada Lovelace Day, as well as Tech Girls Movement, 500 Women Scientists, Women Who Code, Tech Talent Charter, and Girls in Tech have closed or halted work over the last eighteen months due to lack of financial support[67]. It is essential that government and industry prioritise investment in interventions that promote gender diversity in STEM fields.

FIGURE 3

Barriers for girls to take part in computing education.



66 Ada Lovelace Day. 2024. Ada Lovelace Day Live to end. See https://findingada.com/ (accessed 20 November 2024).

67 *Ibid*.

Computing qualifications

Getting curriculum, assessment and qualifications right across all subjects is an essential first step in ensuring pupils leave education with the skills to embark on successful careers and become responsible citizens. Since September 2014, computing has been mandatory from primary to age 16. However, GCSE Computer Science does not map directly onto the national curriculum, and taking the GCSE is optional. The Royal Society supports the compulsory teaching of computing, but more needs to be done to ensure the subject is relevant, appealing, and engaging to students beyond their mandatory lessons[68]. This is a significant area of concern, which the Curriculum and Assessment Review should seek to put right and the Department for Education should seriously consider in planning the implementation of the Review's recommendations.

Perceptions of difficulty

Computing is perceived as a difficult subject by students and teachers alike, and this is one of the reasons why students decide not to study computing courses[69, 70]. This matches the concerns raised by the Royal Society (2017) in *After the reboot*, as well as BCS, in their review of computing qualifications in the UK[71]. The belief that GCSE Computer Science, and computing in general, is harder than other subjects is damaging young people's futures by putting them off a subject and career path in which they could succeed. The stereotype that computing is only for 'smart' students makes computing inaccessible, narrowing the future job prospects of certain groups.

This particularly affects girls, who are less likely than boys to describe themselves as 'smart', which could be due to perceived and persistent gender stereotypes about intellectual ability in STEM subjects[72]. Similarly, school leaders and teachers are less willing to offer GCSE, A levels, and other qualifications in the subject if they believe it is too difficult, which has a detrimental impact on young people's opportunities and the supply of computer scientists into the economy[73]. Addressing the negative perception of computing as 'difficult' and removing the stereotype that computing is a 'natural talent' would encourage more students to pursue computing subjects.

Computing is perceived as a difficult subject by students and teachers alike, which is one of the reasons why students decide not to study computing courses (DJS, 2021; Chrysalis, 2024).

68 DfE. 2013. National Curriculum in England: computing programmes of study. See https://www.gov.uk/government/publications/national-curriculum-in-england-computing-programmes-of-study/national-curriculum-in-england-computing-programmes-of-study (accessed 24 October 2024).

69 DJS. 2021. Diversity in Computing Education.

70 Chrysalis. 2024. Representation in Computing Education.

71 BCS. 2021. BCS Landscape Review: Computing Qualifications in the UK. See https://www.bcs.org/media/8665/landscape-review-computing-report.pdf (accessed 24 October 2024).

72 Chrysalis. 2024. Representation in Computing Education.

73 DJS. 2021. Diversity in Computing Education.

High-achieving students will also avoid choosing to study computing courses at key stages 4 and 5 if they can achieve better grades in other subjects (Figure 3)[74, 75]. Maintaining or improving grades can be a significant motivation for students and teachers, for a range of reasons including progression to the next stage of education, or work, or because of accountability structures within the system. A potential side effect of this is that students and teachers alike may be less likely to choose a subject that comes with a risk of lower grades, even if they understand its importance for future jobs, so ensuring grade parity between STEM subjects is important[76].

A review by the government's Office of Qualifications and Examinations Regulation (Ofqual) agreed that GCSE Computer Science was unfairly marked and found small incremental changes to the qualification standard between 2014 and 2017 led to a substantive, cumulative change in grading standards and the subject being more difficult than intended. Whilst this was found to have a limited impact on the progression of students to further study in computer science, larger changes could begin to have undesirable consequences for the skills and knowledge shown by students and undermine the value of the qualification.

Ofqual asked exam boards to award more generously at grades 9, 7, and 4 for GCSE Computer Science in 2024, and as a result, 68% of entries were awarded a grade 4/C or above, a rise from 65% of entries in 2023. Experts consulted in the Ofqual review also highlighted that teacher expertise, curriculum time, subject content, and resourcing influence the perceived and actual difficulty of the subject, beyond grading[77].

After the change to the national curriculum, researchers from Kings College London found the number of ICT/computing teaching hours in state schools dropped by 60% at key stage 4 and 28% at key stage 3 between 2012 and 2020, possibly influencing the decision making of students choosing not to study computing qualifications between this time[78]. Similarly, a survey of key stage 3 students across the UK found almost one third receive two or more hours of computing per week and 17% receive less than one hour per week[79, 80]. The amount of time afforded to computing education is insufficient to teach the subject content in the national curriculum, making it difficult for schools to achieve the aims of the national curriculum, and having reduced teaching hours increases the workload of teachers to cover the curriculum in a short amount of time[81].

74 *Ibid*.

75 Chrysalis. 2024. Representation in Computing Education.

76 DJS. 2021. Diversity in Computing Education.

77 Stratton, T. 2024. A review of standards in GCSE computer science. Ofqual. See: https://www.gov.uk/government/publications/a-review-of-standards-in-gcse-computer-science/a-review-of-standards-in-gcse-computer-science#overall-conclusion (accessed 17 October 2024).

78 Kemp, P., Wong, B., Hamer, J. & Copsey-Blake, M. 2024. The future of computing education: considerations for policy, curriculum and practice. King's College London. See https://www.kcl.ac.uk/ecs/assets/kcl-scari-computing.pdf (accessed 23 September 2024).

79 DJS. 2021. Diversity in Computing Education.

80 Chrysalis. 2024. Representation in Computing Education.

81 The Royal Society. 2017. After the reboot: computing education in UK schools. See https://royalsociety.org/~/media/policy/projects/computing-education/computing-education-report.pdf (accessed 9 October 2024).

Despite computing being a mandatory subject in the national curriculum, inconsistencies with its delivery in schools mean some pupils finish formal study of computing at 14[82]. With reduced curriculum time, there is a risk that the status of computing as a subject may be undermined, and students will be ill-equipped for study at further and higher education.

Patterns in higher education

There are high drop-out rates on computing degree courses and degree students feel A level Computer Science does not prepare them for degree study[83]. Research commissioned by The Royal Society investigated the factors shaping young people's trajectories into, through and out of computing education, found 37% of computing degree students expressed high concerns about completing their degree, the highest of all STEM fields, with academic issues paramount. These concerns were most likely to be expressed by women, students from minoritised groups, and those from backgrounds of high deprivation[84]. This highlights the need to give greater consideration and policy prominence to underrepresentation in computing to support more equitable retention and transition on computing degrees targeted to underrepresented students.

Target interventions for underrepresented groups

Research by DJS (2021) commissioned by the Royal Society (Table 1) characterised the values, beliefs, attitudes, world views, and social groups of students aged 11 – 18 across the UK to understand their decisions to study computing qualifications. The research identified 6 clear groups of students (Figure 4) that policymaking and teaching interventions can be targeted towards to increase uptake and diversify computing classrooms. Two segments in particular – 'education enthusiasts' and 'future planners' – show significant potential in computing. Other segments – specifically 'school dissenters' – highlight the importance of technical and vocational routes to engage computing talent.

82 BCS. 2019. Non examined subjects at key stage 4 – especially computing. See https://www.bcs.org/media/2936/scac-ofsted-response-0419.pdf (accessed 24 October 2024).

83 Archer, L., DeWitt, J., Godec, S., Henderson, M., Holmegaard, H., Liu, Q., Macleod, E., Mendick, H., Moote, J., Watson, E. 2023. ASPIRES 3 Summary Report: Computing. UCL. See https://discovery.ucl.ac.uk/id/eprint/10182299/1/ASPIRES3%20Computing.pdf (accessed 19 September 2024).

84 Archer, L., DeWitt, J., Godec, S., Henderson, M., Holmegaard, H., Liu, Q., Macleod, E., Mendick, H., Moote, J., Watson, E. 2023. ASPIRES 3 Summary Report: Computing. UCL. See https://discovery.ucl.ac.uk/id/eprint/10182299/1/ASPIRES3%20Computing.pdf (accessed 19 September 2024).

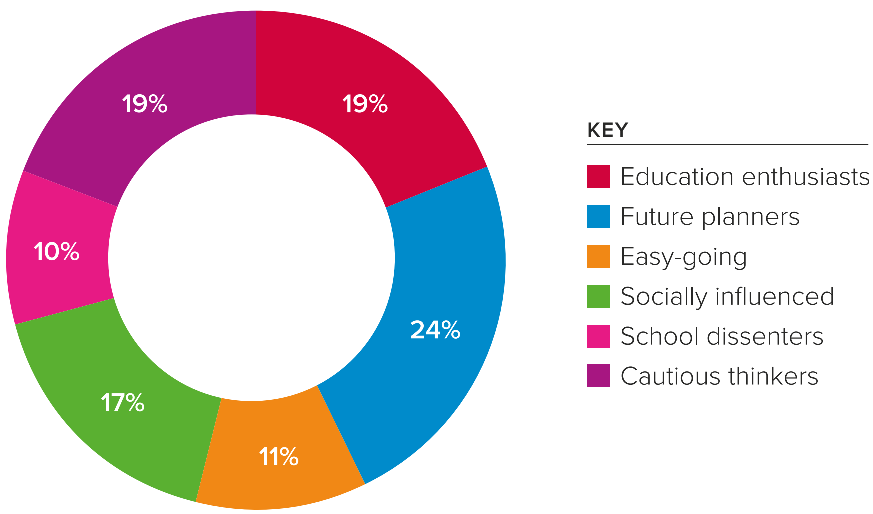
TABLE 1

Description of the segmentations that emerged from the DJS study commissioned by the Royal Society in 2021.

Education enthusiasts	Education Enthusiasts enjoy school and learning. They describe themselves as organised, smart, and determined, and they see hard work as important in life.
Future planners	Future Planners care deeply about, and are planning for, their future careers. They often describe themselves as self motivated and believe that it's important to be motivated, enthusiastic and to have a plan for the future.
Easy-going	Easy-going students describe themselves as sociable and easy to talk to. They're confident and open-minded and enjoy new experiences.
Socially influenced	Socially Influenced students are very conscious of how their peers perceive them. They describe themselves as eager to please and are easily swayed by others' views.
School dissenters	School dissenters students describe themselves as outspoken, strong-willed, tough and brave. However, this outward impression of confidence does not translate into a strong sense of self-efficacy – School dissenters are less likely to believe they can accomplish their goals.
Cautious thinkers	Cautious thinkers describe themselves as quiet, worriers and perfectionists. They can find social interaction difficult and are often nervous to try new things in front of others.

FIGURE 4

Segments of students in relation to their attitudes towards computing and education, based on survey data from a research sample representative of the UK 11 – 18-year-old population (n = 2,273; data from DJS, 2021)[85].



85 DJS. 2021. Diversity in Computing Education.

A particular attribute of 'easy-going' students, who are sociable and enjoy new experiences, is that they prioritise having a job they enjoy and helping others, over traditional markers of success. They are comfortable in school but less likely to enjoy computing, often because computing is perceived to be 'boring' or 'antisocial'[86]. Despite these negative perceptions, good communication skills are important in computing and beyond to convey complex ideas and collaborate with team members. Around half of young people describe themselves as 'easy to talk to'[87]. Showing how computing involves team work and positive social interactions will increase engagement with these students. This would also benefit 'socially influenced' students who are less education- and career-orientated and heavily influenced by their peer groups. Incorporating collaborative elements into computing education and associated qualification pathways could enable students to positively engage with others and strengthen peer networks. Changing the societal view of computing and challenging negative stereotypes is important to increase the study of computing among students.

Creative skills are core to working in computing, although sadly few people associate computing education with creativity and related skills. Most students choose to study Computer Science alongside other STEM subjects; 36% of A level Computer Science students also study A level Mathematics, and very few students study Computer Science in combination with arts or languages[88]. Around half of young people describe themselves as creative, and it is the top attribute used by girls, students from areas of higher deprivation, disabled students and neurodiverse students to describe themselves. Therefore, changing the language in conversations around computing to emphasise the creative skills involved could increase the appeal among students, particularly from those underrepresented groups mentioned.

Computing curricula and qualifications should be developed to ensure themes from science, arts and humanities are reflected in the content, allowing students to make links to other disciplines and increasing the awareness and understanding of the potential application of computing skills more broadly[89]. Furthermore, hands-on experience of using digital technology should be incorporated into subjects across the national curriculum to improve knowledge of computing applications, particularly among students with limited use of digital technology outside of school. Ensuring that as many young people as possible have opportunities to see computing as a creative and engaging subject with great potential for everyday use would be a step towards boosting participation[90].

Ensuring that as many young people as possible have opportunities to see computing as a creative and engaging subject with great potential for everyday use would be a step towards boosting participation.

86 DJS. 2021. Diversity in Computing Education.

87 Chrysalis. 2024. Representation in Computing Education.

88 Ofqual. 2024. A level subject combinations and outcomes. See https://analytics.ofqual.gov.uk/apps/Alevel/SubjectCombinations/ (accessed 10 October 2024).

89 Google. 2023. Breaking Barriers. See https://services.google.com/fh/files/misc/breaking_barriers_europe_report.pdf (accessed 19 September 2024).

90 Chrysalis. 2024. Representation in Computing Education.

Systemic changes to formal education are needed to dismantle participation barriers for disabled and neurodiverse students in the classroom and beyond, allowing them to achieve their full potential across the curriculum.

Both neurodiverse and disabled students are more likely to have self-directed computing hobbies outside of school, including playing video games with an element of coding, building web pages and designing video games, and do so more frequently compared to other students. However, due to their struggles with formal education they are unlikely to pursue academic study[91, 92]. Neurodiverse and disabled students are less likely to enjoy computing in school compared to other students and commonly cite not being 'good' at computing as a reason why they choose not to study the subject[93]. Neurodivergence is significantly prevalent among 'cautious thinkers', who despite having an average academic achievement, struggle in a formal education environment and report feeling as though they do not belong in the computing classroom[94]. Systemic changes to formal education are needed to dismantle participation barriers for disabled and neurodiverse students in the classroom and beyond, allowing them to achieve their full potential across the curriculum.

Changes to the delivery of computing education and acknowledgement of the computing talent demonstrated through their informal experiences can be used to guide their interest in computing and promote students' self-confidence in the subject.

Many students experience low self-efficacy and find school environments challenging, with a preference for practical subjects. These students are also more likely to pursue hobbies such as computing activities outside of formal education[95]. To engage them more and attract their interest, computing could be positioned as a practical, hands-on subject, rather than an abstract academic one, and their creative hobbies can be connected to a real-world context in the computing classroom, for example by using coding to design games. It is also important to develop and promote non-academic routes in computing careers to offer inclusivity to students who struggle in formal education environments. Challenging the stereotype that computing is better suited to more academically able students is important to this. Whilst 'neurodivergent' and 'disabled' can be useful umbrella terms, it is important to note that all students will have a unique individual experience of education[96].

91 DJS. 2021. Diversity in Computing Education.

92 Chrysalis. 2024. Representation in Computing Education.

93 *Ibid*.

94 DJS. 2021. Diversity in Computing Education.

95 DJS. 2021. Diversity in Computing Education.

96 *Ibid*.

Technical routes in computing

Developing technical and non-academic routes into computing enables the subject to be accessible for a diverse range of students and challenges the stereotype that computing trajectories are only for the most academically able students. However, vocational and technical qualifications (VTQs) in computing are not currently seen as alternatives that are effectively promoted to young people[97]. Since 2016, there has been a significant reduction in the number of level 1 and level 2 computing qualifications offered. Uptake of key stage 4 VTQs has declined since 2019 and is in no way comparable to the uptake rate of GCSE Computer Science. In 2023, 3.7% of the cohort took an ICT technical award, only 27% of which were girls[98].

T levels were introduced in September 2020 offering a mix of learning in school or college and practical experience through an industry placement. There are three T levels currently offered in digital subjects: Digital Business Services; Digital Production, Design and Development; and Digital Support Services[99]. DfE does not allow much of the content from the key stage 3 computing curriculum or the GCSE Computer Science subject specification to be included in computing-related VTQs, which limits topic coverage. As a result, some students following the T level pathway may leave compulsory education without access to the same level of digital skills or computing education as their peers taking GCSEs.

A diverse approach to both teaching and to the range of qualifications on offer are valuable in enabling students with different needs, aptitudes and interests to participate and succeed in computing education. Girls, neurodiverse students, disabled students, and students who prefer technical routes are less engaged with the current computing curriculum and qualifications than other young people. Understanding how particular modes of study may suit different groups and their motivation for selecting specific types of qualifications can help to inform how computing education and qualifications can appeal to more young people. Having access to information about the range of digital/ computing courses on offer at all levels, particularly creative subjects and courses, is important for students to make informed decisions about their pathways. Digital skills relevant to all occupations should be included across subjects throughout the curriculum, giving students and future employers the confidence that school and college leavers and graduates will have the digital proficiency needed for employment.

Having access to information about the range of digital/ computing courses on offer at all levels, particularly creative subjects and courses, is important for students to make informed decisions about their pathways.

97 BCS. 2021. BCS Landscape Review: Computing Qualifications in the UK. See https://www.bcs.org/media/8665/landscape-review-computing-report.pdf (accessed 24 October 2024).

98 DfE. 2024a. Key Stage 4 Performance. See Key stage 4 performance, Academic year 2022/23 – Explore education statistics – GOV.UK (accessed 18 November 2024).

99 DfE. 2024b. A level and other 16 to 18 Results. See https://explore-education-statistics.service.gov.uk/find-statistics/a-level-and-other-16-to-18-results (accessed 23 October 2024).

Teaching

Teachers play an integral role in the enjoyment of computer science beyond the subject itself. For pupils to engage with computing, knowledgeable and confident teachers are needed, who in turn need support via specialist subject training and continued professional development (CPD)[100]. As the digital economy grows, access to quality computing teaching for all pupils is vital for the digital workforce of the UK.

46% of students say that teachers have an impact on their subject choices[101]. Girls are significantly more likely to take advice from their teachers about which subject to choose for GCSE, compared to boys and non-binary students, and neurodiverse students are more likely to choose computing if they like(d) their computing teacher[102]. This highlights the pivotal role of specialist teachers in a student's progression in computing education, particularly for students from groups underrepresented in computing fields. It is therefore essential that teachers have comprehensive knowledge of computing course content, qualification pathways, and career opportunities when advising students.

CASE STUDY 1

Institute of Physics (IoP): Improving gender balance

The IoP ran a pilot project in six schools across the country to assess techniques aimed at improving gender balance in physics education targeted individually at pupils, teachers, and senior staff. Targeted programmes aimed at building the confidence of year 9/10 girls included science ambassador training, extracurricular clubs, and organised talks from outside speakers. Teachers were trained in unconscious bias, inclusive teacher techniques, and how to integrate physics-related careers in the curriculum.

A culture of gender awareness was developed across the schools by designing and implementing tools and techniques with senior staff such as a self-auditing tool and school action plan, PSHE activities, external career events, and student equality groups. The number of girls taking AS level physics in the six schools trebled over two years from 16 to 52 students (IoP, 2017)[103].

100 The Royal Society. 2017. After the reboot: computing education in UK schools. See https://royalsociety.org/~/media/policy/projects/computing-education/computing-education-report.pdf (accessed 9 October 2024).

101 DJS. 2021. Diversity in Computing Education.

102 Chrysalis. 2024. Representation in Computing Education.

103 Institute of Physics. 2017. Improving gender balance: reflections on the impact of interventions in schools.

Shortage of specialist computing teachers

The demand for computing teachers is growing in England and issues with recruiting and retaining specialist teachers persist. In 2023/24, computer science achieved just 36% of its initial teacher training (ITT) recruitment target set by DfE[104, 105]. The shortage of computing teachers means some schools, particularly those in disadvantaged areas, are unable to offer computing qualifications, including GCSE and A level Computer Science, as they struggle to recruit qualified teachers. 30% of secondary school students attend a school that does not offer GCSE Computer Science[106], and only one third of students surveyed are aware that their school offers level 3 computing qualifications[107]. Lack of expert teachers can reduce the quality of students' experience and awareness of computing-related career opportunities in fields related to computing and digital skills, particularly in areas of high deprivation. As well as a lack of specialist teachers, there is also a lack of female teachers which further perpetuates the idea that computing is a masculine field. Targeted support is needed to recruit and retain teachers from diverse backgrounds, and teacher recruitment and retention interventions should target female teachers and schools in areas of high deprivation.

Computing teachers often have responsibilities in other subjects such as business studies, mathematics, and design and technology. Due to the shortage of expert teachers, computing is often taught by non-specialists[108]. Only 40% of computing teachers have a relevant post-A level qualification, and only 29% have a computing degree, making it one of the poorest subjects in terms of specialised teachers.

The rate of teacher recruitment in computing is considerably lower than that of other STEM subjects. 88% of biology, 73% of chemistry, 77% of mathematics, and 58% of physics teachers have a post-A level qualification relevant to their subject field. Just 54% of computing hours taught in secondary schools are delivered by a teacher with a relevant post-A level qualification, which is substantially lower than other EBacc subjects[109]. A review by Ofsted (2022) that explored computing education found that specialist teacher recruitment and retention issues in computing will have "significant consequences for the quality of education that pupils receive if nothing is done to remedy the situation".

In 2023/24, yet computer science achieved just 36% of its ITT recruitment target set by DfE (Maisuria *et al*., 2023; McLean *et al*., 2024). The shortage of computing teachers means some schools, particularly those in disadvantaged areas, are unable to offer computing qualifications, including GCSE and A level Computer Science.

104 Maisuria, A., Roberts, N., Long, R. & Danechi, S. 2023. Teacher recruitment and retention in England. House of Commons. See https://researchbriefings.files.parliament.uk/documents/CBP-7222/CBP-7222.pdf (accessed 7 October 2024).

105 McLean, D., Worth, J. & Smith, A. 2024. Teacher labor market in England: Annual report 2024. National Foundation for Educational Research. See https://www.nfer.ac.uk/publications/teacher-labour-market-in-england-annual-report-2024/ (accessed 7 October 2024)

106 The Royal Society. 2017. After the reboot: computing education in UK schools. See https://royalsociety.org/~/media/policy/projects/computing-education/computing-education-report.pdf (accessed 9 October 2024).

107 Chrysalis. 2024. Representation in Computing Education.

108 The Royal Society. 2017. After the reboot: computing education in UK schools. See https://royalsociety.org/~/media/policy/projects/computing-education/computing-education-report.pdf (accessed 9 October 2024).

109 DfE. 2024. School workforce in England: Specialist teachers and hours. See https://explore-education-statistics.service.gov.uk/data-catalogue/data-set/f9a648c1-487d-471d-8599-41dc89631949 (accessed 8 October 2024).

After the national curriculum change from ICT to Computer Science in 2013, teachers received little to no subject specific training or professional development to support the change. Teachers can lack confidence in helping students solve problems in computing, particularly helping students with advanced programming[110]. As a result, teachers themselves often perceive computing as difficult and may subconsciously, discourage all but the most academically able students from pursuing the subject, excluding others who have potential. Lack of teaching specialism can reduce the number of students opting for computing courses, as teaching quality predicts students' subject-related interest.

Prioritise teacher training and professional development

Having subject specific knowledge and value perception of a subject is essential to design and deliver a high-quality curriculum, particularly in the ever-growing fields of computing and technology[111]. This is why teacher professional development is essential and has been proven to expand participation in computing education, particularly among students from underrepresented groups[112]. However, the quality of access to professional development for computing teachers, particularly since the curriculum change from ICT, has been variable[113]. Some computing teachers receive no professional development training at all[114]. It is particularly important in computing, where a high proportion of teachers are unlikely to be subject specialists, that school leaders provide sufficient subject specific training and actively support teachers in accessing these opportunities and resources.

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110 Kemp, P., Wong, B., Hamer, J. & Copsey-Blake, M. 2024. The future of computing education: considerations for policy, curriculum and practice. King's College London. See https://www.kcl.ac.uk/ecs/assets/kcl-scari-computing.pdf (accessed 23 September 2024).

111 Ofsted. 2022. Research review series: computing. See https://www.gov.uk/government/publications/research-review-series-computing/research-review-series-computing (accessed 22 November 2024).

112 Nugent, G., Chen, K., Soh, L., Choi, D., Trainin, G. & Smith, W. 2022. Developing K-8 computer science teachers' context knowledge, self-efficacy, and attitudes through evidence-based professional development. In Proceedings of the 27th ACM Conference on Innovation and Technology in Computer Science Education, Volume 1 (pp. 540 – 546). See https://dl.acm.org/doi/proceedings/10.1145/3502718 (accessed 7 October 2024).

113 Kemp, P., Wong, B., Hamer, J. & Copsey-Blake, M. 2024. The future of computing education: considerations for policy, curriculum and practice. King's College London. See https://www.kcl.ac.uk/ecs/assets/kcl-scari-computing.pdf (accessed 23 September 2024).

114 The Royal Society. 2017. After the reboot: computing education in UK schools. See https://royalsociety.org/~/media/policy/projects/computing-education/computing-education-report.pdf (accessed 9 October 2024).

Professional development training focused on inclusive teaching techniques is essential for teachers to cultivate an inclusive and supportive learning environment for all students. Teachers can then find and implement ways to actively support and augment young people's computing identities to enable them to see the relevance of computing education to their current and future lives.

In 2017, *After the reboot* highlighted the need to upskill the existing teaching workforce to deliver the computer science curriculum[115]. Following the report and the Government's *Digital Skills for the UK Economy* report[116], the National Centre for Computing Education (NCCE) was set up in 2018, funded by the Department for Education, which aims to improve the provision of computing education for every child in England. As described in Case study 2, the NCCE provides the foundations for developing teacher training infrastructure that can be expanded.

CASE STUDY 2

National Centre for Computing Education[117].

The NCCE provides continuing professional development (CPD) to computing teachers across the country, that aims to improve teacher knowledge and ability of the subject and support implementation in the classroom. Training is delivered via in-person and online training courses, resources and workshops.

Out of the 1,600 schools that have engaged with their 'Computing Quality Framework' programme, teachers reported improved subject and pedagogical knowledge, improved quality of teaching, reduced workload, increased confidence, and overall positive changes.

115 The Royal Society. 2017. After the reboot: computing education in UK schools. See https://royalsociety.org/~/media/policy/projects/computing-education/computing-education-report.pdf (accessed 9 October 2024).

116 Ecorys. 2016. Digital skills for the UK economy. See https://www.gov.uk/government/publications/digital-skills-for-the-uk-economy (accessed 6 November 2024).

117 NCCE. 2022. Impact Report. See https://static.teachcomputing.org/NCCE-Impact-report-2022.pdf?_ga=2.107270666.945374219.1728305755-1220234602.1726152588 (accessed 7 October 2024).

Careers

Surveys of secondary school students found that the most common reasons for not studying computing relate to the belief that other subjects have more value: for example, it is often believed that computing will not help young people get into their chosen career or into their preferred university/ onto their preferred course (DJS, 2021; Chrysalis, 2024).

Computing education provides digital literacy and skills that are transferable across many sectors and job roles. However, students – as well as parents and teachers – can often have a limited understanding of the breadth of careers that utilise computing skills and knowledge, and the routes available to get there. The government's latest Employer Skills Survey estimated 30% of skill-shortage vacancies in the UK involve a lack of basic skills, for example, the use of digital applications[118]. Surveys of secondary school students found that the most common reasons for not studying computing relate to the belief that other subjects have more value: for example, it is often believed that computing will not help young people get into their chosen career or into their preferred university or onto their preferred course[119, 120]. The diversity of roles that studying computing can lead to, as well as the importance of having digital literacy in all professions, are key messages to be communicated via the curriculum to ensure students leave education with the digital skills needed[121].

Plans for the future

Although computing is recognised by young people as a useful skill, it is also viewed as a highly specialist subject needing deep technical knowledge and only for students who have a clear plan. Around a quarter of young people aged 11 – 19 in the UK know what job they want in the future, showing it is important to engage with young people and their influencers early to ensure computing is a career they would consider[122]. Around 75% of students do not know which job they would like in the future[123, 124], and over half of students aged 16 – 18 are unsure of their career path[125]. This lack of clarity about career opportunities in general, combined with many students' limited awareness of careers related to computing, may add to a sense that computing is 'not for them'.

118 DfE 2023. Employer Skills Survey 2022. https://assets.publishing.service.gov.uk/media/672a2743094e4e60c466d160/Employer_Skills_Survey_2022_research_report__Nov_2024_.pdf (accessed 14 March 2024).

119 DJS. 2021. Diversity in Computing Education.

120 Chrysalis. 2024. Representation in Computing Education.

121 Kemp, P., Wong, B., Hamer, J. & Copsey-Blake, M. 2024. The future of computing education: considerations for policy, curriculum and practice. King's College London. See https://www.kcl.ac.uk/ecs/assets/kcl-scari-computing.pdf (accessed 23 September 2024).

122 Chrysalis. 2024. Representation in Computing Education.

123 *Ibid*.

124 DJS. 2021. Diversity in Computing Education.

125 *Ibid*.

BCS has established three groups that encompass all students based on their future career progression. The computing curriculum and associated careers information and guidance must address the needs of each of these: (1) pupils who become specialist computing professionals who require coding and programming expertise, (2) pupils who will work as professionals in other fields who will need to understand how to use digital technology in their sectors, and (3) pupils who do not require more specialist skills, but need to be digitally literate citizens. This was presented as evidence to The House of Lords Education for 11 – 16-year-olds Committee and published in their *Requires improvement: urgent change for 11 – 16 education* report[126].

What is important in a career?

Computing skills are in demand, and jobs requiring advanced computing skills pay well. High earnings in the technology sector provide motivation for 55% of students, particularly among 'future planners' who are self-motivated and prioritise a high-status career. However, these students can be put off studying computing if they don't see it as useful or find it too difficult[127]. These students are more likely to be from ethnic minority backgrounds, and to know what career they want compared to other students, and mention high earnings, travel, and progression opportunities as important attributes to their desired career[128].

Increasing their understanding of outward-facing computing jobs in well-known and respected companies is important to gain these students' interest. Convincing students that studying computing will give them the career attributes they look for and that this subject will pay dividends will increase the numbers choosing to study computing.

However, for most students high earnings are less of a priority in their career choices[129]. Instead, 46% of students prioritise having a job that they enjoy, which includes learning new things, having friendly colleagues and a varied role. 26% of students, particularly girls and neurodivergent students, prioritise having a job that helps others[130, 131]. It is important that students are aware of the importance of having computing and digital skills in job roles beyond those typically associated with jobs in the technology sector. Emphasising how computing skills can be useful for careers that offer variety, creativity, opportunities to explore new skills, and teamwork will challenge the stereotype of computing pathways and increase the appeal of computing subjects among students with varying career aspirations.

126 House of Lords. 2023. Requires improvement: urgent change for 11-16 education. See https://publications.parliament.uk/pa/ld5804/ldselect/ldedu1116/17/17.pdf (accessed 22 November 2024).

127 DJS. 2021. Diversity in Computing Education.

128 Chrysalis. 2024. Representation in Computing Education.

129 DJS. 2021. Diversity in Computing Education.

130 DJS. 2021. Diversity in Computing Education.

131 Chrysalis. 2024. Representation in Computing Education.

As well as in formal education, diverse digital opportunities can be showcased through extracurricular clubs, university visits, and inviting various computing professionals into schools and colleges to talk about their experiences and careers, which could raise aspirations among students and promote diverse role models in the industry. Provision of such opportunities must be accessible and available to all students, with additional provision for those who would usually struggle to take part in such activities.

There are geographical restrictions on roles available in the technology sector across the UK, with most tech job vacancies being in London and South East England and relatively very few vacancies in North East England, East Midlands, Yorkshire and the Humber, and outside of England[132]. It is important that outreach events and computing education initiatives are particularly focused in areas with lower computing and technology industry links. All students having a comprehensive understanding of careers that utilise digital skills can foster inclusivity in the field of computing.

Inclusivity of students from deprived areas

Young people from areas of high deprivation (UK schools in areas in deciles 1 to 3 of the IMD) appear less likely to be informed about computing as a possible career trajectory. They have reported not knowing much about computing careers but are significantly more interested in finding out about them, and choosing GCSE and other level 2 computing qualifications compared to students from areas of low deprivation[133].

The effects of reduced science capital of students from disadvantaged areas, along with a lack of specialist computer science teachers and reduced access to technology both inside and outside of school, mean students from areas of high deprivation may miss out on a coherent computing education. Despite their significant interest in and motivation to study the subject, these students may have little access to computing careers. Students from areas of high deprivation are less likely to know what job or career they want, or sector they would like to work in, but are particularly focused on job attributes that can help them progress such as learning new skills and opportunities for fast career progression[134]. It is important that students across the country have equitable access to computing education.

132 TechNation. 2023. People and Skills Report 2022. See https://technation.io/report/people-and-skills-report-2022/ (accessed 1 November 2024)

133 Chrysalis. 2024. Representation in Computing Education.

134 Chrysalis. 2024. Representation in Computing Education.

Computing capital

Interactions between a student's capital, identity, and the subject field are key factors influencing their engagement with a subject. Developing a computing identity is affected by a young person's access to computing-related capital from an early age and is often derived from informal experiences such as family support or extracurricular activities and hobbies[135]. This experience plays a key role in building computing knowledge. The primary reasons given by suitably qualified students for not taking computing at key stages 4, 5, or degree level are not liking or not being interested in the subject[136, 137, 138]. Therefore, increasing computing capital over time and from a young age could enable students to develop a computing identity, and consequently an interest and passion for the subject[139].

Interpersonal influence

Computing-related capital is often derived from being encouraged to continue with the subject by family, friends or social contacts with computing knowledge, interests, jobs or qualifications. Parents and other familial figures are often a child's most influential role model[140].

As with other STEM subjects, the computing capital of families strongly affects how likely young people are to take computing qualifications post-16 and aspire to a computing-related career. However, families with strong STEM capital are more likely to be middle class[141] and therefore measures which enable students from all backgrounds to access specific and sustained support would help these students to continue with computing.

When choosing subjects to study, students are often influenced by conversations with teachers around subject choices and potential career interests, and encouragement from family members to follow a particular path[142]. 65% of students named parents or carers as having an impact on their subject choices, while 46% of students named teachers as a key influence[143]. In practice, this led to students taking established STEM subjects such as science and mathematics at A level, rather than the newer and less familiar subject of computer science. Children in families where parents and carers valued jobs in computing were 61% more likely to aspire to working as a computer scientist[144].

65% of students named parents or carers as having an impact on their subject choices, while 46% of students named teachers as a key influence.

135 Holmegaard, H., Archer, L., Godec, S., Watson, E., MacLeod, E., Dewitt, J. & Moote, J. 2024. Feeling the weight of the water: a longitudinal study of how capital and identity shape young people's computer science trajectories over time, age 10-21. Computer Science Education, 1-29. https://doi.org/10.1080/08993408.2024.2320009

136 DJS. 2021. Diversity in Computing Education.

137 Archer, L. *et al* ASPIRES 3 Summary Report: Computing. UCL. See https://discovery.ucl.ac.uk/id/eprint/10182299/1/ASPIRES3%20Computing.pdf (accessed 19 September 2024).

138 Chrysalis. 2024. Representation in Computing Education.

139 Archer, L. *et al*. 2023. ASPIRES 3 Summary Report: Computing. UCL. See https://discovery.ucl.ac.uk/id/eprint/10182299/1/ASPIRES3%20Computing.pdf (accessed 19 September 2024).

140 Chrysalis. 2024. Representation in Computing Education.

141 Archer, L *et al*. 2023. ASPIRES 3 Summary Report: Computing. UCL. See https://discovery.ucl.ac.uk/id/eprint/10182299/1/ASPIRES3%20Computing.pdf (accessed 19 September 2024).

142 Chrysalis. 2024. Representation in Computing Education.

143 DJS. 2021. Diversity in Computing Education.

144 Kemp, P., Wong, B., Hamer, J. & Copsey-Blake, M. 2024. The future of computing education: considerations for policy, curriculum and practice. King's College London. See https://www.kcl.ac.uk/ecs/assets/kcl-scari-computing.pdf (accessed 23 September 2024).

Schools with a higher number of girls taking computing tend to offer a range of extracurricular clubs that foster relationships with students and promote an inclusive computing culture. Workshops, coding clubs, competitions and other outreach engagement programmes could increase computing capital and enjoyment in all schools.

Equipping teachers and family members with knowledge about computing course content, digital job opportunities and the importance of digital skills in today's work environment can empower young people to make informed choices.

It is important to students who fall into the 'future planners' category that their parents approve of their future lives[145], and so increasing the understanding and prospects of computing jobs in wider society is important to engage students. Similarly, 'socially influenced' students are strongly externally focused, meaning their decisions are influenced by how their family and peers behave and what they think[146]. Increasing science capital across society will improve understanding and appreciation of science among the parents and peers that students look up to.

Access to digital technology

Having access to digital technology from a young age builds computing capital. This can be done at home through unstructured and informal computing-related activities, often self-directed hobbies, such as playing or designing computer games, teaching oneself to code, or building computers. However, access to digital resources at home is not equitable over different economic, social and geographical ranges.

In 2020, the Covid-19 pandemic highlighted the scale of the digital divide across young people in the UK and, as a result, the DfE's Get Help with Technology service delivered 1.3 million laptops and tablets to disadvantaged children with limited or no access to the internet[147]. This service has since closed and currently a third of all school children do not have continuous access to a suitable device at home for learning, a figure that has risen since 2021[148]. An education technology survey of 12,000 schools carried out by DfE in 2020 – 2021 found that just 1% of primary schools and 2% of secondary schools provide access to at least one mobile device for every pupil[149]. The same study showed the majority of headteachers and teachers believe that technology resources would contribute to improved pupil attainment, but financial barriers at school and home, as well as teachers' skills and confidence, mean access to educational technology is patchy[150]. This can put students from low socioeconomic backgrounds at a disadvantage relative to their more affluent peers since they are less likely to access digital technology.

145 DJS. 2021. Diversity in Computing Education.

146 *Ibid*.

147 DfE. 2020. Get help with technology for remote education. See https://www.gov.uk/government/collections/get-help-with-technology-for-remote-education (accessed 24 October 2024).

148 Ofcom. 2024. Children and parents: media use and attitudes report. See https://www.ofcom.org.uk/siteassets/resources/documents/research-and-data/media-literacy-research/children/children-media-use-and-attitudes-2024/childrens-media-literacy-report-2024.pdf?v=368229 (accessed 24 October 2024).

149 CooperGibson Research. 2021. Education technology (EdTech) survey 2020-21. See https://assets.publishing.service.gov.uk/media/621ce8ec8fa8f54915f43838/Education_Technology_EdTech_Survey.pdf (accessed 22 November 2024).

150 Ecorys. 2022. Future opportunities for education technology in England. See https://assets.publishing.service.gov.uk/media/629f2065e90e070395bb3e4c/Future_opportunities_for_education_technology_in_England_June_2022.pdf (accessed 22 November 2024).

Recognition of informal learning

With reduced computing capital and low or no access to digital technology, 43% of students report that they don't feel as though they belong in computing education, and students from lower socio-economic backgrounds and without anyone who has completed tertiary education are significantly less likely to feel that they belong in computing[151]. With young people feeling that they belong in the computing classroom being associated with a 53% increase in students' aspirations to become a computer scientist[152], supporting students' computing identity will enable more students to see computing as a possible subject choice.

Attendance at computing or coding clubs outside of school is lower compared to other types of formal enrichment activity such as sports or music[153]. To encourage participation in extracurricular clubs from diverse groups of students it is important that the clubs take place at accessible times, and that opportunities available match students' interests, such as creative digital opportunities that many girls report are most appealing to them[154, 155]. Even so, provision usually depends on the staff, resources, and budget available in schools.

Schools that have a higher number of girls taking computing tend to offer a range of extracurricular clubs that foster relationships with students and promote an inclusive computing culture. Workshops, coding clubs, competitions and other outreach engagement programmes could increase computing capital and enjoyment[156].

Computing is more commonly an informal hobby pursued outside school that young people may spend many hours each week doing. For example, 17% of students surveyed solve coding challenges outside school, 14% build web pages, 9% design their own video games and 8% build computers.

Neurodivergent individuals and other students who are typically disengaged with formal computing education are significantly more likely to design their own video games and build computers than their neurotypical counterparts[157, 158]. This offers a non-traditional route into the technology sector that could be better exploited to tap into this talent. Outreach programmes and extracurricular activities could find computing talent outside of formal education and guide young people with potential in computing into related professions or sectors according to their interests and abilities[159].

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151 DJS. 2021. Diversity in Computing Education.

152 Kemp, P., Wong, B., Hamer, J. & Copsey-Blake, M. 2024. The future of computing education: considerations for policy, curriculum and practice. King's College London. See https://www.kcl.ac.uk/ecs/assets/kcl-scari-computing.pdf (accessed 23 September 2024).

153 *Ibid*.

154 Google. 2023. Breaking Barriers. See https://services.google.com/fh/files/misc/breaking_barriers_europe_report.pdf (accessed 19 September 2024).

155 Kemp, P., Wong, B., Hamer, J. & Copsey-Blake, M. 2024. The future of computing education: considerations for policy, curriculum and practice. King's College London. See https://www.kcl.ac.uk/ecs/assets/kcl-scari-computing.pdf (accessed 23 September 2024).

156 Chrysalis. 2024. Representation in Computing Education.

157 DJS. 2021. Diversity in Computing Education.

158 Chrysalis. 2024. Representation in Computing Education.

159 DJS. 2021. Diversity in Computing Education.

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