Who wants to be a computer scientist? The computing aspirations of students in English secondary schools

International Journal of Science Education

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tsed20

Who wants to be a computer scientist? The computing aspirations of students in English secondary schools

Jessica M. M. Hamer, Peter E. J. Kemp, Billy Wong & Meggie Copsey-Blake

To cite this article: Jessica M. M. Hamer, Peter E. J. Kemp, Billy Wong & Meggie Copsey-Blake (2023): Who wants to be a computer scientist? The computing aspirations of students in English secondary schools, International Journal of Science Education, DOI: 10.1080/09500693.2023.2179379

To link to this article: https://doi.org/10.1080/09500693.2023.2179379

Published online: 11 May 2023.

INTERNATIONAL JOURNAL OF SCIENCE EDUCATION
https://doi.org/10.1080/09500693.2023.2179379

Routledge
Taylor & Francis Group

OPEN ACCESS Check for updates

Who wants to be a computer scientist? The computing aspirations of students in English secondary schools

Jessica M. M. Hamer [a], Peter E. J. Kemp [a], Billy Wong [b] and Meggie Copsey-Blake [a]

[a] King's College London, London, United Kingdom; [b] University of Reading, Reading, United Kingdom

ABSTRACT
Despite being in a digital age, the diversity of young people choosing to study and work in computing is of ongoing concern, especially low numbers of girls. This paper aims to determine the profile of students who are more likely to aspire to be computer scientists and provide insights into the key factors that shape their aspirations in this area. We draw on questionnaire data from 4,983 secondary school students in England, who have a higher-than-average uptake of GCSE Computer Science (a national exam taken by students at age 16). Amongst students who have chosen to study GCSE Computer Science, girls have a lower odds of aspiring to be a Computer Scientist compared to boys. Amongst younger students yet to pick their GCSE options, there are significantly more girls than boys wanting to work in digital art. Multivariable regression analysis identified 10 factors that were associated with aspirations to become a computer scientist. These include being a boy, being of Asian ethnicity, currently studying GCSE Computer Science, having a parent in computing, as well as having higher 'coding self-belief', elevated levels of 'family support' and aspiring towards 'technical jobs'. Implications for practice and curriculum design are discussed.

ARTICLE HISTORY
Received 7 July 2022
Accepted 7 February 2023

KEYWORDS
Secondary/high school; computing; gender

Introduction and rationale

There are concerns internationally about the low numbers of young people choosing to study and work in computing post-compulsory education (e.g. UNICEF, 2020). Young people lose out on the social and economic opportunities that studying and/or working in this area can provide for both the individual and society. In England, girls in particular miss opportunities to learn digital skills, which if not addressed, will result in their potential remaining untapped. This can perpetuate social inequalities through lower pay and unemployment associated with the increasing automation in the workplace (e.g. UNICEF, 2020; Vitores & Gil-Juárez, 2016).

CONTACT Jessica M. M. Hamer Jessica.hamer@kcl.ac.uk School of Education, Communication and Society, King's College London, London, SE1 9NH, United Kingdom @DrJessicaHamer

Concerns about the numbers of young people in England leaving school with little or no digital skills, especially programming, are ongoing (e.g. BBC News, 2021; The Guardian, 2011). Consequently, considerable discussion has been had about the value of computer science and its 'enormous importance to the economy', as well as its place as a subject that underpins the sciences and engineering – subjects which are becoming ever more crucial (Royal Society, 2012). Furthermore, as the workplace becomes increasingly digitalised, the demand for digital skills, such as those developed by a comprehensive computing curriculum, will increase. This is likely to be particularly true for those young people seeking to work in 'digital jobs' such as animation, design in engineering, research and quantitative data analysis (Djumalieva & Sleeman, 2018). Research by the Learning and Work Institute (2021) indicates that 94% of employers in the United Kingdom (UK) believe that the digital skills required by their workforce will either stay the same or increase in the following 5 years. This demand is also highlighted by AND Digital (2002) who estimate an additional 3–5.7 million jobs in the UK will require digital skills by 2025, with the low end being equivalent to more than every graduate entering the workforce each year.

At around 14–16 years of age, young people in English schools can opt in to computing with a General Certificate of Secondary Education (GCSE) qualification in Computer Science (CS). GCSE CS is a relatively new qualification that began in 2014, replacing the GCSE Information Communication Technology (ICT), which was fully discontinued in 2017. The current computing curriculum and GCSE CS have a greater emphasis on coding and programming as a means of creating a 'rigorous, fascinating and intellectually challenging subject' (Department for Education, 2012). However, since 2014, there are now fewer young people choosing any computing qualification at GCSE than before the curriculum changes. In 2020 alone, there were around 25,000 fewer young people selecting any computing GCSE subject than in 2014 (Joint Council for Qualifications, 2014; 2020). This represents a 29% drop in the number of young people choosing a digital GCSE. Furthermore, the change in the computing curriculum appears to have disproportionately affected some groups of young people more than others, in particular girls, who made up just 22% of the GCSE CS cohort versus 43% of the GCSE ICT in 2017 (Joint Council for Qualifications, 2017; 2020; Kemp & Berry, 2019). This represents a substantial loss of opportunity for young people, especially girls, to study a subject and pursue a career that can offer them the skills and knowledges they need to be successful in a technology-rich future (Royal Society, 2017).

The apparent inequitable impact of the curriculum changes in computing needs to be explored further so that we can begin to address this issue. This paper, therefore, explores the factors associated with aspirations to work in computer science and who aspires to become a computer scientist. At a time when shortfalls in computing participation are becoming increasingly important for the individual and society, a better understanding of who is and who is not interested in becoming a computer scientist will provide valuable insights for parents, teachers, careers advisors and educators in higher education, concerning strategies for increasing participation in computer science.

Background literature

Factors associated with the aspirations of young people in STEM and computing

The association between the aspirations of young people and their later career choices has been well-studied (Croll, 2008; Hartung et al., 2005). However, whilst there is considerable research on the aspirations of young people in science and engineering, there is a dearth of literature that looks specifically at the domain of computer science (e.g. Archer et al., 2013; Chan et al., 2019). Within this review of the literature on career aspirations, we focus on aspirations in Science, Technology, Engineering and Mathematics (STEM), as well as computing and computer science more specifically.

There is research to suggest that a student's interest in science is mostly formed by the age of 14 and career aspirations in science at this age are strongly associated with university science uptake (Lindahl, 2007). Research by Gottfredson (1981) found that by 6–8 years of age, children associate different jobs with different genders, and are less interested in those that do not appear to be aligned with their gender. By the age of 9–12 years, children consider some jobs as having greater status and requiring more intelligence than others and are less inclined towards those that are perceived as dissimilar to abilities. By the age of 14, young people have chosen their career paths based on their knowledge and experience of these fields up to this point in their lives and some years before they start work (e.g. Chen, 2009). This is confirmed by the work of Archer et al. (2020) who identified that job aspirations across a range of STEM and non-STEM jobs were generally stable between the ages of 10 and 18 years. High aspirations to work in STEM are strongly associated with being a boy, being from some minority ethnic backgrounds (especially being Asian or Black) and having elevated levels of cultural capital (DeWitt & Archer, 2015). Furthermore, studies have found that academic attainment, self-beliefs, parental influence, school environment, student interest and gender are among the factors that influence aspirations in young people (e.g. Archer et al., 2014b; DeWitt & Archer, 2015; Pottorff et al., 1996; Strand & Winston, 2008; Whitehead, 1996).

Attitudes and aspirations

Career aspirations in the STEM subjects have been associated with expectancy-value models that explore domain-specific self-beliefs. Where self-beliefs are positive, students' aspirations in these subjects are higher (e.g. DeWitt & Archer, 2015; Eccles et al., 1998; Papanastasiou & Papanastasiou, 2004). Furthermore, an association exists between attitudes and aspirations in computing, but these have not yet been fully explored (e.g. Makrakis, 1993).

There have been numerous studies that explore self-beliefs in relation to computing. However, most have been focused on students in the United States (e.g. Mason & Rich, 2020; Torkzadeh & Koufteros, 1994; Vandenberg et al., 2021). In England, Leonard, Quinlan and Sentance (2021) found that there was a difference in attitudes towards computing between boys and girls aged 10–11 and 12-13. Girls reported less programming experience (e.g. He & Freeman, 2010) and seemed to show interest in computer science at an older age than boys, which can, in turn, impact their attitudes and future aspirations (Lang, 2010). Although Leonard et al. (2021) were unable to demonstrate that the difference in attitudes between girls and boys had an impact on subject choice at age 13, they speculate that it is highly probable, especially as previous research suggests that girls' computing and mathematical self-beliefs tend to correlate with participation in computer science (Lips & Temple, 1990).

The classroom experience

There is considerable literature that describes how positive experiences of STEM in school can increase aspirations to jobs in STEM. This includes supportive relationships with class teachers and teaching methods that highlight the value and relevance of science (e.g. Aschbacher et al., 2010; Barmby et al., 2008). Research suggests that positive classroom experiences can influence a young person's decision to choose a subject post-compulsory education (e.g. Lyons et al., 2012; Murphy & Whitelegg, 2006). A study of physics education by Mujtaba and Reiss (2013) found that teacher support and encouragement were mostly associated with future participation in physics post-compulsory education. They found that girls were less likely to receive as much encouragement. Another recent study found that being underrepresented in a mixed classroom may have an impact on feelings of 'belonging' for girls in the computing classroom (Leonard et al., 2021). These studies suggest that girls may often underestimate their computing skills by comparing themselves to boys, who are more likely to have had more computing experience. This may then affect girls' belonging and identity in computing. There is some, limited, research that suggests that amongst younger students (< 11 years), having positive computing experiences at school may have some role in increasing the likelihood of them wanting to work in computing (Tran, 2018), and that computing self-beliefs already differ by gender in primary school-aged children (Leonard et al., 2021).

The impact of computing stereotypes

Stereotypes exist in computing, where people who 'do' computing are considered clever but antisocial, which can be unattractive for young people who do not identify with those characteristics (Wong, 2016). The study found that whilst most enjoy computing, few aspired to becoming a 'computing person'. Exposure to computer scientists who demonstrate stereotypical interests and characteristics has been found to reduce aspirations into computer science for girls, regardless of the gender of the computer scientist role model (Cheryan et al., 2013). Furthermore, if students believe that computer scientists demonstrate a 'geek culture', which does not align with their own view of themselves, they are unlikely to see the relevance of CS to their future (Varma, 2007).

The influence of parents and carers

Parents and carers have an important influence on the aspirations of young people (e.g. Archer et al., 2015), but is often under-explored in the STEM subjects (Jones & Hamer, 2022). Archer et al. (2015) found that the strongest association with aspirations in science has been linked to a young person's attitude towards science at school and the attitudes of their parents. Furthermore, in the physics domain, Jones and Hamer (2022) found that whether parents themselves enjoyed physics, if they thought of their child as academic and whether they considered physics useful for getting a job, were the most important predictors of whether the parents thought their child would go on to study physics post-16. Jacobs et al. (2006) demonstrated that parents' attitudes towards occupation expectations when their child was 15 were later associated with their child's aspirations at 17. Furthermore, the parents' job expectations for their child at 17 were found to be related to the actual job that their child had at 28.

In the Wellcome Trust (2020) report, family science connections were identified as an important influence on the aspirations of young people in science. This reinforces the findings of Archer et al. (2012) who determined that the science career aspirations of young people are formed within the family environment, and therefore families play an important yet complex role. They describe the sum of the knowledge, attitudes, resources and experiences in and of science by an individual as their 'science capital' (Archer et al., 2015). The authors found that middle-class families, that had significant science capital, were more likely to have a child that aspired to be a scientist. In these families, science was as a 'natural' choice – albeit one that was encouraged and supported. Conversely in working-class families, even if the child expressed an interest in science, the lack of science capital within the family meant that, in many instances, there was less of a 'push' by the family towards the subject (Archer et al., 2012).

A study by Lindley et al. (2019) of 2,074 pairs of students and their parents in secondary schools in England, and found that the parents and carers of Asian, Asian British, Black African, Black Caribbean and Black British young people, as well as those living in the most deprived areas, were more likely to advise their child to take GCSE CS. They also discovered that both parents and students were less likely to know about jobs in computer science compared to more traditional subjects such as mathematics and that the parents of girls were less likely to talk to them about jobs in computer science than the parents of boys (Lindley et al., 2019).

However, it is important to note that these links are complex in that enjoyment of science and positive parental attitudes do not necessarily translate into aspirations to be a scientist (Archer et al., 2010; DeWitt & Archer, 2015; Jones & Hamer, 2022).

Computing jobs and interests

There is limited research on the factors that explore aspirations in computing and computer science. Research by the Wellcome Trust (2020) found that young people aged 7–13 in England cited creativity, interest and relevance to real life as motivations to study computer science. However, lack of interest, difficulty and lack of fit with future aspirations were given as reasons for not choosing the subject. The same report found that computer science was more popular as a higher education subject amongst the boys surveyed than the girls, who demonstrated a greater interest in a healthcare pathway. Moreover, the aspiration to a career in computing was not associated with GCSE Science attainment (Wellcome Trust, 2020).

A qualitative study by Wong and Kemp (2018) on the career aspirations of young people aged 13–19 identified that many of those interviewed aspired to use their digital skills creatively, especially girls. They found that much of the discourse around computer science demonstrated gender stereotypical views, whereas that around using digital skills creatively did not. A pilot study by Archer et al. (2014a) in a secondary school in England found that student aspirations in STEM are very resistant to intervention. However, student's understanding of 'where science can lead' may be easier to influence and change.

With the relatively recent changes to the computing curriculum in England, our study provides an opportunity to explore whether the digital aspirations of young people are in alignment with the current computing curriculum in co-educational state secondary schools. Furthermore, there is an opportunity to understand who aspires to be a computer scientist, and it is important that we begin to address the issues faced by underrepresented and underserved groups of young people in computing. This research also enables us to compare findings with research in other areas of STEM and suggests how transferable ideas around 'science capital' can be linked to computing education.

Methodology

This paper uses quantitative methods to explore students' aspirations in computing. The study was undertaken in 15 secondary schools with a higher-than-average uptake of GCSE CS in England.

This paper aims to answer the following research questions:

(1) What are the background characteristics of young people who are more likely to aspire to become a computer scientist?
(2) Which factors influence aspirations to become a computer scientist?
(3) Which 'digital jobs' do young people aspire to?

The survey was online and based on the background literature described above. Survey items were developed using pre-validated scales where possible, with the addition of new items covering aspects identified as potentially useful in existing studies. The next subsection describes an outline of the development and deployment of the survey items. Composite factors were identified through factor analysis and detailed elsewhere (Hamer et al., under preparation). Multivariable logistic regression analysis was then undertaken with 'aspiration to be a computer scientist' as the dependent variable.

Students from 15 co-educational state secondary schools in England completed the survey. Single-sex, selective and independent schools were not invited as the focus of the research is to explore the aspirations and experiences of diverse groups of learners from state schools. Schools were identified through national datasets, local contacts, computing networks and via social media. The participating schools all offered GCSE CS and had at least two classes of students in each GCSE year group choosing the subject, so they are not representative of the national population, but reflect schools with the current 'best scenario' of computer science uptake in England. Students in years 7–11 (ages 11– 16) were invited to complete the survey online during school time.

The project received institutional approval on ethics, and consent was agreed with the schools, students and their families. Data collection was undertaken between June 2021 and March 2022. Table 1 describes the background characteristics of the students surveyed.

Table 1. Background characteristics of the sample, split by whether they are studying GCSE Computer Science or if they have not yet chosen their GCSE option subjects.

Background characteristic	*n*	GCSE Computer Science		
		Not yet chosen, *n* = 3300	No, *n* = 684	Yes, *n* = 927
Gender, n (%)	4590			
Boy		1485 (50%)	282 (41%)	671 (73%)
Girl		1316 (44%)	375 (55%)	206 (22%)
Not listed		59 (2%)	13 (2%)	19 (2.1%)
Prefer not to say		126 (4%)	13 (2%)	25 (3%)
Ethnicity, n (%)	4606			
Asian		462 (15%)	72 (11%)	153 (17%)
Black		232 (8%)	56 (8%)	49 (5%)
Chinese		29 (1%)	9 (1%)	15 (2%)
Mixed		208 (7%)	39 (6%)	67 (7%)
Other		212 (7%)	36 (5%)	57 (6%)
White		1793 (60%)	466 (68%)	568 (62%)
Prefer not to say		66 (2%)	6 (1%)	11 (1%)
Family members work in IT or a job that uses advanced computing skills, n (%)	4655			
Yes		1020 (33%)	205 (30%)	322 (35%)
No		1278 (42%)	343 (50%)	444 (48%)
Don't know		754 (25%)	135 (20%)	154 (17%)
Parents/carers went to university, n (%)	4653			
Yes		1544 (51%)	346 (51%)	453 (49%)
No		726 (24%)	229 (34%)	285 (31%)
Don't know		779 (26%)	108 (16%)	183 (20%)
Primary computing, n (%)	4195			
Yes		1913 (74%)	456 (67%)	560 (61%)
No		457 (18%)	157 (23%)	297 (32%)
I'm not sure		224 (9%)	66 (10%)	65 (7%)
Number of books in the home, n (%)	4013			
None-few (0-25)		739 (28%)	178 (30%)	242 (30%)
Many (>26)		1857 (72%)	425 (70%)	572 (70%)
Recipient of free school meals in the last 6 years, n (%)	4606			
Yes		901 (30%)	138 (20%)	179 (19%)
No		1655 (55%)	491 (72%)	687 (75%)
Don't know		444 (15%)	55 (8%)	56 (6%)

The survey instrument

The survey instrument consisted of 244 items in total, which were grouped according to prior research and theoretical constructs. This also included demographic information, items about the students' future job aspirations, their experiences of computing, as well as teacher and family support. The survey began with items relating to the background of the student (e.g. gender, year group and ethnicity). The survey was adapted from several sources, such as items relating to 'cultural capital' and the number of books at home (Sieben & Lechner, 2019), and whether a parent/carer works in computing or technology (DeWitt & Archer, 2015). This was followed by Likert-type items covering multiple aspects of the learner's experience of classroom computing (DeWitt & Archer, 2015), including extra-curricular participation in computing (Quinlan, 2015), parental support (Jones & Hamer, 2022), job aspirations (Mujtaba & Reiss, 2013) and self-beliefs in coding (Vandenberg et al., 2021). Additional open-text questions around thoughts on gender and computer science (new item) and student descriptions of the 'ideal' computer science student were also included but are not discussed in this paper. The survey was initially trialed in two schools, to refine the survey items

Table 2. Summary of composite factors.

Composite factor	Example items	Items, n	Chronbach α
Coding self-beliefs	I would like to use coding to make something new; Using code will be important in my future jobs.	5	0.91
Computing and society	Computers make the world a better place; Computers are a force for good.	5	0.77
Computing lesson	I understand everything in computer lessons; I am better at computing than my classmates.	4	0.89
Computing literacy	In my spare time I read about computing or IT online (e.g. news websites, blog posts); In my spare time I read a book, magazine or newspaper about computing or IT.	3	0.71
Creative jobs	I would like to work as a designer; I would like to work as a digital artist.	3	0.67
Digital making	In my spare time I make computer games; In my spare time I make phone Apps.	6	0.66
Family support	My parents/carers would be happy if I became a computer scientist in the future; My parents/carers think computing or IT is interesting.	4	0.83
Perceptions of computer scientists	Computer scientists do valuable work; Computer scientists have to be creative in their work.	6	0.78
Professional jobs	I would like to work as a doctor; I would like to work as a lawyer.	3	0.63
Stereotypes	Spend most of their time working by themselves; Are usually men.	5	0.70
Teacher support	My computing teacher is interested in me as a person; My computing teacher listens to what students think.	6	0.91
Technical jobs	I would like to work as an electrician, plumber, builder, or in a trade; I would like to work as an engineer.	4	0.72

further prior to sharing with the 15 participating schools. Details of the validation of the survey instrument and individual items are described elsewhere (Hamer et al., under preparation).

Exploratory factor analysis identified 12 composite factors within the survey. These are summarised in Table 2.

Survey analysis

In order to create a picture of who is likely to express aspirations to be a computer scientist, the 'aspirations in computer science' Likert-item was transformed into a dichotomous dependent variable. Students who reported that they 'Somewhat agree' or 'Strongly agree' that they are interested in a job in computer science were interpreted as aspiring to become a computer scientist ('yes'). Those that responded by saying they 'Strongly disagree', 'Somewhat disagree' and 'Neither agree nor disagree' in being interested in a job in computer science were interpreted as having 'no' aspirations in computer science. A multivariable logistic regression, which explores which variables most strongly predict a categorical (yes – no) outcome, was undertaken to determine which background variables predict aspirations to computer science. McFadden's pseudo-R^2 for logistic regression was found to be 0.17 for a 5-variable model of the background characteristics (Table 2). A pseudo-R^2 can be up to 1 but values are generally much lower than a standard R^2. Pseudo-R^2 values between 0.2 and 0.4 are deemed an 'excellent' fit by McFadden (2021).

To determine the job aspirations of young people who do, do not or have not yet chosen to study computer science, simple logistic regressions were undertaken with a range of other jobs as the dependent variable and gender as the independent variable. The jobs have been similarly transformed into a dichotomous dependent variable as described above.

A further multivariable logistic regression (using a stepwise deletion method) was used to identify associations between the identified composite factors (Table 2) and aspirations in computer science in addition to the background variables. The McFadden psuedo-R^2 for this model was 0.46.

Results

A total of 4983 students from 15 state secondary schools took part in the survey. After data cleaning, they could be split into 3 groups according to whether they were studying GCSE CS (ages 13-16) or whether they were yet to choose the subject (ages 11–14) (Table 1).

Who aspires to be a computer scientist?

To identify who aspires to be a computer scientist, the Likert item 'Wanting to work as a computer scientist' was used as the dependent variable. Of all students in our sample, 29% aspired to be a computer scientist. 39% of boys, 15% of girls, 31% of those whose gender was not listed, and 27% of those who preferred not to disclose their gender, wanted to work as a computer scientist, Figure 1.

The multivariable logistic regression analysis shown in Table 3 display data as odds ratios to the reference groups, normally the largest group for a particular variable (e.g. Parent/carer not in tech or computing), and thus gives a perspective of the relative strength of the relationship between independent and dependent variables.

Multivariable logistic regression modelling identified seven significant predictor background variables, Table 3.

Regardless of whether students have chosen to take GCSE CS, or are as yet undecided, girls appear to have a lower odds of aspiring to become a computer scientist than

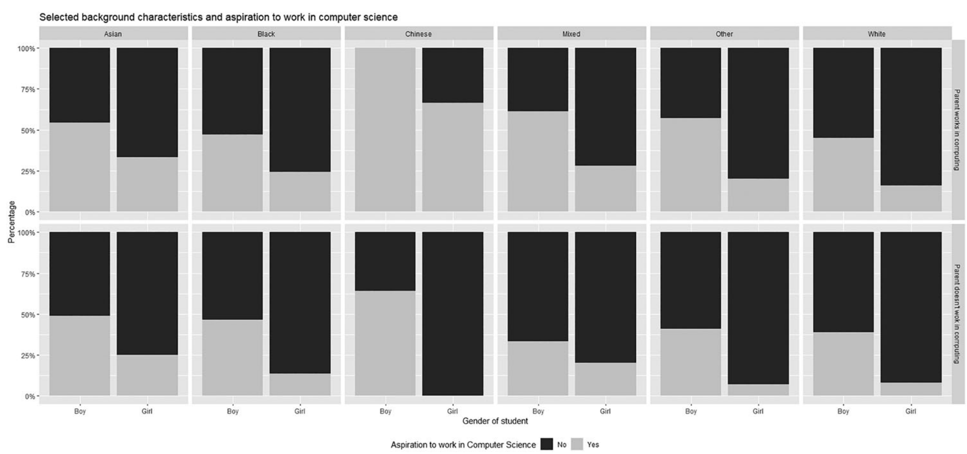

Figure 1. Selected background characteristics and aspiration to work in computer science.

Table 3. Multivariable logistic regression models for a) background variables only b) all variables, including composite factors.

a) Background variables				b) All variables			
Variable	Odds Ratio (OR)	95% Confidence Interval (CI)	Difference, %	Variable	Odds Ratio (OR)	95% Confidence Interval (CI)	Difference, %
Being a girl **	0.22	0.15, 0.32	−78	Taking CS GCSE **	2.74	1.91, 3.95	174
Being of Asian ethnicity*	1.63	1.10, 2.41	63	Coding self-belief **	2.98	2.32, 3.86	198
Prefer not to say ethnicity *	4.03	1.28, 12.60	303	Computing lessons **	1.53	1.23, 1.90	53
Taking CS GCSE**	3.93	3.00, 5.19	293	Computing stereotypes **	0.61	0.47, 0.80	−39
Not taking CS GCSE*	0.52	0.29, 0.88	−48	Family support **	1.61	1.25, 2.09	61
Parent/carer **not** in tech or computing *	0.68	0.49, 0.94	−32	Technical jobs **	2.49	2.05, 3.07	149
Unsure as to whether did computing at primary school*	0.39	0.20, 0.71	−61				

*$P < .05$, ** $p < .001$.

boys (Figures 2–4). Of those students' undecided about their GCSE subjects, 13% of girls and 35% of boys aspire to become a computer scientist. The odds of a girl not aspiring to be a computer scientist compared to boys of that group is 72% less than boys. Furthermore, less than 4% of girls who have not chosen the course aspire to become a computer scientist compared to 20% of boys. In the group that have chosen GCSE CS, 44% of girls versus 58% of boys aspire to become a computer scientist. This represents a reduction of 42% in the odds associated with girls aspiring to be a computer scientist compared to boys. Overall, someone who aspires to be a computer scientist has a greater odds of already studying the subject at GCSE, being a boy, of Asian ethnicity or prefer not to disclose this information, have a family member in the computing or technology industry, and can recall doing computing at primary school.

Which factors influence aspirations to become a computer scientist?

When composite factors and the statistically significant background variables were added into a further multivariable logistic regression model, six variables were retained (Table

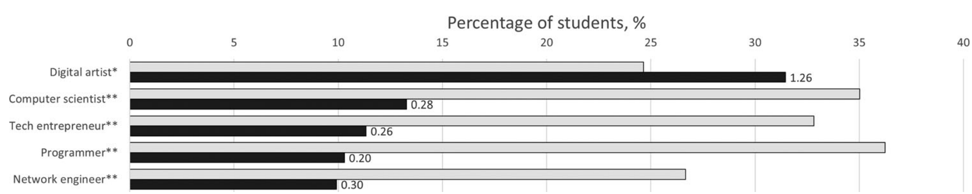

Figure 2. Digital job aspirations of those who have not yet chosen their GCSE subjects. Data labels are the odds ratios for gender (girls black, boys grey). ** $p < 0.001$, * $P < 0.05$.

2). Only one of the background variables 'GCSE Computer Science – Yes', which is the variable for those currently taking the subject, was kept within the model. This variable indicates that the odds of aspiring to be a computer scientist are almost 3 times greater than those younger students that have yet to choose the subject at GCSE. The five composite factors, 'coding self-belief', 'computing lessons', 'computing stereotypes', 'family support' and 'technical jobs' were all included in the model. All, apart from 'computing stereotypes', are associated with an increase in odds of aspiration to be a computer scientist, with each increment in composite factor score. For 'computing stereotypes', each 1 Likert scale incremental increase (1–5) is associated with a reduction in the odds of aspiring to be a computer scientist of 39%.

Which digital jobs do young people aspire to and how does this vary by gender?

The 'not yet chosen'

Young people who have yet to choose their GCSE subjects are most likely to aspire to work in business (All = 58%, Girls = 54%, Boys = 62%), be a celebrity (All = 46%, Girls = 46%, Boys = 45%) and work in sports (44%, Girls = 33%, Boys = 54%). The most popular 'digital job' aspiration in this group is become a digital artist (All = 28%, Girls = 31%, Boys = 25%). The difference reflects a 26% increase in the odds of girls aspiring to digital art compared to boys and is the only digital subject where girls have a greater aspiration compared to boys. However, for those in this cohort, it is also the digital subject that most young people would like to pursue regardless of gender. Aspiration to become a computer scientist is lower for girls than boys in this group (All = 25%, Girls = 13%, Boys = 35%), with girls having 72% lower odds of wanting a job in this area compared to boys (Figure 2).

Those taking GCSE computer science

Those taking GCSE CS most aspire to work in Business (All = 60%, Girls = 53%, Boys = 62%), be a computer scientist (All = 55%, Girls = 44% and Boys = 58%) and programmer (All = 51%, Girls = 42%, Boys = 54%). Despite the higher number of girls choosing computer scientist and programmer in this group, there is still a considerable difference in the aspirations across the digital subjects compared to boys. There is a decrease in the odds of a girl aspiring to digital jobs across all the subjects of between 38% and 54%, except for digital art which shows no statistically significant difference between boys and girls. It is also important to note that whilst the top 5 jobs for boys taking GCSE CS are: business, computer scientist, programmer, engineer and tech entrepreneur; girls aspire to the slightly different combination of: business, doctor, computer scientist, programmer and to work in education (Figure 3).

Those who have not chosen computer science GCSE

Those not taking GCSE CS have considerably different digital job aspirations to those that do take the subject, especially girls. Unsurprisingly, only 11% of students that chose not to take computer science wish to pursue a career as a computer scientist. Less than 4% of girls aspire to work as a computer scientist which contrasts with 20% of boys – the odds of a girl aspiring to be a computer scientist in this cohort are 84% less than boys. Similarly, to those who have not yet chosen and those currently taking

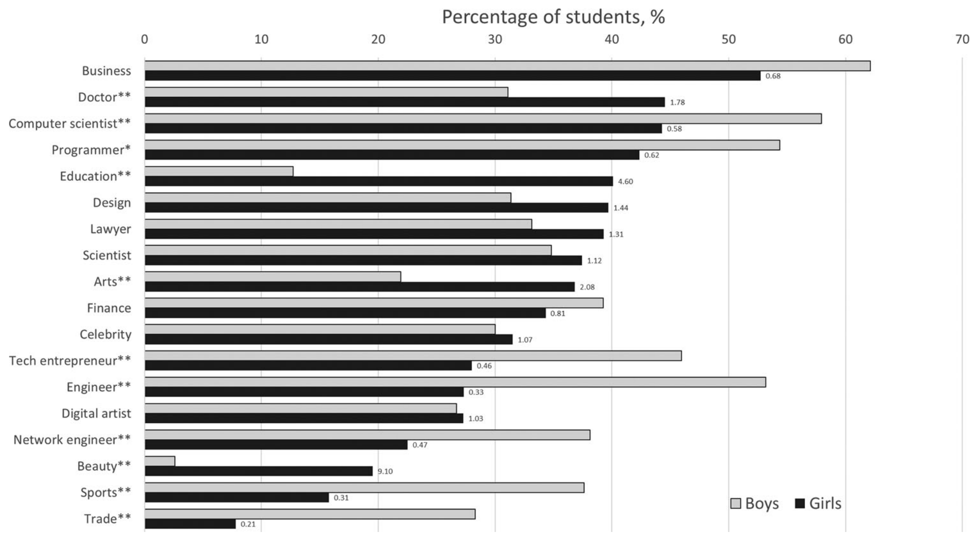

Figure 3. Job aspirations of those are currently studying Computer Science GCSE. Data labels are the odds ratios by gender (girls black, boys grey). ** *p* < 0.001, * *P* <0.05.

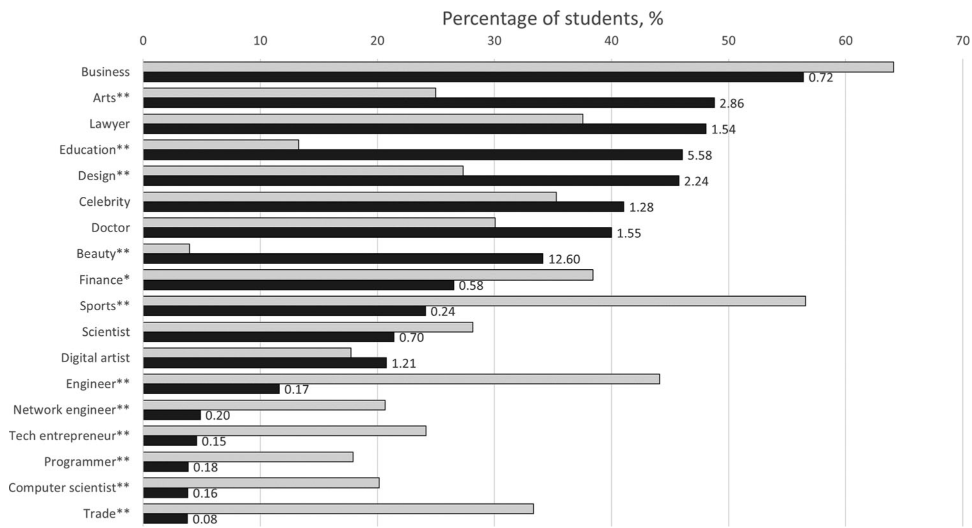

Figure 4. Job aspirations of those who chose not to study Computer Science GCSE. Data labels are the odds ratios by gender (girls black, boys grey). ** *p* < 0.001, * *P* <0.05.

GCSE CS, digital art is the only digital job where there is no significant difference in the odds of girls and boys wanting to work in this area (Figure 4).

Discussion and conclusion

Despite a large sample size, the generalisablity of these findings needs to be considered as the sample of students are from schools with at least two classes of students taking GCSE CS. The aspirations of the students are likely to reflect the 'best scenario' in terms of in-school opportunity for computing and computer science, and so the situation in other schools where there are perhaps fewer or no, specialist teachers may yield different results. Furthermore, we need to be mindful that an absence of aspiration to being a computer scientist does not necessarily mean that a young person will never pursue a career in computer science or a computing related field. However, some conclusions can be drawn and are discussed below.

When considering the background characteristics of the young people in this study, we can see similarities with other areas of STEM such as engineering and physics. Girls are less likely to aspire to be a computer scientist than boys (e.g. Chan et al., 2019). Furthermore, the association between whether a student has a parent or carer that works in computing or tech, is something that has also been observed in other areas of STEM (e.g. Archer et al., 2013; Jones & Hamer, 2022). Family support was a significant predictor of aspiration to become a computer scientist which gives further insight into the role of the family in job aspirations. If a causal link is confirmed, this suggests that by increasing family knowledge around jobs in computing, we will see increases in aspirations to computer science in the future, as suggested in the physics domain by Jones and Hamer (2022). Jacobs et al. (2006) and DeWitt and Archer (2015) found that some ethnic minority backgrounds (especially being Asian or Black) were more associated with aspirations in science. The same was true for this study with Asian (but not black students) as well as those students that 'prefer not to say' being more likely than white students to aspire to be a computer scientist. Those that were unsure whether they had experience of computing at primary school had a lower odds of aspiring to be a computer scientist than those who did computing at primary school. It is possible that these students who are unsure have had such little exposure to computing in school that they cannot identify or recall any experience at all, and therefore represent a negative association with computer science aspirations. These findings, particularly the importance placed on parents and self-beliefs in computer science, begin to hint at the idea that individuals can have varying degrees of 'computing capital', akin to the idea of 'science capital' (Archer et al. 2015). However, further research is merited.

The gender differences in digital job aspirations, even amongst those students choosing computer science at GCSE, are striking and concur with previous work (Wong & Kemp, 2018). Our findings show how the inclusion of digital art in computing education might help engage students, especially girls. This expands the findings of Sefton-Green and Brown (2014), who suggest that girls' digital interests are more likely to be around 'creative' computing (e.g. digital art) and boys' interests are more likely to be around 'technical' computing (e.g. programmer). We similarly found that digital art is popular with young people, regardless of gender, and with younger girls statistically more likely to prefer digital art compared to their boy peers. This finding is further supported by the regression analysis, which identified the 'technical jobs' composite variable as a significant predicator for the aspiration to work in computer science, and 'technical jobs' being historically more associated with men than women. Additionally, the aspiration to be a computer scientist was associated with 'coding self-belief', where previous research (e.g. Vandenberg et al., 2021) suggests that high computing and coding self-beliefs are much more common amongst boys than girls. Our work takes this further by indicating that higher self-beliefs in coding are associated with an increased likelihood of having computer science aspirations.

Furthermore, student self-beliefs within their computing lessons are also associated with increased aspiration to be a computer scientist, indicating that the teacher has a role in supporting young people to feel more confident in their ability in the computing classroom. Margolis and McCabe (2006) suggested strategies for developing self-beliefs in the classroom, such as having a clear roadmap through the curriculum that has frequent small, achievable goals. It has previously been recognised that stereotypes, especially gendered stereotypes, are linked with different aspirations in STEM (e.g. Chambers et al., 2018; McGuire et al., 2020; Wong, 2016). So, it is unsurprising that stereotypical views of the computer scientist as being male, 'odd' and having few other interests were associated with a decreased likelihood of wanting to become a computer scientist. According to Wong (2016), to identify as a 'computing person', a student may have to identify in themselves stereotypical characteristics of being antisocial and strange, and whilst young people might be happy to do computing, few are keen on becoming a computing person. We do not know if the relationship between student background and attitudes and aspirations to be a computer scientist are causal, however we are confident that this is a key area to investigate in greater depth. If there are modifiable factors and there is a causal link, then targeted interventions can be put in place. For example, working with parents and carers to ensure they have information about the opportunities that studying computer science can offer.

The computing curriculum in England currently has a strong emphasis on technical skills, especially coding (Wong & Kemp, 2018). There has been a substantial shift in content at GCSE, with the previous GCSE ICT emphasising collaborative working and communication of information and data to different audiences, and the current GCSE CS which prioritises skills such as designing, writing, testing and refining programmes, and using at least one high-level programming language (Ofqual, 2011; 2018), with large amounts of theory (Berry, 2019). Furthermore, computing teachers in England agree that programming and coding is the curriculum topic which receives the most attention in computing lessons (Mee, 2020). As the digital job aspirations of girls appear to be less well aligned with the current computing curriculum than is the case for boys, it is perhaps unsurprising that girls are less inclined to choose GCSE CS, Consequently, girls are currently less inclined to choose GCSE CS, but it seems possible with curriculum reform that greater gender parity in computing could be achieved. especially with moves towards including more digital art.

There is no doubt that computer science is valuable for individual, national and global prosperity. However, when these findings are viewed with the knowledge of the current gender imbalance in computer science, from school to the workplace, this should be of concern for us all.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by the Nuffield Foundation under Grant (EDO/FR-000022621).

Ethics statement

Approval for this research was given by the King's College London Research Ethics Committee.

ORCID

Jessica M. M. Hamer http://orcid.org/0000-0003-4587-6631
Peter E. J. Kemp http://orcid.org/0000-0003-1131-0787
Billy Wong http://orcid.org/0000-0002-7310-6418
Meggie Copsey-Blake http://orcid.org/0000-0002-6752-1201

References

AND Digital. (2002). *The nature of the UK's digital skills gap AND what this means for people and our economy*.

Archer, L., Dawson, E., Dewitt, J., Seakins, A., & Wong, B. (2015). "Science capital": A conceptual, methodological, and empirical argument for extending bourdieusian notions of capital beyond the arts. *Journal of Research in Science Teaching*, *52*(7), 9. https://doi.org/10.1002/tea.21227

Archer, L., DeWitt, J., & Dillon, J. (2014a). 'It didn't really change my opinion': Exploring what works, what doesn't and why in a school science, technology, engineering and mathematics careers intervention. *Research in Science & Technological Education*, *32*(1), 35–55. https://doi.org/10.1080/02635143.2013.865601

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2010). 'Doing' science versus 'being' a scientist: Examining 10/11-year-old schoolchildren's constructions of science through the lens of identity. *Science Education*, *94*(4), 617–639. https://doi.org/10.1002/sce.20399

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2012). Science aspirations, capital, and family habitus: How families shape children's engagement and identification with science. *American Educational Research Journal*, *49*(5), 881–908. https://doi.org/10.3102/0002831211433290

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2013). 'Not girly, not sexy, not glamorous': Primary school girls' and parents' constructions of science aspirations. *Pedagogy, Culture & Society*, *21*(1), 171–194. https://doi.org/10.1080/14681366.2012.748676

Archer, L., DeWitt, J., & Wong, B. (2014b). Spheres of influence: What shapes young people's aspirations at age 12/13 and what are the implications for education policy? *Journal of Education Policy*, *29*(1), 58–85. https://doi.org/10.1080/02680939.2013.790079

Archer, L., Moote, J., Macleod, E., Francis, B., & DeWitt, J.. (2020). Aspires 2: Young people's science and career aspirations. *Age*, 10–19. https://discovery.ucl.ac.uk/id/eprint/10092041/

Aschbacher, P. R., Li, E., & Roth, E. J. (2010). Is science me? High school students' identities, participation and aspirations in science, engineering, and medicine. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *47*(5), 564–582. https://doi.org/10.1002/tea.20353

Barmby, P., Kind, P. M., & Jones, K. (2008). Examining changing attitudes in secondary school science. *International Journal of Science Education*, *30*(8), 1075–1093. https://doi.org/10.1080/09500690701344966

BBC News. (2021). *"Huge shortage" in Digital Skills Says Apprentice Winner*. 2021. https://www.bbc.co.uk/news/technology-57101527#::text=Yet

Berry, M. (2019). We need a GCSE in computing. *Hello World*, *9*, 49. https://pure.roehampton.ac.uk/ws/files/5157322/Pages_from_HW_9_Digitaledition_4_.pdf

Chambers, N., Kashefpakdel, E. T., Rehill, J., & Percy, C. (2018). *Drawing the future: Exploring the career aspirations of primary school children from around the world*. London: Education and Employers.

Chan, C. K. Y., Yeung, J. N. C., Kutnick, P., & Chan, R. Y-Y. (2019). Students' perceptions of engineers: Dimensionality and influences on career aspiration in engineering. *International Journal of Technology and Design Education*, *29*(3), 421–439. https://doi.org/10.1007/s10798-018-09492-3

Chen, X. (2009). *Students Who study science, technology, engineering, and mathematics (STEM) in postsecondary education*. Stats in brief. NCES 2009-161. National Center for Education Statistics.

Cheryan, S., Drury, B. J., & Vichayapai, M. (2013). Enduring influence of stereotypical computer science role models on women's academic aspirations. *Psychology of Women Quarterly*, *37*(1), 72–79. https://doi.org/10.1177/0361684312459328

Croll, P. (2008). Occupational choice, socio-economic status and educational attainment: A study of the occupational choices and destinations of young people in the British household panel survey. *Research Papers in Education*, *23*(3), 243–268. https://doi.org/10.1080/02671520701755424

Department for Education. (2012). *Michael Gove Speech at the BETT Show 2012*. 2012. https://www.gov.uk/government/speeches/michael-gove-speech-at-the-bett-show- 2012

DeWitt, J., & Archer, L. (2015). Who aspires to a science career? A comparison of survey responses from primary and secondary school students. *International Journal of Science Education*, *37*(13), 2170–2192. https://doi.org/10.1080/09500693.2015.1071899

Djumalieva, J., & Sleeman, C. (2018). Which digital skills do you really need? *Nesta*. https://www.nesta.org.uk/report/which-digital-skills-do-you-really-need

Eccles, J. S., Wigfield, A., & Schiefele, U. (1998). Motivation to succeed. In W. (. E.). Damon & N. Eisenberg (Eds.), (Vol. Ed.), *Handbook of child psychology: Social, emotional, and personality development* (Vol. 3, 5th ed, pp. 1017–1095). Wiley.

Gottfredson, L. S. (1981). Circumscription and compromise: A developmental theory of occupational aspirations. *Journal of Counseling Psychology*, *28*(6), 545. https://psycnet.apa.org/doi/10.1037/0022-0167.28.6.545

Hartung, P. J., Porfeli, E. J., & Vondracek, F. W. (2005). Child vocational development: A review and reconsideration. *Journal of Vocational Behavior*, *66*(3), 385–419. https://doi.org/10.1016/j.jvb.2004.05.006

He, J., & Freeman, L. A. (2010). Understanding the formation of general computer self-efficacy. *Communications of the Association for Information Systems*, *26*, 255–244. https://doi.org/10.17705/1CAIS.02612

Jacobs, J. E., Chhin, C. S., & Bleeker, M. M. (2006). Enduring links: Parents' expectations and their young adult children's gender-typed occupational choices. *Educational Research and Evaluation*, *12*(4), 395–407. https://doi.org/10.1080/13803610600765851

Joint council for qualifications. (2014). *Provisional GCSE (full course) results - June 2014*. 2014. https://www.jcq.org.uk/wp-content/uploads/2018/11/GCSE-Full- Course-Results-by-Age-Group-2014.pdf

Joint Council for Qualifications. (2017). *GCSE (Full Course) outcomes for all grade sets and age breakdowns for uK Candidates*. 2017. https://www.jcq.org.uk/wp-content/uploads/2018/11/GCSE-Full-Course-Results-Summer-2017.pdf

Joint Council for Qualifications. (2020). *Gcse (full course) outcomes for Key grades for UK, England, Northern Ireland & Wales, Including UK Age Breakdowns*. https://www.jcq.org.uk/wp-content/uploads/2020/09/GCSE-Full-Course-results-Summer-2020.pdf

Jones, K. L., & Hamer, J. M. M. (2022). Examining the relationship between parent/carer's attitudes, beliefs and their child's future participation in physics. *International Journal of Science Education*, *44*(2), 201–222. https://doi.org/10.1080/09500693.2021.2021457

Kemp, P. E. J., & Berry, M. G. (2019). *The Roehampton annual computing education report*. London: University of Roehampton.

Lang, C. (2010). Happenstance and compromise: A gendered analysis of students' computing degree course selection. *Computer Science Education*, *20*(4), 317–345. https://doi.org/10.1080/08993408.2010.527699

Learning and Work Institute. (2021). *Disconnected: Exploring the digital skills gap*.

Leonard, H. C., Quinlan, O., & Sentence, S. (2021). Female pupils' attitudes to computing in early adolescence. *United Kingdom and Ireland Computing Education Research Conference*, 1–6. https://doi.org/10.1145/3481282.3481289

Lindahl, B. (2007). *A longitudinal study of students' attitudes towards science and choice of career.* In NARST Annual Conference, April 15-18, 2007, New Orleans.National Association for Research in Science. https://www.diva-portal.org/smash/record.jsf?pid=diva2%3A296009&dswid=9510

Lindley, L., Clemens, S., Knibbs, S., Stevens, J., & Bagge, L. (2019). Omnibus survey of pupils and their parents or carers: Wave 5: Research report: March 2019. Ipsos MORI.

Lips, H. M., & Temple, L. (1990). Majoring in computer science: Causal models for women and men. *Research in Higher Education*, *31*(1), 99–113. https://doi.org/10.1007/BF00992559

Lyons, T., Quinn, F., Rizk, N., Anderson, N., Hubber, P., Kenny, J., Sparrow, L., West, J., & Wilson, S. (2012). *Starting out in STEM: A study of young men and women in first year science, Technology, Engineering and Mathematics Courses.*

Makrakis, V. (1993). Gender and computing in schools in Japan: The 'We can, I can't' paradox. *Computers & Education*, *20*(2), 191–198. https://doi.org/10.1016/0360-1315(93)90087-Y

Margolis, H., & McCabe, P. P. (2006). Improving self-efficacy and motivation: What to do, what to say. *Intervention in School and Clinic*, *41*(4), 218–227. https://doi.org/10.1177/10534512060410040401

Mason, S. L., & Rich, P. J. (2020). Development and analysis of the elementary student coding attitudes survey. *Computers & Education*, *153*. https://doi.org/10.1016/j.compedu.2020.103898

McFadden, D. (2021). Quantitative methods for analysing travel behaviour of individuals: Some recent developments. In D. A. Hensher & P. R. Stopher (Eds.), *Behavioural travel modelling* (pp. 279–318). Routledge.

McGuire, L., Mulvey, K. L., Goff, E., Irvin, M. J., Winterbottom, M., Fields, G. E., Hartstone-Rose, A., & Rutland, A. (2020). Stem gender stereotypes from early childhood through adolescence at informal science centers. *Journal of Applied Developmental Psychology*, *67*, 101109. https://doi.org/10.1016/j.appdev.2020.101109

Mee, A. (2020). Computing in the school curriculum: A survey of 100 teachers. https://doi.org/10.13140/RG.2.2.19883.59689

Mujtaba, T., & Reiss, M. J. (2013). Inequality in experiences of physics education: Secondary school girls' and boys' perceptions of their physics education and intentions to continue with physics after the age of 16. *International Journal of Science Education*, *35*(11), 1824–1845. https://doi.org/10.1080/09500693.2012.76269

Murphy, P., & Whitelegg, E. (2006). *Girls in the physics classroom: A review of the research on the participation of girls in physics.* Institute of Physics.

Ofqual. (2011). *GCSE subject criteria for information and communication technology*. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/371250/11-10-19-gcse-subject-criteria-ict.pdf

Ofqual. (2018). *GCSE subject level conditions and requirements for computer science.* https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/779203/GCSE-subject-level-conditions-and-requirements-for-computer-science-examined-2019-2021.pdf

Papanastasiou, C., & Papanastasiou, E. C. (2004). Major influences on attitudes toward science. *Educational Research and Evaluation*, *10*(3), 239–257. https://doi.org/10.1076/edre.10.3.239.30267

Pottorff, D. D., Phelps-Zientarski, D, & Skovera, M. E (1996). Gender perceptions of elementary and middle school students about literacy at school and home. *Journal of Research and Development in Education*, *29*(4), 203–211. https://eric.ed.gov/?id=EJ535018

Quinlan, O. (2015). *Young digital makers.* London: Nesta. https://media.nesta.org.uk/documents/youngdigmakers.pdf

Royal Society. (2012). *Shut down or restart?*. https://royalsociety.org//media/education/computing-in-schools/2012-01-12-computing-in-schools.pdf

Royal Society. (2017). *After the Reboot.* https://royalsociety.org/-/media/policy/projects/computing-education/computing-education-report.pdf

Sefton-Green, J., & Brown, L. (2014). Mapping learner progression into digital creativity: Catalysts & disconnects. *Nominet Trust.* https://socialtechtrust.org/wp- content/uploads/2017/11/Mapping-learner-progression-into-digital-creativity- FINAL.pdf

Sieben, S., & Lechner, C. M. (2019). Measuring cultural capital through the number of books in the household. *Measurement Instruments for the Social Sciences*, *1*(1), 1–6. https://doi.org/10.1186/s42409-018-0006-0

Strand, S., & Winston, J. (2008). Educational aspirations in inner city schools. *Educational Studies*, *34*(4), 249–267. https://doi.org/10.1080/03055690802034021

The Guardian. (2011). *Shut down or Restart?* https://www.theguardian.com/technology/2011/aug/26/eric-schmidt-chairman-google-education

Torkzadeh, G., & Koufteros, X. (1994). Factorial validity of a computer self-efficacy scale and the impact of computer training. *Educational and Psychological Measurement*, *54*(3), 813–821. https://doi.org/10.1177/0013164494054003028

Tran, Y. (2018). Computer programming effects in elementary: Perceptions and career aspirations in STEM. *Technology, Knowledge and Learning*, *23*(2), 273–299. https://doi.org/10.1007/s10758-018-9358-z

UNICEF. (2020). *Towards an equal future: Reimagining girls' education through STEM.* https://www.unicef.org/media/84046/file/Reimagining-girls-education-through- stem-2020.pdf

Vandenberg, J., Rachmatullah, A., Lynch, C., Boyer, K. E., & Wiebe, E. (2021). Interaction effects of race and gender in elementary CS attitudes: A validation and cross- sectional study. *International Journal of Child-Computer Interaction*, *29*, 100293. https://doi.org/10.1016/j.ijcci.2021.100293

Varma, R. (2007). Women in computing: The role of geek culture. *Science as Culture*, *16*(4), 359–376. https://doi.org/10.1080/09505430701706707

Vitores, A., & Gil-Juárez, 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): 666–680. https://doi.org/10.1080/09589236.2015.1087309.

Wellcome Trust. (2020). *Young People's views on Science Education*. https://wellcome.org/reports/science-education-tracker-2019

Whitehead, J. M. (1996). Sex stereotypes, gender identity and subject choice at a-level. *Educational Research*, *38*(2), 147–160. https://doi.org/10.1080/0013188960380203

Wong, B. (2016). 'I'm good, but not that good': Digitally-skilled young people's identity in computing. *Computer Science Education*, *26*(4), 299–317. https://doi.org/10.1080/08993408.2017.1292604

Wong, B., & Kemp, P. E. J. (2018). Technical boys and creative girls: The career aspirations of digitally skilled youths. *Cambridge Journal of Education*, *48*(3), 301–316. https://doi.org/10.1080/0305764X.2017.1325443