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Is being clever enough? Young people's construction of the ideal student in computer science education

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ABSTRACT

Popular discourses of computing and computer science can often frame the sector and the people within it as highly intelligent yet socially challenged, contributing to stereotypes that can potentially exclude those perceived to lack these skills or characteristics. For young people, such stereotypes can influence their educational and career aspirations, especially if there are discrepancies between their own identity and perceptions of what is desirable for computer science students. Drawing on open-ended questionnaire data from 3235 young people in England (aged 11–16), we collected 9442 keywords that students used to describe their "ideal student" in computer science education. An understanding of these perceptions allows us to recognise the prevailing stereotypes that may be shaping young people's views and aspirations. In this paper, we employ an innovative large-scale descriptive analysis of the most common words that students use to describe the ideal computer science student, including its differences, if any, by students' demographic background (e.g. gender, ethnicity, free school meal) and responses to the questionnaire (e.g. aspirations to be a computer scientist). We tentatively identified eight clusters of popular ideal student characteristics, namely being *Smart & Clever; Knowledgeable & Interested; Determined & Hardworking; Kind & Helpful; Creative; Independent; Confident*; and *Collaborative*. By examining how students imagine the ideal student in computer science, we gain better understanding of their educational aspirations and choice of study and provide educators with valuable insights to potentially challenge and reshape these perceptions. These insights can inform educational interventions to foster a more inclusive computing education.

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Introduction

In Western countries such as the UK, there continues to be a gender difference in the study of computer science. Boys consistently outnumber girls in co-educational school

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settings, with a larger percentage gap as we move up from secondary school qualifications (JCQ, 2023; Kemp et al., 2019). Aside from being typically seen as a masculine subject, there are also wider stereotypes of those who participate and excel in computing or technology, exemplified with the favoured labels of geeks or geniuses (Varma, 2010). Popular imaginations of who can or should study computer science might inadvertently position the subject as exclusive, suitable and intelligible only for those who appear to fit the dominant (but highly gendered) discourse. Given considerable concerns around ensuring a diverse workforce with the digital skills to meet industry demand (e.g. AND Digital, 2022; Guardian, 2021), as well as the missed opportunities for young people to choose a subject that will prepare them well for the future workplace, it is critical to address the gaps in existing research on computer science identities and choices amongst young people. These gaps include the limited understanding of how societal stereotypes and educational environments shape students' perceptions and aspirations towards computer science careers. This study will provide a detailed analysis of students' perceptions of the ideal computer science student, thereby informing interventions that can challenge existing stereotypes and support diverse student engagement in the field.

To evidence but also challenge these popular perceptions, this paper draws on the notion of the "ideal student" to build a more detailed picture of how young people imagine computer science students. An understanding of how students describe what is expected and considered to be desirable of students in computer science will enable us to better recognise how these constructions can shape young people's future aspiration and identity in the discipline. We unveil the prevailing perceptions and stereotypes that may deter certain groups from pursuing careers in this field, which may also provide us with the understandings needed to develop targeted interventions aimed to address the underrepresentation of specific groups in the computer science workforce. Such insights would support the work of educators in their effort to build diverse and inclusive discourses of who can excel in computing science education and beyond.

This paper presents a descriptive analysis and presentation of the most frequent words that students use to describe the ideal student in computer science education, using open-ended responses in a questionnaire that collected 9442 keywords from 3235 students. Through a word frequency and cluster analysis of similar word characteristics, we identified eight overarching ideal student characteristics in computer science. These include being *Smart & Clever; Knowledgeable & Interested; Determined & Hardworking; Kind & Helpful; Creative; Independent; Confident*; and *Collaborative*. We also mapped these ideal characteristics by students' own demographic background, especially gender, as well as their career aspirations to be a computer scientist. In the discussion and conclusion, we explore the potential meanings and implications of these ideal constructions for students, teachers and the broader field of computing.

Who studies computer science?

Computer science is often recognised as a difficult and challenging subject (Royal Society, 2017), which suggests students who study computer science are likely to be perceived and stereotyped as "smart" or "clever", especially in the discipline. The perception of computer science being difficult is supported by exam results with students taking computer science likely to get lower grades than their other subjects; this difference appears to be especially prominent for girls (BCS, 2020; Kemp et al., 2019). In UK secondary education, especially in England, there remains a longstanding participation gender imbalance with significantly more boys than girls in qualifications such as GCSE and A-level computer science. Notably, above all other key demographic differences (e.g. by ethnicity or socio-economic background, see Margolis et al., 2008; Parker & Guzdial, 2015), the gender gap in computer science is one of the largest amongst all Science, Technology, Engineering and Mathematics (STEM) subjects, including physics (JCQ, 2023).

For instance, out of the students typically aged 16 who sat the GCSE computer science exam in 2023 (n = 87,405), 79% were boys (n = 68,904) but only 21% were girls (n = 18,501), indicating a concerning uptake of just one in five girls choosing a computing qualification in England (JCQ, 2023). The gender imbalance worsens as students get older and progress to the more advanced A-Level qualification post-16 (Kemp et al., 2019). Although in recent years there has been a slight increase in the number of young people choosing GCSE computer science, the overall numbers studying a digital GCSE qualification are still substantially lower since the introduction of the new GCSE computer science curriculum in 2014 (JCQ, 2023).

Given considerable concerns around ensuring a diverse workforce with the digital skills to meet industry demand (e.g. AND Digital, 2022; Guardian, 2021), as well as the missed opportunities for young people to choose a subject that will prepare them well for the future workplace, there are still gaps in existing research on the computer science identities and choices for young people.

Stereotypes in computer science

A considerable body of research exists around perceptions of scientists, but this understanding is more limited within the domain of computer science (e.g. Miller et al., 2018). Popular discourses of computing and computer science tend to frame the sector, and the people within it, as predominantly men who are highly intelligent but socially challenged, contributing to stereotypes that can potentially exclude and marginalise those perceived to lack these skills or characteristics (e.g. Cheryan et al., 2013; Google, 2015). Such stereotypes can influence students' educational and career choices, especially if there are discrepancies between their self-identity and perceptions of what is desirable of students in computer science (e.g. Dou et al., 2020; Wong, 2016; Wong & Kemp, 2018). Stereotypes can also affect students' sense of belonging, particularly with masculine cultures being associated with a lower sense of belonging for women (e.g. Cheryan et al., 2017).

Through a critical lens, the attributes typically associated with computer science and scientific disciplines are usually gendered and ascribed to white privileged men, despite the popular belief that science is objective or value-free (Fox, 1999). For example, different STEM disciplines can be perceived as distinctively gendered and hierarchal, with some considered more masculine, challenging or objective than others (e.g. mathematics or physics) (Mendick, 2006; Wong et al., 2023). Similarly, biologically essentialist ideas that imply men and boys are inherently "better" at science may affect students' perceptions and imaginings of their disciplines (Eagly, 2018). Such discourses tend to perpetuate notions of *hegemonic masculinity* that attribute more power, legitimacy and value to men (Connell, 1987), and scientific fields in which men are overrepresented, including computer science. This can obstruct women and girls from developing a sense of identity and belonging in computer science, and the extent they may imagine themselves as intelligible computer science students or future computer scientists (Ardito et al., 2020).

Furthermore, it has been recognised that gendered stereotypes in STEM negatively influence the self-beliefs and outcome expectancies of girls (McGuire et al., 2020). These views are likely formed during the primary or elementary school age and are influenced by numerous social factors such as peers, family and the media (e.g. Bian et al., 2017; Buck et al., 2002; Google, 2015). Research in physics found that parents who judged their child as "not-nurturing", "academic", "courageous" and "self-confident" were more likely to think their child would study physics after the age of 16, suggesting that parents may inadvertently influence their child's subject choice through their own stereotyped views and bias (Jones & Hamer, 2022). Recent research in England, such as Hamer et al. (2023), has indicated that perceptions of computer scientists are associated with young people's (aged 11–16) aspirations to become a computer scientist (Hamer et al., 2023). In particular, that study found that being a boy, of Asian ethnicity, already taking GCSE computer science, or having a parent working in computing or tech, were key variables associated within computer science aspiration. When additional variables were added to the model, predictors include having positive attitudes towards coding, feeling confident in computing lessons, having a positive view of computer scientists, having family support and aspiring to other technical jobs – which all supported young people's computer science aspiration. Understanding how young people perceive computer scientists, and by extension, how individually like or unlike they are to that perception, may determine how likely they are to aspire and pursue the subject – as seen elsewhere in STEM (Hannover & Kessels, 2004).

The ideal student in computer science

This paper provides an innovative approach to understanding how computer science students are perceived and constructed, through the concept of the "ideal student" (Wong & Chiu, 2021a). Here, the notion of the ideal computer science student can refer to the aspirational archetype of a student who possesses a specific set of attributes, skills and characteristics that are considered or imagined as desirable or advantageous for success in the field of computer science (Wong & Chiu, 2021b).

Given the importance of acknowledging that these conceptions are contingent upon the perspectives and positions of those who construct them, this study seeks to unravel how young people themselves construct the ideal computer science student. Understanding how young people construct the ideal computer science student is important as it can highlight popular stereotypes and discourses that are associated with computer science, as well as the factors that shape what it means to be an ideal student in a particular context. For instance, Chiu et al. (2021) found students' constructions of the ideal student at university are influenced by prior educational experiences, interactions with peers and the curriculum, perceptions of lecturers, as well as institutional and employer expectations.

By recognising what is perceived as ideal and desirable of computer science students, we can begin to understand more about the educational choices and aspirations of young people, and the qualities they associate with being successful in the field. This can inform school-based interventions and classroom practices that promote inclusive learning environments, and challenge widely held societal beliefs about who can and should study computer science (e.g. Shimwell et al., 2023; Steinke et al., 2009).

For instance, studies of how computer science students are perceived in university settings can yield surprising results that tend to contradict popular discourses or research findings. Thinyane (2013) found academics in a South African university rated abstract thinking, problem-solving, creativity and computer playfulness as key features in their constructions of the ideal undergraduate computer science student. Such characteristics mostly oppose stereotypical notions of computer scientists that tend to be popular in mainstream media and gendered masculine (e.g. geeks or geniuses) (Varma, 2010). Similarly, Jerkins et al. (2013) found the majority of computer science undergraduate students did not believe mathematical reasoning and problem-solving skills were necessary for success, despite the commonly held belief by educators and researchers that the study of mathematics is an essential part of the computer science curriculum, and this "anti-symbiotic" stereotype is harmful to students' attainment. Tapping into young people's constructions of the ideal computer science student can therefore highlight and even challenge existing stereotypes and narrow views about who can study the subject.

As already inferred, perceptions of computing students can also highlight popular discourses and stereotypes that require disrupting, such as attributes stereotypically ascribed to men (Gaucher et al., 2011). For example, Starr (2018) found gender-based stereotypes (e.g. "STEM is for men") and trait-based stereotypes (e.g. "STEM is for nerds or geniuses") were negatively related to STEM identity, affecting women undergraduates' career motivation and the value they attributed to STEM study (see also Pantic et al., 2018). Cheryan et al. (2015) also argued that prevalent stereotypes and typical portrayals of computer scientists establish a perception that the field is not easily approachable or suitable for women, and "steers girls away" from choosing a computing education. Research therefore suggests that altering such stereotypes and broadening representation can significantly improve women and girls' sense of belonging and interest in computer science (Cheryan et al., 2015; Main & Schimpf, 2017; Starr, 2018). Since stereotypes can limit or shape imagination, Morin-Messabel et al. (2017) also recommend "activating counter-stereotypes", or in other words, "playing on stereotypes" by "reversing them" to combat gender inequalities (p. 4).

Yet, in order to challenge or even reverse such stereotypes, more research is needed on how young people construct computer science students and the characteristics they deem necessary for success, especially in compulsory education contexts. As such, this paper aims to provide an analysis of the type of characteristics and attributes students use to describe their ideal computer science student, including how these expectations map alongside their demographic profiles and aspirations (Main & Schimpf, 2017). More specifically, we are interested in how popular discourses and gendered constructions can shape students' participation and identification with computer science in English secondary schools, as well their aspirations to computer science careers.

The study

Data in this paper are drawn from the SCARI Computing project, which aims to understand the factors shaping schoolchildren's (aged 11-16) participation and performance in computer science. In particular, the project focuses on state co-educational secondary schools with a higher-than-average uptake in computer science for GCSE, especially amongst girls. The project's objective is to better appreciate "what works" in those schools and to identify lessons that might be learnt and possibly applied or replicated to other schools to address concerns regarding the underrepresentation of girls. In England, pupils tend to receive some computer science education between ages 5 and 14, as part of the broader curriculum, before the optional study of computer science as a qualification for GCSE[1] (ages 14–16), if offered by the school. Whilst the study of computer science is not typically a prerequisite for computer science study at degree level or beyond, enrolment at the GCSE stage would likely signify an interest to pursue the discipline in the future. This paper draws on open-ended responses from a questionnaire that explored the views and aspirations of secondary schoolchildren. We are interested in the characteristics that young people would ascribe in their constructions of the ideal student in computing education. In other words, we ask students to describe the desirable traits of computing students and we are also interested in how these constructions vary by their social and school backgrounds.

Our three-year study (2021–2024) is based in England, and over 100 secondary schools were invited to participate based on available data of their pupil subject choices in 2019 and 2020. The project received institutional approval on ethics, and consent was agreed with the schools, students and their families (King's College London, HR/DP-20/21-22501). In the end, 15 schools participated. A full description of the sample and our rationales are detailed elsewhere (Hamer et al., 2023). In short, we opted for state co-educational schools with a relatively high proportion of GCSE computer science students, especially girls. We aimed for schools with at least two classes of GCSE computer science as the first criteria to ensure our schools are relatively large but are not specialists. Potential schools were identified using national databases and cross-checked with individual schools as part of recruitment. These schools are not meant to be representative of the national population but represent the "best scenario" of computer science uptake in state co-educational schools in England. For context, schools from seven of the nine English regions are represented (with East of England and Yorkshire and the Humber the exceptions), although more schools were from London (n = 6) and the South East (n = 4), reflecting the pool of eligible target schools. With the Covid-19 pandemic and additional pressures on schools and teachers during different stages of national lockdowns and remote learning, our recruitment and data collection began in Summer 2021, before the school holidays and continued in Autumn 2021, and eventually rolled into Spring 2022 before our target was reached.

An introductory short video that explains the purpose of the project and how to complete the survey was provided to teachers, highlighting the exploratory nature of the study to understand student views and perspectives, with neither right nor wrong answers. All questions were optional. The questionnaire took around 20–30 min to complete. Participants included those who are studying GCSE computer science as well as those who are not (Key Stage 4, typically aged 14–16), alongside younger students (Key Stage 3, typically aged 11–14) who have yet to decide.

Whilst the development of the survey is discussed elsewhere (Hamer et al., under review), this paper focuses on one open-ended question, which was phrased as follows: "Imagine an ideal computing student. What are they like as a person? List 3 characteristics below". Here, we wanted to know how young people construct the ideal student in computing, and our focus on their text entries was a means to explore and collect a wide range of possible characteristics for the ideal computing student. We appreciate the limitations of open-ended responses, especially potential misinterpretations from often shorter responses, but we believe it is highly appropriate for the purpose of this paper, especially as we scope and explore the breadth but also commonalities between students. In total, we collected 9442 ideal student entries from 3235 students, alongside their demographic information which enabled further analyses (e.g. such as differences by gender). This question was completed by 66% of respondents as part of a longer questionnaire, completed by just under 5000 students (see Hamer et al., 2023), and most students provided three ideal student characteristics (94.1%, n = 3043). For information, the number of participants varied for each school for the full questionnaire (median = 293 students, mean = 331 students).

Each response was manually reviewed for typographical errors and corrected if the mistakes were unambiguous (e.g. missing characters, typographical errors). Ambiguous or incomprehensible text was recoded as "Invalid" (n = 312, out of 9442 responses, 3.3%), which included nonsensical or non-characteristic responses, which were excluded. We had 68 ideal student characteristics each with at least 20 mentions, totalling 9130 mentions (96.7% of all responses). We acknowledge these descriptions highlight the diversity of perceptions about the imagined computer science student and that our "cut off" point is malleable, but a pragmatic and reasonable approach is required as we focus on the most popular characteristics in an ideal computing student. These characteristics then underwent two more stages of refinement and abstraction, collating synonyms and similar meanings. For example, words such as "collaborative", "co-operative" and "working together" were regrouped as "collaborative" for manageability and we ended up with 203 mentions for this characteristic. In the end, we ended up with eight clusters of ideal computing student characteristics, totalling 7545 mentions (82.6% of all valid entries), each with over 200 mentions (or at least 2% of all entries). We also excluded less popular entries, comprised of 198 other keywords that were mentioned for a total of 1585 times, averaging eight mentions each (grouped as "Other characteristics", 17.4% of all mentions, see Table 1). For information, the next eligible characteristics after the eighth ideal student characteristic (i.e. "Collaborative", n = 203) was "funny" (n = 112), "I don't know" (n = 106), "boring" (n = 93), "quiet" (n = 74), "competitive" (n = 48) and "courageous" (n = 40), which had considerably fewer mentions but are noted for

Table 1. Popular characteristics of the ideal student in computing.

Ideal characteristic cluster	Mentions, *n*	Eligible %	Valid total %
Smart & Clever	2606	34.5	28.5
Knowledgeable & Interested	1408	18.7	15.4
Determined & Hardworking	1369	18.1	15.0
Kind & Helpful	925	12.3	10.1
Creative	395	5.2	4.3
Independent	389	5.2	4.3
Confident	250	3.3	2.7
Collaborative	203	2.7	2.2
Eligible total	7545	100.0	
Other characteristics	*1585*		17.4
Valid total	9130		100.0

future exploration. Over 100 characteristics were mentioned three times or less, reminding us of the diverse views that students hold of the ideal computing student.

Given our study focuses on the popular constructions of the ideal student in computing, below we present eight ideal student characteristics we identified for computing students, with open-ended texts as examples of how students described these traits. Multiple logistic regression was then conducted for each ideal characteristic cluster, which constituted the dependent/outcome variable. The background independent/predictor variables used were as follows:

- Gender (boy; girl).
- Ethnicity (White; Asian; Black; Other, following UK's Office for National Statistics ethnic group classifications, ONS, 2023)
- Qualification: GCSE Computer Science (not yet chosen; yes; no).
- Socio-economic background: Recipient of Free School Meals [FSM] in the last 6 years (no; yes).
- Aspiration to be a computer scientist (5-point Likert-style item turned into a dichotomous item of: no, yes, see Hamer et al., 2023).
- Parent(s)/carers went to university (yes; no; don't know).
- Recall doing computing at primary school (yes; no; not sure).
- Parent(s)/carers work in technology or a job that uses advanced computing skills (yes; no; don't know).
- Books at home: Number of books in the home (5-point scale turned in a dichotomous item of: high (26+); low (0–25), adapted from Sieben & Lechner, 2019).

The aim of the multiple logistic regression analysis was to investigate which variables had a statistically significant relationship with each ideal characteristic cluster and to investigate the strength of any relationships. Each model was constructed using both stepwise selection and manual building and were found to be similar, therefore stepwise selection models are presented here.

Characteristics of the ideal computing student

We present the ideal student in computer science under eight clusters of ideal student characteristics (see Table 1, which also includes the respective percentages of all valid responses), namely as Smart & Clever; Knowledgeable & Interested; Determined & Hardworking; Kind & Helpful; Creative; Independent; Confident; Collaborative (see also Supplementary file for further information and breakdowns).

Smart & Clever

Being *Smart & Clever* is the most frequent word or description students used to describe the ideal student in computer science. Mentioned 2606 times, it represents just over a third (34.5%) of eligible mentions within the eight clusters, and 28.5% of all valid responses. The most popular choice of word within this cluster is "smart" (n = 1580, or 61% within this cluster), as expected, followed by "intelligent" (n = 321), "clever" (n = 175) and "brainy" (n = 168). Less frequent words but with similar meanings were also added, including "nerds" (n = 148) and "geeks" (n = 108), although it is recognised that these words, for some, may also embed negative connotations and thus are not semantically ideal. Most entries are single words, without descriptive commentaries, which may reflect the relatively clear and coherent understanding of *Smart & Clever*. That is, someone who has or shows "a high degree of mental ability" (Merriam-Webster, 2023) or "able to think quickly or intelligently" (Cambridge Dictionary, 2023).

Overall, we found statistically significant differences by aspirations to be a computer scientist, number of books at home and whether or not students are studying Key Stage 4 GCSE Computer Science. Using odds ratios from our logistic regressions (see Supplementary file), students with aspirations to be a computer scientist have a 40% lower odds than those without such aspirations to describe the ideal student in computing as *Smart & Clever* (OR = 0.60, 95% confidence interval (CI) [0.49, 0.74], $p < .001$), whilst students who reported none or few books (i.e. 0–25 books) at home have a 28% greater odds (OR = 1.28, 95% CI [1.03, 1.60], $p = .026$) than those who said they had many books (26 or more) to describe the ideal computing student as *Smart & Clever*. Key stage 4 computer science students are also less likely to construct the ideal computing student as *Smart & Clever* (OR = 0.61, 95% CI [0.49, 0.76], $p < .001$), when compared to Key Stage 4 students who have chosen not to study computer science as well as the younger student cohort who have not yet chosen (Key Stage 3).

When focused only on the older Key Stage 4 students, we found statistically significant differences by aspirations to be a computer scientist. Older Key Stage 4 students with aspirations to be a computer scientist have a 54% lower odds than those without to describe the ideal computing student as *Smart & Clever* (OR = 0.54, 95% CI [0.40, 0.73], $p < .001$).

As will be revisited in the discussion, these differences suggest that perceptions of smartness in computer science appear to be held more strongly by those with fewer books at home and those who do not aspire to be computer scientists, which may reflect popular but exclusive outsider discourses of what is imagined to be appropriate or required of computing students and future computer scientists.

Knowledgeable & Interested

The second most popular ideal student characteristic is being *Knowledgeable & Interested*. Here, a disciplinary understanding of, and enthusiasm in, computing is considered to be important and desirable. Open-ended comments include descriptions of those who "know a lot about tech", "enjoy computing" and "understand what they are doing". The frequent keywords grouped under *Knowledgeable & Interested* are more varied and balanced, include being "knowledgeable" (n = 185), "interested" (n = 225), as well as "academic" (n = 203), "skilled" (n = 160), "focused" (n = 139). Less frequent words (under 100 mentions) that were also grouped here include more specific skills such as "coding", "logical" and "problem-solving".

Overall, we found statistically significant differences by number of books at home, parental education and experiences of computing at primary school. Students who reported none or few books (i.e. 0–25 books) at home have a 27% lower odds than those who said they had many books (26 or more) (OR = 0.73, 95% CI [0.59, 0.90], $p = .004$) to describe the ideal computing student as *Knowledgeable & Interested*. Similarly, students without parents who attended university (OR = 0.77, 95% CI [0.62, 0.95], $p = .017$) or were unsure (OR = 0.76, 95% CI [0.60, 0.97], $p = .024$), alongside students unsure if they did computing in primary school (OR = 0.60, 95% CI [0.41, 0.89], $p = 0.011$), all have a lower odds to describe the ideal computing student as *Knowledgeable & Interested*. Key stage 4 computer science students also have a 48% greater odds than younger students to mention *Knowledgeable & Interested* (OR = 1.47, 95% CI [1.18, 1.83], $p < .001$).

Similarly, within the older Key Stage 4 subgroup, students with fewer books (OR = 0.66, 95% CI [0.48, 0.90], $p = .010$) and those unsure about their parents' university education (OR = 0.57% CI [0.38, 0.86], $p = .007$) are less likely than their counterparts to mention *Knowledgeable & Interested*. We also find students from Black (OR = 0.46, 95% CI [0.23, 0.93], $p = .032$) as well as Other minority ethnic backgrounds (including mixed) (OR = 0.62, 95% CI [0.40, 0.95], $p = .030$) less likely than White students to describe the ideal computing student as *Knowledgeable & Interested*, with a 54% and a 38% lower odds.

In short, being *Knowledgeable & Interested* appears to be a more popular ideal student characteristic for those with more books at home, as well as with parents who attended university, those with experiences of computing in primary school and older students from white ethnic backgrounds.

Determined & Hardworking

The third characteristic is *Determined & Hardworking*, highlighting the importance of dedication and work ethic. Here, comments include "someone who is determined and works hard consistently", "study and put in the extra effort", and that "they don't give up on questions they don't know". The keywords grouped under this cluster were mostly the words "determined" (n = 603) and "hardworking" (n = 387), alongside less frequent words, with similar meanings, such as "resilient", "dedicated", "passionate" and "studious".

On the whole, statistically significant differences are found by gender, aspirations to be a computer scientist, Key Stage, number of books at home and experiences of computing in primary school. Here, girls (OR = 1.39, 95% CI [1.15, 1.67], $p < .001$), those with computer science career aspirations (OR = 1.34, 95% CI [1.10, 1.64], $p = .004$) and older Key Stage 4 students (OR = 1.40, 95% CI [1.09, 1.81], $p = .010$ for non-computer science students, OR = 1.95, 95% CI [1.57, 2.42], $p < .001$ for computer science students) all showed a greater odds in describing the ideal computing student as *Determined & Hardworking* than boys, those without computer science career aspirations, and younger Key Stage 3 student counterparts, by 39%, 34% and 40% (for noncomputer science students) or 95% (for computer science students), respectively. Furthermore, students who reported none or few books (i.e. 0–25 books) at home have a 28% lower odds than those who said they had many books (26 or more) (OR = 0.78, 95% CI [0.63, 0.96], $p = .021$) to describe the ideal computing student as *Determined & Hardworking*.

Within the Key Stage 4 cohort, this continues to apply for girls, with a 54% greater odds (OR = 1.54, 95% CI [1.14, 2.07], $p = .005$) than boys to mention *Determined & Hardworking* in their ideal computing student, whilst Key Stage 4 non-computer science students have a 33% lower odds (OR = 0.67, 95% CI [0.49, 0.93], $p = .016$) to use this description than their GCSE Computer Science student counterparts.

Here, the largest differences are gender and Key Stage, where girls and older students, especially those studying computer science, are more likely to recognise the importance of being *Determined & Hardworking* in an ideal computing student.

Kind & Helpful

The fourth characteristic of the ideal student in computing is being *Kind & Helpful*. Mentioned 925 times in different ways, students included keywords such as "kind" (n = 187), "helpful" (n = 178), "nice" (n = 121) and "patient" (n = 102). Similar and less frequent words included "friendly", "good", "honest", "respectful" and "modest". For example, these traits are also described as those who "might help people/show how computing works", "are open to other people's opinion" and "are just kind and nice and not rude", being "considerate to others" and "helps others who don't understand the subject".

Overall, we find statistically significant differences by gender and age group. Girls have a 22% lower odds (OR = 0.78, 95% CI [0.63, 0.97], $p = .023$) of describing the ideal computing student as *Kind & Helpful*. Similarly, compared to those in Key Stage 3, older students in Key Stage 4 have a lower odds of describing the ideal student in computing as *Kind & Helpful*, by 56% for those not studying computer science (OR = 0.44, 95% CI [0.31, 0.61], $p < .001$) and 42% for those studying computer science (OR = 0.58, 95% CI [0.45, 0.75], $p < .001$). There were no statistically significant differences within the older Key Stage 4 cohort.

In short, girls and especially those from the older Key Stage 4 age group are less likely to describe the ideal computing student as *Kind & Helpful*, which may reflect wider gendered discourses as well as greater awareness or personal experiences for older students.

Creative

The fifth most common characteristic of the ideal student in computing is being *Creative*, which is dominated by the namesake keyword, "creative" (n = 374). According to students, the ideal computing student would be "quite imaginative and creative", "think outside the box", "have an open mind" and "like creating new things, rather than sticking to old methods".

On the whole, we find statistically significant differences by free school meal (FSM) status, aspirations to be a computer scientist and number of books at home. Compared to those who have not received FSM in the last 6 years, students who have received FSM have a 45% lower odds in describing the ideal computing student as *creative* (OR = 0.55, 95% CI [0.40, 0.76], $p < .001$). This is also the case for the older Key Stage 4 cohort, where the only significant outcome is FSM students who have a 62% lower odds than non-FSM students to use *Creative* in their descriptions of the ideal computing student (OR = 0.38, 95% CI [0.21, 0.70], $p = 0.002$). Furthermore, all students with aspirations to be a computer scientist also have a 67% greater odds than those without such aspirations to use *creative* (OR = 1.67, 95% CI [1.25, 2.22], $p < .001$). Students with none or few books at home have a 29% lower odds than those with more books at home to describe the ideal computing student as *creative* (OR = 0.71, 95% CI [0.51, 0.98], $p = 0.036$).

In short, non-FSM students (who tend to be more socioeconomically advantaged) and those with computer science career aspirations and more books at home seem to have a stronger tendency to describe the ideal computing student as *Creative*.

Independent

The sixth ideal student characteristic is being *Independent*, constituted by the namesake keyword and is presumably self-explanatory. In the context of student attributes, the relevant dictionary definitions of independent here would likely involve "showing a desire for freedom" (Merriam-Webster, 2023) and "not influenced or controlled by other people but free to make your own decisions" (Cambridge Dictionary, 2023). In other words, the ability to think, act and work on their own. A handful of open-ended comments also linked independent with the ability to also "work in a team", or being collaborative, which is the eighth ideal student characteristic.

Overall, we find two statistically significant differences, by gender and whether a family member worked in computing and technology. Girls have a 77% greater odds than boys to describe the ideal computing student as *independent* (OR = 1.77, 95% CI [1.35, 2.33], $p < .001$). Students who are unsure whether a family works in computing or technology have a 49% higher odds (OR = 1.49, 95% CI [1.04, 2.13], $p = .030$) than students who said they do have a family member working in this field to say the ideal computing student is *independent*.

Within the older Key Stage 4 cohort, the same applies to gender (OR = 1.61, 95% CI [1.03, 2.52], $p = .035$) and those unsure of family occupation in technology (OR = 2.00, 95% CI [1.09, 3.65], $p = .025$), with the addition of a 40% lower odds amongst students without parental university education to describe the ideal computing student as *Independent* (OR = 0.60, 95% CI [0.37, 0.98], $p = .04$).

It is noted that the confidence intervals for some of these variables are large, suggesting high variability, as well as comparatively higher *p*-values.

Confident

The seventh characteristic is being *Confident*, which includes the namesake keywords "confident" (n = 172), alongside less frequent mentions such as "happy" and "cool". Here, the ideal computing student is described as being "confident in their work" and "believe that they can do it".

There are no statistically significant differences for this cluster between student demographics or their responses to the questionnaire.

Collaborative

The eighth characteristic is being *Collaborative*, which is made up of keywords of very similar meanings, including "collaborative", "cooperative" and "working together". These were all recoded as collaborative in the first stage of the recoding process. Comments from students are quite consistent, including being "able to work in a team when they need to", "very good at taking part in group activities" and "works well in groups".

Overall, we find statistically significant differences by aspirations to be a computer scientist and number of books at home. Students with aspirations to be a computer scientist have a 92% greater odds than those without such aspirations to describe the ideal student in computing as *collaborative* (OR = 1.88, 95% CI [1.29, 2.74], $p < .001$). Students who reported no or few books (i.e. 0–25 books) at home have a 47% lower odds than those who said they had many books (26 or more) (OR = 0.53, 95% CI [0.33, 0.85], $p = .008$) to describe the ideal computing student as *collaborative*. Within the older Key Stage 4 cohort, those who are not studying computer science have a 56% lower odds to describe the ideal computing student as *collaborative* than their GCSE Computer Science student counterparts (OR = 0.44, 95% CI [0.20, 0.96], $p < .040$).

Discussion

This paper presented eight overarching characteristics of the ideal student in computing. While being *Smart & Clever* is the most popular description for young people, we also unveiled seven other prominent ideal student characteristics. These include being *Knowledgeable & Interested*, *Determined & Hardworking*, *Kind & Helpful, Creative, Independent, Confident*, and *Collaborative*. Here, we argue that the breadth of these characteristics highlights a broadening of perceptions amongst young people about what it means to be a computing student, contributing to wider discussions on underrepresentation and the exclusionary landscape of the discipline. This shift suggests that educational and policy interventions focusing on a more inclusive narrative of computer science can meaningfully impact students' aspirations and participation rates. By understanding and addressing the nuanced views of what constitutes an ideal computing student, educators can better tailor their approaches to foster a more diverse and welcoming environment.

It is unsurprising that *Smart & Clever* is the most frequent characteristic in the ideal computing student (28.5% of valid responses). Being perceived as smart and clever is consistent with popular and public imaginations of computer science as a field excelled and stereotyped by those with strong technical and technological skills (Cheryan et al., 2013). Whilst *Smart & Clever* can imply biological essentialist beliefs about ability or competence, the characteristics of *Knowledgeable & Interested* (15.4%) and *Determined & Hardworking* (15.0%) illustrate the value attributed to interest and work effort, although these factors are likely to vary amongst diverse student groups. As the second and third most popular clusters – together making up almost a third of all valid descriptions (30.4%) – these characteristics also highlight how the ideal student in computing is constructed as those who are diligently building their interests and skills in the discipline. Such views may suggest a widening of perceptions about who can participate and excel in computing, beyond the "natural brilliance" stereotypes, which are often gendered (Dou et al., 2020). The remaining five characteristics (*Kind & Helpful, Creative, Independent, Confident*, and *Collaborative*) made up 23.7% of all valid descriptions, which again highlight a growing breadth of desirable qualities associated with the ideal computing student, with more gender fluid and feminine-oriented traits.

For example, sometimes framed as the opposite of being *Independent*, the qualities of *Collaborative* can be perceived as more stereotypically feminine-oriented (Gaucher et al., 2011), where the ideal computing student is envisioned as someone who can work well alongside others. In some schools, collaborative learning is promoted in the computing classroom through pedagogies such as paired programming, where students are grouped together, although the effects of this on computing skills development or confidence remain inconclusive (Ardito et al., 2020; Wei et al., 2021). That said, the inclusion of *Collaborative* in students' most popular characteristics of the ideal student in computing adds to the growing range of characteristics that stretches and challenges the traditionally masculine-oriented traits that have dominated wider perceptions of the field. As discussed below, there are differences by student backgrounds or viewpoints across these traits, highlighting the nuances in how the ideal student in computing is envisioned, which is key in the development of inclusive and culturally relevant approaches to computing student identities.

Difference by gender

Our findings indicate that girls were more likely than boys to associate certain characteristics with the ideal student in computing, namely *Determined & Hardworking* and *Independent*. On the one hand, the attribution of these characteristics, especially *Independent,* may appear to align more with masculine-oriented traits traditionally attributed to men (Gaucher et al., 2011). Yet, the emergence of *Collaborative*, as the eighth cluster, is an interesting possible counterview, although no gender differences were found. The increased likelihood of girls when compared to boys to mention *Determined & Hardworking* may also suggest that girls must work harder to identify and participate in the discipline, and therefore the ideal student in computing is also perceived to require a strong work ethic and dedication. In other words, a full-on commitment to the discipline is probably not for the faint-hearted, and therefore not realistic for everyone, especially given the barriers that can limit how girls participate and identify with the subject (Starr, 2018).

As the only reverse pattern, girls are less likely than boys to mention *Kind & Helpful*, which is included as the fourth most popular cluster (10.6%). This might suggest that boys are generally more likely to find other boys more approachable, for example, in a male-dominated environment such as computer science. It is interesting that this seems to be perceived differently by girls who are underrepresented in the field, who may also be less likely to develop a sense of belonging in the computing classroom (Cheryan et al., 2017). Yet, since the field of computer science is predominantly occupied by men, the ideal characteristic of *Kind & Helpful* serves to counter dominant views about how boys and men are traditionally expected to behave and express gender, especially in male-dominated environments (Archer et al., 2023; Connell, 1987; Wong & Copsey-Blake, 2023). Such views tend to be reproduced by popular discourses that can permeate the educational context, as well as at home, where expressions of gender identity may be more or less limited. Students may therefore be encouraged to do particular subjects that are stereotypically ascribed to their perceived gender, or vice versa (Jones & Hamer, 2022). Yet, more work is needed to widen narrow preconceptions of the computing discipline.

Differences by ethnicity and free school meal status

There were just two statistically significant outcomes. Older Key Stage 4 Black and students from other minority ethnic backgrounds were more likely than their white counterparts to mention *Knowledgeable & Interested*, whilst students on free school meals (FSM) were less likely to state *Creative* when compared to non-FSM students. Further research is merited to unpack these apparent anomalies, and the potential wider influence of racial and classed discourses in computing (Margolis et al., 2008).

Differences by Key Stage year groups

Younger Key Stage 3 students were more likely to mention being *Kind & Helpful*, while older Key Stage 4 students were more likely to state *Knowledgeable & Interested* and

Determined & Hardworking in their perceptions of the ideal computing student. For *Determined & Hardworking*, the shift in emphasis on work ethics may be attributed to age-related maturity, personal experiences, and the influence of educational contexts (Ardito et al., 2020). Key stage 4 computer students are also less likely than other students to construct the ideal computing student as *Smart & Clever*, which is interesting and merits further research. One interpretation is that these students, as current students of the subject, are downplaying the wider discourse of cleverness as an adequate representation of students like them.

Within the Key Stage cohort, interestingly, those studying computer science were significantly more likely to include *Collaborative* in their descriptions compared to their non-computer science counterparts, which also suggests that students' experiences in studying the discipline contribute to a greater recognition of the importance of collaborative work in computing (Wei et al., 2021).

Access to resources

As a partial proxy of socioeconomic background, the number of books available at home emerged as a statistically significant variable in students' construction of the ideal student in computing. Students with greater access to books were more likely to associate the ideal student with being *Knowledgeable & Interested*, *Determined & Hardworking*, *Creative* and *Collaborative* than those with fewer or no books. Whilst this link cannot be framed as causal (Sieben & Lechner, 2019), this association is often seen to reflect the influence of cultural capital, and thus socioeconomic privilege (Bourdieu, 1984), wherein access to such educationally-related resources is typically linked to higher social class backgrounds. These patterns highlight the importance of addressing disparities in resource availability and ensuring equitable access to opportunities in computing education (Kirby, 2016; Parker & Guzdial, 2015). Students with none or few books at home are also more likely to construct the ideal computing student as *Smart & Clever*, which may suggest the potential influence of books as a resource to challenge wider popular discourses. Further research is merited to explore how access to and availability of computers at home and various digital resources are likely to shed light on digital equality and inequalities.

Aspirations to be a computer scientist

For some characteristics, namely *Smart & Clever*, *Determined & Hardworking*, *Creative* and *Collaborative*, those who expressed a computer science career aspiration were more likely to associate these traits than those without such aspiration. These patterns may indicate that students who envision themselves in the profession might perceive the ideal computing student as possessing qualities aligned with their own career aspirations (Proudfoot et al., 2015). This insight provides valuable implications for promoting student engagement and identity formation within the field of computing.

It is useful to recap that no other meaningful statistical differences were found from our analysis, including by students' qualification in GCSE computer science, their computing education at primary school, their parental education and experiences, and the type of state schools attended (see earlier under data analysis).

Limitations

It is important to recognise the scope and limitations of this paper, especially the methodology. Our sample, whilst relatively large, are not nationally representative due to the main project criteria, which focused on highly successful state co-educational schools in computer science participation. Students are therefore arguably in the "most fertile" of school environments to engage in computer science. This also meant the views of non-computer science students are proportionally underrepresented, despite constituting the majority of our student sample. Furthermore, we targeted schools with an above average enrolment of girls, skewing the sample towards a more balance and diverse sample of the focal discipline.

This exploratory paper centres on one open-ended question within a larger survey, essentially counting and interpreting keyword entries, which inevitably limits analysis of multiple meanings. For example, the cluster of *Smart & Clever* included words such as "nerds" and "geeks" and whist these are considerably less frequent entries, their intended meanings are open to further interpretations, which are better suited to a qualitative inquiry (Wong & Chiu, 2021b). Indeed, even the same word could have different or subtle differences in meanings and there may be more nuances if these were discussed and deliberated (Wong & Chiu, 2021b), with consideration of its contexts and circumstances (Maass et al., 2006). Our data analysis also yielded limited intersectional analysis across different student demographic groups (e.g. by gender *and* ethnicity), with differences by age group (i.e. Key Stage 3 and Key Stage 4) the only viable additional layer of analysis due to data size once dissected into subgroups. As such, our data provided limited scope to explore intersectional variations within key demographics such as gender.

Despite these limitations, this paper offers an innovative mapping of ideal student characteristics from a large student dataset that would otherwise be difficult if not impossible to gather, providing us with eight tentative clusters of the ideal student in computer science.

Implications

What does this mean for students, teachers and the broader field of computing? With this innovative insight into how students construct the ideal student, our data indicate there is a broadening range of desirable characteristics in computer science education, beyond just being *Smart & Clever*. The ideal computing student is also *Knowledgeable & Interested*, *Determined & Hardworking*, *Kind & Helpful, Creative, Independent, Confident*, and *Collaborative*. These characteristics demonstrate there already exists a wider imagination about the type of people who can study or even excel in computing. More importantly, the emergence of these attributes is evidence that traditional gender stereotypes can be successfully challenged and disrupted, especially the discourse of computing and STEM as a field typically perceived as for men (*see* Shimwell et al., 2023). For example, the recognition of creativity and collaboration as key attributes for an ideal computing student suggests that educational interventions could emphasise these qualities in curriculum design and the classroom. Such emphasis could broaden the appeal of computer science to a more diverse student body. Therefore, educators and policymakers should prioritise integrating these diverse characteristics into educational practices and policy frameworks to foster an inclusive environment that reduces or removes the perceived barriers to computing careers.

Here, the role of teachers and schools is crucial in dismantling the historical and pervasive male representation of computing. Emerging evidence suggest that computing teachers are adopting a more diverse and inclusive approach in their classrooms, from pedagogies such as paired programming to broader curriculum content and materials that consider computing knowledge and figures beyond the white male archetype (Childs, 2022). Scholars such as Morales-Chicas et al. (2019) and organisations such as the Raspberry Pi Foundation (2021) advocate for a culturally relevant curriculum that fosters equitable and authentic learning experiences.

Beyond the classroom, wider discourses of computing, as perpetuated by popular culture and the media, offer reasons for optimism. Whilst progress may be slow (WomeninTech, 2023), many global computing and IT companies have made gender equality and representation a priority commitment. Third-sector organisations in particular have led national and local programmes to promote girls into coding and computing (Sentence, 2023), with the aim to broaden perceptions of who can code and excel in computing, promoting a more inclusive and diverse field.

Conclusion

This study offers innovative insights into the construction of the ideal computing student. An understanding of how students imagine the ideal student allows us to appreciate how such views may shape or be shaped by their educational experiences or career aspirations, which highlights the importance and potential of educational interventions that challenge and counteract existing stereotypes in computer science. Our study offers new important insights that can inform curriculum changes and teaching strategies. Educators and policymakers should leverage these findings to create and promote environments that recognise and actively counteract the biases, thereby encouraging a more diverse range of students to pursue further studies or careers in computing. By aligning educational practices with these evolving perspectives, we can contribute to a more inclusive and equitable future in computing education. More work is needed, but the results offer cautiously optimistic evidence of promise, especially to challenge and disrupt traditional gender stereotypes.

Note

1. General Certificate of Secondary Education (GCSE) is an academic qualification generally taken by students aged 14–16 in England.

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