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Feeling the weight of the water: a longitudinal study of how capital and identity shape young people's computer science trajectories over time, age 10–21

Henriette Holmegaard[a], Louise Archer[b], Spela Godec[b], Emma Watson[b], Emily MacLeod[b], Jennifer Dewitt[b] and Julie Moote[b]

[a]Department of Science Education, University of Copenhagen, Copenhagen, Denmark; [b]IOE, University College London, London, UK

ABSTRACT

Background and Context: There is a call for more young people to continue into higher education computer science (CS).

Objective: To understand young people's choices into and away from CS, by addressing the inequalities their trajectories as shaped over time and in relation to their capital and identities.

Method: Ninety-four longitudinal interviews were conducted with nine young people and their parents from age 10/11 to age 21/22, analysed through the lens of identity and capital.

Findings: CS-related capital facilitated "smooth" transitions into CS-degrees, with family capital being salient in the choice-process, and out-of-school experiences for navigating CS-courses. Other young people faced disjunctures between their capital, identity and the field of CS education, feeling "the weight of the water", experiencing study challenges and being at risk of withdrawing. Finally, a group of young people were "navigating a different waterway", reflecting a greater fit with a different field.

Implications: We call for actions to broadening what counts as CS.

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Science capital; computer science; aspirations; computer science identities; choices

The 'participation problem' in computer science

Internationally, it is widely recognized that there is an urgent and growing need for a highly skilled workforce with advanced Computer Science (CS) expertise who can meet and develop the complex demands of the growing digital and technological markets (Bailey & Stefaniak, 2002; Ezell, 2021; Montoya, 2017). Beyond national economic concerns regarding the value of CS for meeting key workforce and skills gaps, it has also been noted that supporting more children and young people into computer science may be important for a range of social justice-orientated reasons too. For example, Santo and colleagues discuss how increased and widened participation in CS can support increased agency and technological literacy, so that children and young people engage in active

CONTACT Louise Archer l.archer@ucl.ac.uk IOE, University College London, London, UK

citizenship and contribute critically as agents in their own lives, living within an increasing technologically advanced world (Santo et al., 2019).

While UK figures suggest a cause for concern (Markes, 2006) despite a range of initiatives aimed at raising participation (Kallia & Cutts, 2021). Our analyses of HESA data[1] reveal that CS remains one of the most gender-imbalanced degree subjects, with women remaining a significant and persistent minority. For example, in 2020/21, only 14% of the first-year CS undergraduate degree cohort from England domicile was made up of female students[2], and Hayes (2020) reported that similar gendered patterns are present from secondary school age, where only 20% of students taking a CS GCSE[3] (age 16) and 15% of students taking a CS A Level are women[4]. In other words, for many years, CS, together with some areas of engineering, has been one of the least demographically diverse STEM fields (Morrison et al., 2021). A study by P. E. Kemp et al. (2019) additionally highlights the role of socioeconomic background; using the IDACI poverty indicator, they found that boys from low socioeconomic backgrounds are less likely to study CS (21%), compared to boys from high socioeconomic backgrounds (25%). While, interestingly, the opposite pattern was found for girls (with 7% of girls from lower socioeconomic backgrounds choosing CS in comparison with 5% of girls from higher socioeconomic backgrounds), however, this pattern of a modest relative increased uptake of CS amongst girls from more disadvantaged backgrounds does not apply to Asian, Black, and Chinese girls. The authors conclude that the trend of the most socioeconomically disadvantaged girls being more likely to take CS was heavily influenced by the larger numbers of White students in the population. A range of studies also show how inequalities of race/ethnicity interplay with aspirations and trajectories towards CS (Hamer et al., 2023; Ross et al., 2020; Wong et al., 2021). For instance, a study conducted in England by P. Kemp et al. (2018) showed that GCSE CS primarily attracts white (76%) and South Asian (12%) students, and that participation among students who identify as black or mixed ethnicity is lower than among comparable STEM-subjects such as physics and mathematics (P. Kemp et al., 2018). In the literature, an effort has been made to understand the underrepresentation of minority ethnic groups and particularly the acute under-representation of black women in CS. For example a study applying an intersectional lens showed how black women had fewer social contacts and relations in CS than their peers, and that these social relations were significant for supporting CS career choices (Ross et al., 2020). It has also been noted that black women in CS experience a range of injustices within the classroom, institutions and internships (Rankin et al., 2021). Attracting a more diverse student cohort into CS has, as outlined above, been a key focus within the literature, largely reflecting labour market calls for more a more diverse talent pool of candidates as well as in order to increase the number of qualified candidates to meet the needs of the job market. Arguably, computational thinking – programming and advanced mathematics-based computing competences should be part of other areas of STEM as well, where for example big data, advanced algorithms and data driven inquiries are becoming increasingly important and exceeding disciplinary boundaries (Rude et al., 2018; Vergara et al., 2009). However, more importantly, calls have been raised to attract the next generation of computer scientists by supporting the interest and aspirations of young people from early on in their lives. These calls are particularly relevant in the context of research reporting that, compared with other STEM areas, young people tend to express lower levels of interest in CS and their interest also declines earlier (Hamlyn et al., 2020).

To encourage more young people to see CS as something "for them" in their lives, and to support their aspirations to and continue into a career within CS, there have been numerous policy initiatives, such as building on the playfulness and creativity of CS, by introducing coding into the curriculum from early childhood as a form of language learning, and by introducing CS qualifications into schooling (Bers, 2019). In England, where this study is situated, one major initiative in this area was the introduction of CS in school. In 2013, the elective Information and Communications Technology (ICT) subject was replaced with the subject Computer Science, which was added to the national curriculum for primary and secondary education in 2014, together with a new elective GCSE qualification that students take at the age of 16 (Department for Education, 2013). The intention was to support more children in seeing themselves as not only users but also creators of technology. The hope was that such moves could support more children to see CS careers as desirable future pathways, thus helping to meet the so-called "digital skills crisis" (House of Commons, 2016; P. E. Kemp et al., 2019). It is important to highlight that although CS was introduced to boost skills, this is not actually a formal requirement for most CS degree courses. While Science and Maths A Levels are often listed as entry criteria for higher education STEM study programmes, Computer Science A Level is typically not listed as a formal entry requirement even for CS degrees (rather, students are often expected to have done Maths A Level).

The literature points to a number of factors and inequalities that discourage and exclude young people from continuing with CS. Several studies have shown how CS often is associated with stereotypes as of being smart, nerdy and antisocial, which some young people (and interacting with gender, race and social background) experience as conflicting with their sense of selves, and report feeling "not clever enough" to fit into CS (Kunkeler & Leonard, 2021; Wong, 2016), or that they must compromise and "tone down" their identities to do so (Berg et al., 2018). Challenges of "fitting in" have been a focus of several studies, where identity as a conceptual lens has proven particularly useful for exploring exclusion and resulting inequalities (Mooney et al., 2018; Peters & Pears, 2013; Rodriguez & Lehman, 2017). The challenges pointed out in these studies show how exclusions from CS are powerfully shaped by the learning environments. For example, research conducted within higher education has been found to often be impersonal, hierarchical and celebrating students' specific skills and experience (such as programming), while tending to overlook other areas (Barker et al., 2002) cross-disciplinarily, creativity and the value of CS for society (Peters, 2017).

Traditionally, research (along with policy and practice) has largely located the responsibility for not pursuing CS within the young person (such as due to a lack of interest, fit or skills), a focus which we argue can be regarded as deficit-oriented. Such framings also hinder CS teachers from recognising and addressing how the differential provision of representations, relations, resources and experiences within CS education mean that not all young people experience CS as engaging, valuable and a field that they could see themselves contributing to (Zhou et al., 2020). However, more recently, increased attention has been given to the structures and systems that exclude many young people from entering and staying in CS pathways. In particular, feminist theories have contributed with a critical focus towards understanding the lack of diversity within the student body by asking: "what is computer science and who is it for" (Vitores & Gil-Juárez, 2016). Also, attention has been raised regarding social inequalities in CS, and a review shows, that initiatives that intend to support more (and more diverse) young people in seeing CS as a future avenue for them, are often short term, detached from formal education and aimed at changing the students to fit in with CS, rather than vice versa. Thus, despite good intentions, many initiatives/interventions do not solve the participation problem because they reply on young people as the sole agents of change. Rather, the authors argue that changes are required in the way CS-education is practiced and enacted, restructuring the rules of participation and providing young people with long term support (Kallia & Cutts, 2021).

Calls have been made for more qualitative studies to provide rich, in-depth accounts to help continue developing and enhancing our understanding of the lack of diversity within CS (Winter et al., 2021; Yates & Plagnol, 2022). Within science education research, qualitative longitudinal studies have proved valuable in understanding how choices and aspirations develops over time, and in relation with young people's backgrounds, resources and their experiences in and outside school (Carlone et al., 2014, Author ref 1, Author ref 2). With this paper, we strive to enrich existing discussions within the field of CS education, by delving into the inequalities which shape the development of young peoples' CS-related choices and aspirations. Our contribution draws on a unique longitudinal interview data from parents and young people in England, produced over a 12-year period, from the age of 10 to the age of 22, providing an extensive examination of their journeys as they negotiate trajectories into and away from CS. In particular, we focus on 94 longitudinal interviews conducted with nine young people (and their parents) who at some point aspired to CS routes and either did ($n = 4$) or did not ($n = 5$) go on to study for a CS degree at university. The longitudinal framework of our study grants us unique in-depth access to the ongoing, evolving dynamics in CS aspirations and choices over time. Consequently, our research offers a rare and illuminating window into children and young peoples' choice-making processes. Specifically, our paper poses the following questions:

(1) How and when did aspirations towards CS appear within the young people's narratives?
(2) How were aspirations towards CS negotiated and sustained, or dropped, over time?

We are interested in the young people's aspirations and choices and thus focus on *their* definitions and meaning-making of the future. This means that we apply CS as an overall category covering a range of subjects, studies and careers that young people mention that might relate to CS (including Information Technology (IT), technology and computing).

Theoretical framework

We apply a sociological conceptual framework to approach young people's choices as dynamic processes that are continuously negotiated over time (Holmegaard, 2015; Holmegaard et al., 2014a) and across contexts (or *fields*, (Bourdieu, 1984)). We focus particularly on the role capital plays in how young people navigated their CS-trajectories, while also considering the interactions of capital with habitus/identity and the field of CS – with a particular interest in higher education CS.

Capital refers to the range of cultural, economic, social and symbolic resources that a person might possess and accrue. In this study, we find particularly useful the extensions of capital to specific STEM areas, including science capital (Archer et al., 2015), STEM capital (Moote et al., 2020), maths capital (Archer et al., 2023b) and computing/computer science capital (Copsey-Blake et al., 2021; Vrieler & Salminen-Karlsson, 2022). Previous research has shown that young people who possess forms of capital that are most highly valued by dominant fields (that is, symbolic capital, or exchange value capital) are more likely to aspire to science, see science as being for them and participate in science/STEM at degree level (Moote et al., 2021). It is important to note that the value of capital is not absolute, but is determined by the field (where some forms of capital might have more exchange value than others, see Skeggs, 2004), which Bourdieu outlined as socio-spatial contexts of power that set the "rules of the game" and determine what is valuable and what less so (Bourdieu, 1977, 1986). That is, young people from less privileged communities still possess a wealth of forms of capital, but these may not necessarily be valued within dominant fields. An example of field could be a CS lesson at school, or a wider context of CS higher education.

The other key Bourdieu's concept is habitus, which includes internalised dispositions that shape what a person might see as "normal" and "thinkable" for them. As Bourdieu explains, habitus is both structured and structuring: that is, while the habitus may involve the exercising of choice and agency, this agency is always situated and shaped by structural relations of inequality, such as being enabled or constrained by the differential distribution of capital and power relations within the field. As Bourdieu argues, when a person's capital and habitus "fit" with the field in question, this can lead to experiencing the particular field like "fish in the water" where they do "not feel the weight of the water" (Bourdieu & Wacquant, 1992, p. 127). Such fit, or alignment, between one's capital, habitus and field can generate social advantage, through resources and behaviours being recognised and rewarded, such as by teachers and lecturers. In contrast, young people who experience misalignment between their habitus and capital within a given field are likely to "feel the weight of the water" and, as a result, be less likely to "get on", navigate the field, and experience that field as being "for me". In line with this, Bourdieu introduces the concept of symbolic violence to characterise the subtle mechanisms of power that sustain inequalities. Symbolic violence operates as an invisible force that upholds the existing social order by presenting unequal opportunities and outcomes as "natural", for instance as simply the result of a differential distribution of "natural talent". It ensures that the dominant norms align with the worldview, desires, and practices of privileged groups (who are seen/see themselves as "deserving" of their privilege), while non-privileged groups may come to see their disadvantage as also "right" or "natural" due to their own "deficits" (e.g. of talent, interest, skill), rather than due to inequitable power relations and practices of dominationand exclusion (Bourdieu & Wacquant, 1992). The final concept we introduce as part of our theoretical framework is identity. We recognise that adopting a Bourdieusian framework, we may be expected to stick with habitus, rather that identity. The two do much of the same explanatory work, such as to help us consider how people come to imagine what is thinkable, possible and desirable for them (e.g. the extent to which they might see CS as being for them, or not). While there are some nuanced conceptual differences between the two, as discussed elsewhere (Archer, Godec, et al., 2023), we suggest that our particular use of the concept of identity is sufficiently conceptually congruent with habitus. Our decision to work with a concept of identity rather than habitus is, we argue, being more accessible and relevant for the computer science education research community, where identity has been become a productive lens for understanding educational experiences, choices and trajectories in the CS education field (see for example, Kinnunen et al., 2018; Peters & Pears, 2013) and science/STEM more widely (Avraamidou, 2020; Fowler, 2010; Holmegaard & Archer, 2023). Thus our use of "identity" draws substantially on notions of habitus (as both structured and structuring, highlighting the role of social inequalities in relation to both capital and field in shaping agency and "choice") but extends these further through attention to some of the micro-dynamic and ongoing negotiations that takes place within young people's negotiations of their sense of self and their trajectories (Holmegaard et al., 2014, 2014b). In particular, we use the term identity to capture how young people's navigations are shaped by social axes such as gender, race/ethnicity, social class, and so on (Archer & Francis, 2006; Avraamidou, 2020); and can be performative (Butler, 1993), that is, produced and enacted through complex discursive and bodily acts, rather than emanating from any "natural" or essentialised biological basis. In other words, identity is fluid, constructed and context-dependent, rather than a fixed and stable entity. In this way, we approach children and young people's narratives as expressions of how they comprehend and make meaning of their lives as *consistent* and *progressive* stories, that may construct and convey a sense of identity as being stable and coherent (Polkinghorne, 1988) despite flexible, fluent and sometimes contradictory performances (Bruner, 1990). In particular, we understand identity as shaping and mediating young people's choices and negotiations over time (Holmegaard et al., 2014a), producing ideas about whether a CS identity might be "for me", or not and the construction of a (constantly negotiated) trajectory towards the future. Drawing on the work of Bourdieu (Bourdieu, 1984; Bourdieu & Wacquant, 1992), we understand identity as being negotiated in the interaction with capital, and where both capital and identity operate within a particular field (in this study, CS education).

Applying our theoretical lenses we strive to understand how capital and identity influence and shape young people's CS degree trajectories over time, paying particular attention to how the norms and expectations within the field of CS education and what is being recognized and valued, shaped young people's trajectories in and out of CS. Due to the limitations of our sample, we focus particularly on interactions of gender and social class within interplays of identity and capital – although we recognise that these will always also be intrinsically racialised.

Methods

Longitudinal interviews

The data for this paper are drawn from the [name] project, a 13-year longitudinal mixed methods study funded by [funder] that has been following a cohort of young people from age 10–22. The wider study includes surveys conducted with over 40,000 young people and longitudinal interviews conducted with a sample of 50 young people (along with their parents) from age 10–22. Interviews with young people were conducted at six time points: at the end of primary school (age 10/11), through compulsory secondary education (at ages 12/13, 13/14, 15/16) and at ages 17/18 and 20/21. Interviews with these young people's parents were conducted at five of the same age points (excluding when their children were aged 13/14).

In this paper we focus on 94 longitudinal semi-structured (Kvale, 1996) interviews that were conducted with 9 young people, and their parents, from the qualitative cohort who at some point aspired to and/or studied for a GCSE (age 14–16), A Level (age 16–18) or degree in CS (one participant, Gerrard, missed one interview due to ill health). Four of these nine went on to study CS, of whom two had graduated, one was still studying and one had withdrawn at the age of 21 (see Table 1 for key demographic characteristics and participants' subject choices, and Table 2 for their aspirations at each time point). As such, our data are not representative or generalisable of all CS students in England nor the available range of potential post-compulsory CS routes.

Parental interviews and the most recent young person interviews typically lasted around 1.5 hours but interviews were shorter when children were younger (e.g. typically around 30 minutes at age 10). Interviews reported in this paper were conducted by 11 members of the wider project research team over the ten years of the study, including several of the paper authors. Interviews were recorded and professionally transcribed.

Parent and child interview protocols were informed by the literature and iteratively developed over the course of the study to capture the (changing) nature and range of influences on young people's educational and occupational aspirations and trajectories. Both parent and child schedules mirrored key topics such as: favourite and least favourite school subjects, views and experiences of school science (generally and by disciplinary area); STEM, subject experiences, preferences/dislikes; aspirations; reasons for and influences on aspirations; educational and occupational choices and reasons for these; out-of-school interests; experiences of careers advice, guidance; experiences of outreach and work experience. Parents were also additionally asked about their parenting styles and practices (e.g. Horvat et al., 2003; Lareau, 2002).

Analysis

The analysis deciphers the longitudinal negotiation process of aspirations towards technology and CS, and their interaction with the choices-narratives expressed over time by a group of nine young people and their parents. First, parent and child interviews were combined into a single, chronologically ordered mapping summary which was then inductively mapped against the different emergent trajectories, as per Table 3. The combined transcripts were read by the team, in particular, pairing readings between researchers who had and had not directly interviewed the young person in question, to check interpretations. Codes were developed, checked and refined iteratively by the team. This process produced three main groupings (reflecting those who had taken ICT/CS at GCSE, A Level and Degree level, which formed the overarching structure of the below findings) that were then inductively and deductively coded, moving back and forth between the data and the theoretical framework to produce a gradient of negotiation-patterns, mapped against the themes of identity and capital. Table 3 shows a summary of each groups' aspiration (age of first CS-related aspiration, whether the aspiration was mostly intrinsic, extrinsic, or both), liking of and competence in CS and supporting subjects (Science and Math), educational experiences at A Level and degree (where applicable) and key forms of (CS and maths) capital, namely, family support and out-of-school experiences.

Table 1. Background information of interviewees who during the interviews considered choosing CS or IT-related higher education studies.

Interviewee (pseudonym)	Gender	Ethnicity	Social class	GCSE subjects*	A Level subjects (grade)	Age when first aspired towards computing or IT careers	Degree subject/status at age 22
Josh	Man	White British	Lower middle-class	IT, Geography, Religious Education (RE), Physical Education (PE), Statistics	Maths (A*), Further Maths (B), Physics (B), Computing (A)	10/11	Completed Computer science undergraduate, working
Bob	Man	White-South Asian	Upper middle-class	Resistant materials, Geography, Spanish, ICT	Maths (A), Physics (A), Computer Science (B)	10/11	Computer science undergraduate working as Software Engineer
Gerrard	Man	White Eastern European	Working-class	ICT, PE, Business studies, Graphics, Mandarin	Maths (A*), Further Maths (A*), Physics (A) [HSK Level 3 Chinese]	13/14	Maths with computer science undergraduate
Bethany	Women	White	Lower middle-class	Product Design, History, Business Studies	English Literature, Sociology, Applied ICT (grades C, C, D – subjects not specified)	17/18	Started (but didn't finish) Computer science undergraduate, now working in retail management
MacTavish	Man	White	Working-class	German, Geography, PE and Drama	AS Levels only: Geography, IT, Use of Maths and PE	10/11	Working in landscaping (landscaping qualifications gained age 18)
Kaka	Man	South Asian	Middle-class	Computer Science, Spanish, History and PE	Biology (A), Chemistry (A), Maths (A) [AS Level in PE]	17/18	Medicine degree
Poppy	Woman	White	Upper middle-class	Geography, ICT, Music	Chemistry (A), Maths (A*), Biology (A*)	None	Chemistry undergraduate with postgraduate law conversion
Victor	Man	White	Lower middle-class	Computing, Product Design, French, History, German	Physic (C), Maths (D), Economics (C)	13/14	Astrophysics undergraduate working in Administrative/data role
Finch	Man	Mixed	Middle-class	Italian, Chinese, German, started Computing but dropped it	Biology (E), English Literature (C), Music (B)	13/14	Music performance undergraduate working as a freelance musician

*All young people took GCSEs in English language, Mathematics and Science in addition to the ones mentioned here.

Table 2. Young people's aspirations over time.

Interviewee	Age 10/11	Age 12/13	Age 13/14	Age 15/16	Age 17/18	Age 20/21
Josh	Pharmacy or IT	Marine biology	Programming, army, marine biology	Cyber security, electronic engineer, software programmer	Computer science, cyber security	Cyber security (something well-paid)
Bob	Fireman, IT-consultant, or scientist	Electronics engineer	Electronics engineer	Electronic engineer or web design	Programming job, or something well-paid	Job in tech – cloud architect
Gerrard	Footballer, Doctor, Lawyer, or a scientist working at NASA	Maybe a scientist or astronomer	Maybe something linked to computers, web design	*Not interviewed*	Pure maths, astronomy, computer science, cryptography, or software engineering	Earn enough to support family
Bethany	Teacher or surgeon	Teacher or nurse	Architect or scientist	No clear aspiration but suggested something to do with English or History	Computer science, programmer	Work in Human Resources
MacTavish	Police officer, footballer, or computer technician	Video games designer or footballer	Something involving sport	Something to do with sports or sports coaching	No clear aspiration	*Not interviewed*
Kaka	Scientist, mathematician, or footballer	Scientist, footballer, or mechanic	scientist, or surgeon (or something to do with science)	Biology of PE or sports physiotherapist	Medicine specialising in sporting injuries, perhaps computing	Doctor in America or Middle East
Poppy	Something adventurous involving science	Veterinarian	Veterinarian	Something in science (Natural Sciences)	Something that isn't purely science – law conversion	Law conversion (patent law)
Victor	Scientist, inventor, or engineer	Science teacher, musician in a band	Science teacher or IT technician	Astrophysicist	Astrophysicist	Classic car mechanic, or space exploration
Finch	Nuclear physicist, astrophysicist, or policeman as backup	Scientist (chemist), classical musician, or property developer.	Musician or application developer	Concert flautist	Orchestral flute player	More "academic" study, or session musician

Table 3. CS trajectories and aspirations, liking & competences, experiences and capital.

	Aspirations		Liking and competence in CS and supporting subjects		CS educational experiences		Capital	
	Age first aspired to CS job	Nature of CS aspirations	CS	Science and Maths	CS A Level	CS degree	Family CS/Maths capital	Informal CS learning
Smooth CS trajectories (successfully completed CS degree): Bob, Josh	early (10/11)	Intrinsic and extrinsic	Strong	Strong	Positive	Positive	Strong, e.g. multiple immediate family members working in tech	Regular (e.g. afterschool coding club, home resources)
Contested CS trajectories (experiencing challenges on CS degree): Bethany, Gerrard	late (G – 13/14; B – 17/18)	Extrinsic	Weak/ partial	Weak/ partial	N/A or neutral	Mixed/ negative	medium/low e.g. family friend	Occasional
Fleeting CS trajectories (did not enroll on CS degree): MacTavish, Finch, Poppy, Victor, Kaka	late (17/18) or never	Extrinsic or NA	Weak/ partial	Weak/ partial	N/A or negative	N/A	low (one exception - Poppy)	None

Results

We now discuss each of the three main groupings identified by the analysis, as presented in Table 3: (i) the two young men who experienced smooth negotiations of a CS degree trajectory and successfully completed their CS degrees; (ii) the two young people who experienced more contested CS degree trajectories in which they either withdrew or were experiencing an uncertain degree outcome; and (iii) the five young people who had more fleeting negotiations of CS trajectories, either up to GCSE or A Level. The analysis fleshes out the gradient negotiation-pattern of these nine young people's CS-related aspirations and considerations over a 12-year period, with a particular attention given to the role played by symbolic forms of capital and identity (see Theoretical framework above).

"Like fish in water": smooth CS negotiations (Bob and Josh)

Bob and Josh both spoke extensively about resources and experiences that we interpreted as forms of high status, symbolic capital (both specific CS-related capital and wider science/maths/STEM capital), from family involvement and support for engagement with CS-related activities out-of-school from an early age. Bob's mother, for instance, holds a science Ph.D. from a well-recognised university, and has since worked in the science industry. Bob's grandparents on his mum's side were scientists as well, Bob's father has an engineering background and owns an IT-company and Bob's sibling also followed a science degree trajectory (Bob mentioned that his father and both of his brothers worked within "design and technology and things like that", 12/13). Josh comes from a white middle-class background. While neither of his parents attended university, his father and brothers work in the IT sector, while his mother has an online shop, which she runs from home. These examples show that Josh and Bob both have a substantial amount of CS-related family capital.

Josh and Bob's further CS (and wider STEM) capital is evident in their regular engagement with CS-related activities from a young age. Both shared experiences of regular family visits to science museums, attending out of school science clubs, watching documentaries, having science magazines in the household etc. For example, Bob's mother held a membership of a science professional society and brought Bob to events to help support and grow his interest in STEM. Bob attended an afterschool club where he learned how to program (as his mother explained when he was aged 13/14, "he built a simple website and now he's going in and sort of rebuilding it by coding"), went on to construct his own drone at home. He also built a computer together with his father. Similarly, Josh recounted experiences of programming and building his own computer at home in his spare time, activities that arguably were both enabled by home cultural and economic capital and which in turn, translated into experiential forms of capital that helped sustain and grow the young men's computing competence, interest and trajectories.

The case studies of Bob and Josh portray what we call "smooth" negotiations of a CS trajectory. As we show next, the alignment of capital and identity enabled the two young men to successfully navigate a route to a CS degree and eventually land a job in CS. We argue that their family CS-related capital appeared to be particularly important for supporting their early CS-related aspirations and navigating the application process to get to the university CS degree. The capital developed through out-of-school CS-related experiences, where the two learnt coding and programming, turned out to be especially valuable *during* their CS degree, allowing them to smoothly navigate their degree (being able to use their coding and programming skills) and maintain a competent CS identity (feeling a sense of fit in the CS field, in part due to the familiarity that resulted from the out-of-school experiences). Alongside the CS related capital, a specific maths capital (maths skills and knowledge about maths transferability) played an additional important role in both helping the two boys get a place at their desired university as well as later successfully navigating the degree course.

Early and stable aspirations towards CS facilitated by family CS-related capital

Family played a key role in influencing Bob and Josh's CS-related aspirations from a young age. When asked about what he, retrospectively, felt to have had the strongest influence on his route into CS at age 20/21, Bob replied that it was his parents: "they kind of introduced me to it at a young age, and then I developed kind of just an interest in it, and they kind of supported me through it". Indeed, we recorded an interest in technology and a CS-related aspiration already during our first interview with Bob when he was 10/11; he shared that his favorite activities at school were "science, IT and building stuff", and that one of his aspirations was to become an IT-consultant, like his father. Josh, similarly, credited his family support and his father's IT-experiences as the biggest influence on his route into CS. Drawing on Bourdieu's theory, we would also suggest that the strong family CS-related capital likely influenced the young men's dispositions, supporting them to imagine a possible and desirable future for themselves within CS.

The importance of family CS-related experiences and insight, which we interpreted as forms of CS-related family capital, appeared to influence the continuity of Josh and Bob's CS-related aspirations over time. While our data (see Table 2) show that the two expressed a number of aspirations over the years (e.g. after going diving during a vacation, Josh briefly aspired to marine biology when he was interviewed at age 12/13), their CS-related aspirations remained pretty consistent and often stated alongside other, more fleeting interests and/or returned to a CS-focus by the time we had spoken next (e.g. at age 13/14, Josh returned to "programming, things like that" when asked about his aspiration). What appeared to have made a difference to the stability of the CS-related aspirations was the strong awareness and knowledge of the benefits of pursuing a CS trajectory, along with specific encouragement from family members (and teachers, albeit these seemed to have played a smaller role in comparison with family). Josh, for instance, spoke about how both his dad and his teacher emphasised future job opportunities within technology and computing, as high demand areas, which Josh reflected thus: "there's not many people who have those skills because it takes a while to learn them and yeah, so I'll probably have quite a good chance" (age 12/13).

Josh and Bob's families supported the boys through facilitating family conversations and helping them become familiar with the nature of CS-related jobs. At age 10/11, Bob recounted a family dinner where he had learned about his uncle's work with satellite control systems. His mother explained how this conversation had helped Bob to develop "a sense of what people in the family do with that type of qualifications", concluding: "I can't see that he [Bob]'ll do anything other than end up in a job related to computing", which can be understood as seeing computing a normal and "natural" choice for Bob – and Bob well-suited to this trajectory, like the rest of his family. In Bourdieusian terms, computing seemed to be presented as a field that Bob would "naturally" fit, and spending time with relatives who held jobs in this sector further helped facilitate the closeness to the specific field and a "natural" that this is what people like us do.

The transition to and through a computer science degree

Josh and Bob's transitions into a CS degree were well-informed and supported by their families (sitting in stark contrast to the other participants we discuss below). Both the boys and their parents appeared to have a strong understanding of the degree requirements, including formal entry requirements and well as knowledge and skills that would enable a "smooth transition" once the students started their degree.

Josh was strategic in his choice of A Level courses he took at the age of 16/18. Before deciding on the specific degree, he took a range of relevant subjects to keep his options open, including A Levels in Maths, Further Maths, Physics and Computing. This decision appeared to be (at least in part) shaped by his parents, who encouraged Josh to keep the focus on both maths and CS. His parents steered him towards a joint degree, combining CS and mathematics, which they – and Josh – agreed should provide him with better employment prospects after graduation than CS alone. As his mother put it (when Josh was age 17/18), "he sort of agreed with us that it's actually, that must open more of a window". It is important to note while a number of aspects within Josh's trajectory appeared to be led by his own interest and aspirations, looking from an identity perspective his decisions could be also be understood as a coherent choice-narrative negotiated in alignment with the external recognition of desirable pathways, in this case parental expectations for him to make "sensible" choices and get a stable job in a well-paid sector, with CS-related job being a preference. This however does not mean that Josh experienced limited agency in his choice of study, for Josh there are several examples of him exercising individual agency, albeit recognising that this agency was facilitated by his structural location and possession of considerable capital. For example Josh undertook extensive independent research into CS degrees and careers across different CS areas, making considerable use of university league tables and figures on the job destinations and salaries of recent graduates practices commonly associated with middle-class forms of choice-making (Ball & Vincent, 1998). In this way, despite the lack of experiential family capital terms of the experience of studying at university (no one in his close family attended university), Josh's family appeared to have instilled a pragmatic focus or are narrow repertoire of suitable future avenues – even if Josh's pathways was a shift away from his parents plans for Josh to do an internship as a way to get a well-paid job in CS. Josh ended up completing a three-year degree in CS, attained well and after graduation gained a position within a cybersecurity firm. At age 20/21 reflected on his success (and his experience of having to work less hard than his peers during his degree) being facilitated by his prior CS experiences (including entering the degree with the "right set of A-levels", including both Maths and Computing).

Bob's transition to a CS degree was, similarly, well-informed and supported by his family's CS (and wider) capital. Bob chose and was admitted to a selective Russel Group university for a four-year degree in CS, which he attained well in and enjoyed. He explained in an interview when he was 21/22:

> In terms of just getting on with other people, I've felt quite similar. I mean you get a broad range of people obviously. In terms of experience beforehand or like knowledge of the field already, I felt like I had more than most other people on the course, just cos I obviously do it in my free time, and perhaps they hadn't done.

Bob's smooth navigation of his CS degree was supported by feeling he fitted well on the course (e.g. "I've felt quite similar"), and his experience was supported by the CS-related capital he had gained prior to starting the degree ("experience beforehand or like knowledge of the field already"). The above quote can be interpreted how it was this specific CS-related capital that supported his identity and fitting in. Bob's explicit experiences of doing well at his program, suggest that his CS-related capital is not only an asset in academically managing the program, but also supports him in constructing a strong sense of belonging within his studies which from an identity perspectives also can be understood as being able to construct sense of feeling of mattering (Strayhorn, 2018) by recognising oneself and receiving recognition from relevant others and by seeing a fit of own interests and competencies and the ones expected and supported by the program. To return to Bourdieu's metaphor, it was the alignment of Bob's capital and identity with the field that supported him to experience the CS degree "like a fish in the water".

We extrapolate that computer science capital (especially in the form of skills gained from activities such as building computers and coding) can translate into exchange-value assets (Skeggs, 2004) in CS fields, such as degree-level CS education. Both Josh and Bob spoke of experience that helped them develop what we interpret as embodied habitual knowledge of how to interact conceptually and materially with technology/computing. Bourdieu explains that capital can be "embodied" through the acquisition of knowledge and skills that can provide the tacit knowing of how to act in a certain situation that can help the person in question experience the field as a "fish in water" (Bourdieu, 2018). Moreover, computer science education research (Antle, 2013) has similarly discussed how early and steady exposure to coding and technology in family and outside school (which can be interpreted as embodied tacit knowledge, see also (Shapiro & Stolz, 2019)) helped young people develop valuable knowledge of how to interact with computers, the materiality of how computers work, what coding feels and looks like and what different programming languages entails and can be used for. Such exposure, Cutts et al. (2018) and Margolis (2017) have found, can serve as the platform for building more advanced computing skills, the confidence of knowing how to approach and engage with computer problem solving tasks, and support young people's aspirations and their belief that computing might be "for them" – as we noted was the case in Josh and Bob's CS trajectories (Cutts et al., 2018). From an identity perspective, we can gain valuable insights into Bob's and Josh's continuous involvement with computing and technology as these experiences equips them with a multifaceted understanding of what CS are and represents, and who can actively participate and contribute to it ("someone like me"). In the rich landscape of identity literature, the ability to envision a promising and personally meaningful future is acknowledged as the initial crucial step in constructing a course and aspirations towards it (Tolstrup Holmegaard, 2021). This process is inherently intertwined with decision-making, as illustrated by our exploration of selective mathematics in the forthcoming section. The choices made in the present are not only influenced by their immediate consequences but are also deeply entwined with individuals' visions of who they can become and the role that CS plays in crafting such identities.

The interplay between maths capital and a CS trajectory

It was not just the specific CS-related capital that influenced and sustained Bob and Josh's aspirations and participation in CS, but also maths-related capital. Bob and Josh had a keen interest and reported enjoying maths from a young age. At age 12/13, Josh explained how he was "one of those people who people get surprised by" because he liked math and was "also good at it". He furthermore explained how his grandparents wanted him to become a mathematician, and his parents eventually pushed Josh towards studying Computer Science and Mathematics as elaborated in the section above. It was these positive attitudes/relationship with maths and a general family support for maths, along with a clear and early awareness of the requirements of a CS degree, that led the two to take A Level Math, where they achieved high grades. While as we noted above, in the UK, Maths A Level grade is usually an entry requirement for a CS degree (and would therefore have to be achieved by most students applying for CS degrees), Josh and Bob's awareness of the importance of maths is in stark contrast to their peers, whose "contested" CS trajectories we discuss below – did not see maths as important and related to CS, and/or struggled with the subject. Josh's (age 17/18) awareness of the importance of maths for CS trajectory is outlined as follows:

> The main thing, they want you to have done is Maths. So, a lot of unis actually, well some of them it's a must that you've done Maths, for some it's even like a must you've done Further Maths. Even though it [Further Maths] isn't [a requirement], but it basically is to get in. (age 17/18)

Their maths skills and experiences also played an important role in how they were able to "smoothly" navigate their university course, further demonstrating that maths has a high exchange value within the field of CS. From Bourdieusian perspective, the boys' apparent awareness of the importance of maths for CS degrees (as an entry point and beyond) can be interpreted as a form of symbolic cultural capital that they were able to deploy to navigate their CS degree trajectories, and that (as we will return to) was not the case for other young people in our study that did not connect math and CS before entering higher education. Indeed, evidence suggests that for some CS programmes, students with a background in maths typically do better in their studies (Beaubouef, 2002). The prerequisite for taking Maths in order to access and succeed in CS has been pointed out as key issue for higher education to actively address (Takács et al., 2021), in order to retain students that opt in for computing but are pushed out because of math. As such math can act as gatekeeper that weed students out that enter without advanced math skills, but who do meet the enrolment criteria.

"Feeling the weight of the water": contested CS trajectories (Bethany and Gerrard)

We now consider Bethany and Gerrard, who compared with Bob and Josh, had limited forms of dominantly-valued capital that would support and facilitate their CS trajectories. While they succeeded in getting places on their respective CS degree courses, they encountered various challenges to their participation, and had to work hard to maintain a viable CS identity and trajectory – with Bethany eventually withdrawing from the CS degree and no plan to return, and Gerrard expressing concerns about completing his studies.

As we discuss next, the resources that Bethany and Gerrard brought with them, were not valued by the dominant field of CS and hence did not have the same exchange value as that possessed by Josh and Bob. That is, we argue that the field of CS excluded them from the generation and possession of comparable forms of (symbolic) into CS-related capital. Neither of Bethany's parents worked in CS (or broader STEM), although her two older sisters worked in healthcare (one as a nurse and another as a midwife). Gerrard's parents (his family migrated to the UK when he was 6) also did not work in CS; his father worked as a builder and his mother in customer service. Neither of them had close family members who worked in the sector, and while both their parents supported their choices, they did not seem to be able to help facilitate their CS trajectories. The observation voiced by Gerrard when we first interviewed him at the age of 10/11 seem particularly indicative of his family situation when it comes to science: "They don't really talk about science and stuff" (however, he later spoke about his parents' support for mathematics, potentially indicating some form of maths-related capital). Bethany and Gerrard also only recounted sparse examples of CS-related activities from after school or home.

Late and unstable aspirations towards CS hindered by a lack of CS-related capital

Compared with Bob and Josh's early and stable CS-related aspirations, both Bethany and Gerrard's CS-related aspirations developed later (see Table 1). Their aspirations also seem to have been more fleeting and unstable. For instance, Bethany's aspirations changed considerably over time. At age 10/11, she aspired to become a nurse (inspired by her sister and her consumption of medical-related TV programmes). Later, she expressed aspirations both within and beyond STEM, including becoming a teacher, a surgeon, an architect and a scientist. It was only when Bethany was interviewed at age 15/16 that she explained that she decided to take A Levels in Information and Communications Technology (ICT), along with English and Sociology. She first mentioned a CS-related aspiration at the age of 17/18, shortly before enrolling onto a CS degree. Looking back at her trajectory at age of 17/18, she spoke about her choice as being inspired by the experience of ICT, where she had learnt about: "different types of coding and stuff like that … it's kind of just sparked an interest that has probably been there for quite a while but just wasn't really kind of showing through". She enjoyed programming and was encouraged and inspired by her teacher: "who kind of went through a little bit of coding and it just looked really interesting, on how everything was formed behind that". Having no prior experience of coding and programming, Bethany explored some online programming-exercises that she could do at home on her own. What stands out in Bethany's narrative is the serendipitous, unsupported nature of her aspiration. She had herself admitted that the interest in CS "probably been there for quite a while", yet with little exposure at home or outside school (and CS-related school subjects only being available at a later age, as electives) she had little opportunities to explore and develop her interest, skills and knowledge, as well as the opportunity to imagine a future where CS could contribute to the forming of a sense of identity in which CS is experienced as being for "someone like me".

While Gerrard expressed aspirations towards computing at a slightly younger age than Bethany, when he was 13/14, these were similarly fleeting and unstable. Over the years, he had considered becoming a scientist, an astronomer, an architect and an engineer (see the full range of Gerrard's aspirations in Table 2). At the age of 17/18, he was planning to pursue engineering, but he dropped the idea after a negative experience with engineers when visiting his mother's workplace. Instead, he settled on CS, which he felt would offer more suitable job opportunities as "something a bit more innovative. It's something for the future as well. I mean, engineering, obviously, there'll always be work for engineers, but I just felt computer science – that sector's growing quite a lot recently". When asked if his parents held any expectations to his future, Gerrard explained how they wanted him to get "an easy job" that would have good labour market prospects – unlike the "hard jobs" they had to endure themselves: "For example, my dad is a builder and it's really hard for him because he works seven days a week and I think those are the hard jobs". In Gerrard's narrative, a computing degree was framed as a ticket to a job in a field with good employment prospects and thus a safe future with a work life involving good conditions In contrast with Josh and Bob, above, who appeared to be driven be interest and enjoyment of the subject, Gerrard's CS aspiration can be read as more extrinsic, with largely related to the anticipated job prospects for CS graduates – rather than the content or intrinsic interest of the job, as discussed next.

The transition into and through (and out of) a computer science degree

In the absence of capital and support from home or school, Bethany and Gerrard largely took it upon themselves to navigate career trajectories and degree requirements, while also engaging in challenging identity work around their alignment with their planned CS trajectory and trying to reconcile their wider interests in maths (Gerrard) and creativity (Bethany) with CS.

When it came to deciding which degree subject to apply for, Gerrard engaged in extensive identity negotiations, in which he sought to balance his passion for mathematics with his prospects of getting a "good job" following a CS route). From the age of 10/11, Gerrard had loved maths and it remained a favourite subject over the years. However, Gerrard was not aware that maths might constitute a transferable degree in the job market: "I just don't see that [maths], like, leading on to sort of work ... But yeah, that would be something really fun to learn". As a result, he came to view a maths degree as a "selfish" choice that he was not able to reconcile with his own "responsible", family-orientated identity. While he preferred maths to computing, he felt that the job-prospects within computing were clearer and more promising:

> I have to study something that I will sort of like find a job in after as well, and then just make sure that it's a degree that I can get a job in ... I was thinking of pure maths but pure maths seems too broad for me as well (...) It's because I want to be successful financially as well, just so that I support my parents and just give back to them. Because if I only studied what I want to enjoy ... I think that's a bit selfish. (Age 17/18)

As a compromise, Gerrard applied for a degree that combined computing (as a pragmatic choice) with Maths (his passion), thus taking a similar degree option as Josh above. In contrast to Josh, Gerrard seemed less aware of the connectivity between Maths and Computer Science (seeing Maths as a separate discipline), as well questioning the usefulness and utility of math as a platform for gaining an attractive job (the sort of "symbolic capital" we discussed above in the case of Josh and Bob) – these factors played into challenges Gerrard encountered during his degree.

While Gerrard loved math, he did not really have this same strong affinity towards computer science, and he entered the CS degree with little additional skills and experience in coding and programming. He felt disadvantaged compared to his peers who, like Josh and Bob above, came to the course with extensive prior CS-related skills and experiences (CS-related capital), despite these not being prerequisites for admission. Likewise, Gerrard reflected on how he had not been aware, nor had been advised, that he might be disadvantaged relative to other students on a CS degree by his relative lack of experience of coding and computing. Gerrard explained just how important these CS skills appeared to be for his studies:

> The skills that you get from Computer Science aren't really like learnt from lectures, they're more from just your own practice (…) It's a lot of practice that you really need to do … like everyone knows they've had many years of practicing even just knowing the applications that you have to use … basic stuff is like a big hurdle for someone that hasn't done it. And it's completely easy you know like second nature to someone that has done it before you know (Age 21/21)

The tension between Gerrard's reliance on his maths skills (with little prior skills or experience of CS) and the implicit expectation of the CS degree for students to have had "many years of practicing" CS skills, led Gerrard to struggle to keep up and meet the demands of the course. The lack of the "right" skills experiences also seemed to have played a major role in Gerrard failing his exams and having to repeat a year of his CS degree course. This, in turn, knocked his confidence, and as a consequence, he started to doubt his future prospects and his place within CS:

> I mean you know getting a good job and one that you enjoy as well, it's pretty tough, right? I mean, it doesn't look hopeful like currently when I'm … you know, I'm not really enjoying my degree too much, I'm not really doing too amazing in it. So yeah, like in that sense, you start to question, okay would I really enjoy working, you know, in this?. (Age 20/21)

Gerrald had to re-negotiate his initial ideas regarding the worthiness of investing effort into computer science when he struggled to see himself fitting in, which was further compounded by his academic performance, which, in turn, further contributed to his sense of not belonging. However, Gerrald also faces a dilemma when considering his future solely within the realm of mathematics. He discerns that while mathematics offers theoretical enjoyment, it fails to provide a clear career path, leaving him uncertain about his academic identity. As a result, Gerrald is challenged with the construction of a sense of belonging. This uncertainty, both within his academic pursuits and the broader professional landscape, places him at risk of disengaging from his studies.

Bethany's transition into the CS degree, at least on the surface, seemed more hopeful. Her motivation to enrol was drived by her passion for creativity (in a Bourdieusian sense, she seemed to feel there was an alignment between the capital she had gained through her ICT participation, around creativity, and the field of CS). Bethany explained her interest in programming and the link to front-end computing as a form of creative endeavour: "I just find it really fascinating to just look at it and think this is basically what forms what we see online. … I like the idea of kind of being able to create something and then actually be able to see it work". In contrast to the narratives of Josh and Bob presented earlier, Bethany's took on much of her identity-work alone, without drawing on family resources or other out of school experiences. And as it became painfully evident once Bethany started her CS degree, the field of CS was in many ways different to what she had imagined, with the alignment hinted at earlier dissipating.

Upon starting the CS degree, Bethany soon experienced a disconnect between her own identity and the normative, taken-for-granted "coder" identity of other students on the course – while the creative skills and experiences, she intimated, had little value and did not support her during her degree, that is, her creative skills had little exchange value. Like Gerrard, she felt herself to be ill-prepared for the course demands, lacking the kind of skills and experiences that notably helped feeling comfortable, and prepared and fitting in with her CS degrees. Having experienced little or no support either at home or at school, Bethany also recounted being surprised at the gender balance when first meeting CS students on university-visit. She further mentioned being unclear about the CS job and while she had been doing research independently, at the age of 17/18, she admitted she was "not entirely sure, to be honest" about what sort of job she might want. When we interviewed her at the age of 21/22, she explained her CS degree challenges:

> I changed my mind about it, I knew fairly quickly that I didn't really want to do that course, so … I think it's just I'm not like … I'm not a coder, so I don't understand it properly. And obviously computer science, that is like the main part of it, so yeah I wasn't really suited to that course after all (.) I do find like science and maths really interesting, but I don't know if I'd want to kind of work in that field now. Just don't think I'm smart enough to work in it.

Bethany's quote suggests an identity mismatch between herself (as someone interested in CS as a form of creative endeavour) and a "coder" identity, which was aligned with "cleverness" – a discourse that, as we have previously discussed, is inherently gendered, classed and racialized, irrespective of attainment (e.g. Archer et al., 2020; Holmegaard et al., 2023). Wong and Kemp (2018) discuss how computing is traditionally aligned with masculinity and technical computing skills and maths, but point to how creativity might offer a potential avenue for girls to access computing. However, as Bethany's example underlines, while such associations might offer identity "ins" to the subject, it may be unlikely to retain young women like Bethany if the dominant culture and identity of the subject remains aligned with masculinity, maths and coding competence – and where skills like creativity hold little exchange value.

The difficulties encountered by Gerrard and Bethany required them to face and work through challenges, including engaging in difficult identity negotiations of themselves within a field of CS and their reasons for studying. As Henderson (2018) discuss, a clear imagined future that is not realised can leave an individual with a sense of failure – diffused and demotivated. Moreover, Bourdieu and Passeron's (1990) concept of symbolic violence would prompt us to consider the forces of social reproduction that impel those from less privileged social positions to attribute the "blame" for their disadvantaged positions to themselves, rather than the field. As we have shown above, there is an uneven distribution of CS-related capital that appears to be expected/taken-for-granted at CS degree (such as out-of-school and family experiences and know-how that would enable a more effortless, smooth transition into the CS degree coursework). The field of CS higher education, with its rules and regularities of what is valued and rewarded (and what less so – such as creativity), also sends a powerful message about who CS is for, leading to some passionate, prospective future CS professionals to be sent a message that they are not "smart enough" to continue with computing.

"Navigating a different waterway": fleeting CS trajectories

As Table 2 shows, young people had multiple, co-existing aspirations, which for many changed over time. Above, we analysed the negation-patterns of the four young people who ended up starting a CS degree. In this final analysis section, we briefly present the selected cases of young people who at some point during the longitudinal interviews had taken an elective CS or ICT qualifications (at GCSE or A level), and expressed an aspirations towards studies or careers within the field – but who eventually not study CS in favour of other degree subjects or taking up employment. We do not discuss all trajectories (and factors influencing these) in detail, but rather, zoom in on instances that provide additional insight about how the interplay of capital and the field of CS might exclude some CS-interested young people from carrying on.

None of the participants presented here appeared to benefit from symbolic forms of CS-or STEM-related family capital that we discussed above was a key to facilitating aspirations and progressing onto CS degrees. Such capital could have supported them in knowing of potential avenues for studying and working within CS or progressing with computing which can be interpreted as (lack of) capital. MacTavish, for instance, had applied for an apprenticeship in IT, but was unsuccessful ("I actually wanted to get this IT sort of job, but that didn't happen"). He soon after dropped the idea of pursuing a career in this area and went on to apply for jobs in other sectors. While MacTavish's CS aspiration was not as strong as was the case for the participants we discussed above (especially in comparison with Bob and Josh), it is worth noting that the lack of CS-related capital played a key role in hindering MacTavish's exploration of this direction. MacTravish's mother explained how she herself struggled with understanding "fancy names" of CS job-titles when her son was applying for apprenticeships, and that she found it difficult to support him in finding a job, which may have affected his (lack of) persistence in term of trying further.

Victor, in our second example, moved away from CS due to struggling to understand and navigate how he might be able to combine his competing interests in CS and science/physics – despite expressing a relatively consistent and stable CS-related aspirations over the years (e.g. at 13/14: "I've always liked computers. I just I like the whole programming aspect, making them work and using them, playing video games, sort of I've always been into that kind of thing"; 17/18: "I'd really like to go for the computing side, IT technicians type of things but I want to do Computer Science which is Sciences and computers, I don't know what that entails but I'd really like to find out because if Science and Computing can be combined in some way, I'd really like to go for that".). Victor eventually decided to drop computing and just maintain it as a hobby rather than a qualification or potential career route – and ended up studying a degree in astrophysics.

Our data also shows that young people's aspirations and educational trajectories were shaped by a myriad of interwoven factors beyond specific CS- and math-related capital, including substantive family capital in another area (like music, in the case of Finch, who went on to complete a degree in classical music) and other competing interests (like medicine, in the case of Kaka) – reminding us that choices are relational and complex.

Discussion

This paper presents a qualitative study of the choice-processes that young people negotiated over a 12-year period in England from age 10/11 to 21/22. As such, it responds to calls for more in-depth qualitative studies of CS trajectories by offering unique longitudinal insights into the temporal negotiations of whether, or not, to study CS. We interpreted each of the young people's trajectory negotiations through the lens of Bourdieu's concepts of capital, field and the concept of identity (building upon and extending notions of habitus), paying particular attention to how the norms and expectations within the field of CS education and how the differentially classed and gendered distribution of what and who was being recognized and valued within this privileged field shaped young people's differential trajectories in and out of CS and helped reproduce prevalent patterns of participation, whereby young men from privileged backgrounds experienced the "smoothest" trajectories into CS while others experienced more contested and/or curtailed routes.

Smooth negotiations of a CS trajectory were facilitated by dominant forms of CS and maths capital, which supported young people's identity with the field of CS, enabling them to navigate the field like "fish in the water" towards the successful completion of a CS degree and subsequent employment. Yet, this capital was unevenly distributed by class and/or gender. Young people who did not have the same level of CS and maths capital "felt the weight of the water" as they tried to navigate a CS trajectory in which they experienced a lesser degree of fit between their identity, capital and field (and lack of recognition for the resources they did possess) – ultimately leading to a sense of not feeling a sense of belonging within their studies and for Bethany the decision to leave CS for good. The challenge of this differential distribution and valuing of capital (and, subsequently, differential patterns in understanding the expectations and norms within CS degrees and other routes into a CS trajectory) was also noted among the group who expressed CS-related aspiration but who did not go on to studying CS at university level.

Specifically in relation to capital, we argued that, for Bob and Josh, family appeared to have played a key role in generating exchange-value forms of CS capital. This was evident by by providing insights into CS-careers and thus supporting the development of early and stable CS aspiration as well as supporting accrue necessary experiences and resources to navigate onto a university CS degree. We find that extensive CS capital was closely tied to strong affiliations towards Math and out of school experiences with CS. In relation to the first point, children with smooth negotiations of their CS-trajectory found Math to be of high importance, interesting in itself and relevant for their future as Math is often a requirement to enter CS. However, those aspiring to CS after the point of choosing elective subjects (like Bethany) or failing to see Math as a viable future (like Gerrard) appeared to be disadvantaged by their unequal access to capital. While in the UK, where this study was conducted, there is no formal prerequisite of having taken a CS subject before starting a degree (rather, maths qualification is typically required), students without the necessary qualifications or experiences (like Bethany) struggled with the course and its completion.

In relation to the second point, out-of-school experiences turned out to be useful/ valuable for navigating a university CS route. Such experiences were supported in families with resources in computing, such as in the case of Josh, whose father and brothers worked in CS and supported him to learn programming at home. And the pre-entry experiences made Bob explain how he felt he had an easier time than his peers at university as they entered with limited experiences. During the course of the degree, it appeared that the particularly valuable (and expected) form of capital was programming skills. Skills that Gerrald points out was not part of the formal teaching and learning activities within university but turned out as supportive for navigating the course.

Our findings reinforce existing work on inequalities within CS that point to aspirations towards and participation within higher education CS (as admission structures and course expectations) enforce social inequalities (see for example Peters et al., 2014; Vrieler & Salminen-Karlsson, 2022; Wong, 2016). On the one hand, young people in the UK do not need CS A-level (but math) to enter a CS degree programme. On the other hand, to get a sense of fit when entering a CS-programme, there is a clear advantage in having a strong CS-related capital with resources and experiences from family and outside school. In this way, both extensive math and CS-related capital appear to be required as part of both the explicit and "hidden" "rules of the game" within the field of CS.

The current structures produce and reproduce inequalities in ways that are problematic and counterproductive to the wider agenda of diversifying the pool of people entering CS-related careers. We show how other forms of (use-value) capital, such as those (often gendered forms) related to connecting CS to creativity, appeared to be under-valued, a similar point having been raised by Wong and Kemp who discuss how creativity might on the one hand be a more viable avenue into CS more assessable to girls, yet at the same time risk reproducing stereotypes of the soft creative girls and the technical skilled boys. At the same time they raise concern for the artistic and creative interaction with computers that have been left out of the school curriculum in England in order to prioritise more technical skills (Wong & Kemp, 2018). Also within higher education Peters (2014) shows how what is celebrated within the CS study programme is often limited to backend programming and thus perceived as the real and difficult part of computer science, where the solutions cannot be viewed by the user. This is in contrast to frontend or human-computer interaction which are considered as less prestigious and "not real computing". Failing to acknowledge and value a wider spectrum of students' interests, skills, and experiences (capital), will only continue to reproduce existing unjust patterns of participation and will result in those from under-represented communities being pushed away from CS trajectories through practices of both exclusion and self-exclusion. Such practices also hamper such young people's ability to exercise agency and develop CS literacy that might enable them to critically and meaningfully engage with the technology surrounding them. When we strive to broaden what counts and what is counted within the field of CS (e.g. what capital is recognised as valuable and relevant), it becomes imperative to be acutely aware of how the uneven distribution of power within the discipline perpetuates disparities in the formation of a sense of belonging and the construction of a computer science identities for different students (Holmegaard et al., 2023). Hence, efforts to broaden "what counts" within CS (to include creativity) and making resources as programming skills a formal part of the teaching and learning activities (to better support those who enter without such experiences, and also those who earlier on struggling to see how to proceed with CS degree).

Our study adds to existing knowledge by (i) foregrounding how capital is important to supporting and mediating young people's CS identities and trajectories and that the uneven gendered and classed distribution of capital helps produce and sustain inequalities in CS participation, and (ii) suggesting that subject choices and aspirations are also relational negotiations, potentially shaped as much by the existence (or otherwise) of competing options. Finally (iii) we show how higher education admission structures and cultures enforce social inequalities (see also Archer et al., 2023a).

One of the implications of our analyses is that they lend further weight to critiques of the common/dominant policy metaphor of "the leaky STEM pipeline", which implies that young people's choices and aspirations follow stable, linear routes over time, positioning young people as passive assets, while ignoring the wider structural inequalities and power relations behind the metaphor (Mendick et al., 2017). Rather, our data reinforce conceptualisations of young people's trajectories (into or away from CS) as ongoing and dynamic identity negotiations (Archer et al., 2017; Carlone et al., 2014; Rahm et al., 2022) that play out within intersecting structural relation that can make some choices risky, complex and requiring substantial negotiations, identity-work (Archer et al., 2012) and deployment of capital (Archer, Francis, et al., 2023). In this respect, we interpret our data as exemplifying how young people may be expelled from a CS trajectory (e.g. Bethany, Gerrard).

Of course, our study sample is incredibly small and there are many limitations, such as the absence of any women who had successfully completed a CS degree. However, we suggest that there are some potential implications. For instance, our findings do not lend support to proposals that increased early exposure of computer science will necessarily attract more young people towards computing degree routes, as some young people (and in particular those with limited capital) may make their choices of what to do after secondary school quite late. However, findings suggest that there might be value in providing more support to entrants from under-represented communities to help lessen the "weight of the water" and support their identity and capital to facilitate their navigation and experiences on CS degree programmes. There may also be value in efforts to redistribute the forms of CS-related capital that young people like Josh and Bob gained through their families and out-of -school experiences. For instance, our analysis showed how prior knowledge with programming at home seemed to be valuable for those who has such support available.

Our findings suggest that schools could usefully provide more career support to students including helping them better understand the rules and expectations both the explicit ones as admission criteria and pre-entry requisites, as well as the implicit ones as expectations of programming (although we would want to take a position that this would at best be an intermediate step before changes are also made at university level) to create and sustain more inclusive cultures so that young people like Bethany do not feel alienated from narrow, normative notions of "coder identity".

There would be value in rethinking the expectations of what skills and knowledge students are required to have at the point of starting their degree, and how those with different experiences could be adequately supported and not left behind, with the risk of producing a feeling of being inadequate and out of place as is pointed out as a risk in the retention literature (Tinto, 1993; Ulriksen et al., 2010; Yorke & Longden, 2004). Indeed, providing more support to degree entrants from under-represented communities could help lessen the "weight of the water" and support their identity and capital to facilitate their navigation and experiences on CS degree programmes. Increased support would thus help to somewhat "level the playing field" between entrants, and might be beneficial to better support those who aspire towards a degree (with less experience), and also those who earlier on struggle to see how/if to proceed with CS degree.

From an equity perspective, we argue that it would be particularly important to carefully consider how the CS degree level education frames what counts as valuable CS skills and knowledge and how the current focus on technical aspects could be shifted and broadened, to include skills such as creativity as mentioned above, but challenging the norms of what is valued within a field of CS could go further and make room for elements like care ethics and sustainability (Peters et al., 2020), social justice within CS practices (Benjamin, 2020; Bjørn et al., 2023; Noble, 2018). This way, broadening what counts could not only benefit the numbers and demographics of the people entering CS careers, but present a move towards creating a more equitable CS field.

Notes

1. 1. These figures are based on our analyses of national Higher Educational data sets (from HESA, 2015 to 2021), as reported in: Archer, L., DeWitt, J., Godec, S., Henderson, M., Holmegaard, H., Liu, Q., MacLeod, E., Mendick, H., Moote, J. and Watson E. (2023). ASPIRES3 Summary Report: Computing. London, UCL
2. Ibid.
   Limited nor HESA Services Limited can accept responsibility for any inferences or conclusions derived by third parties from data or other information supplied by the Higher Education Statistics Agency Limited or HESA Services Limited.
3. In England, all young people are required to take national school examinations at age 16 General Certificate of Secondary Education (GCSE), for which English, math and science are compulsory – and students, on average, take nine subjects. Attainment at GCSE then plays a part in shaping access to post-compulsory routes, among the most common of which is the academic route of Advanced Level (A Level) qualifications. Students typically study three A Level subjects. A Levels constitute a common degree requirement for entry to undergraduate degrees.
4. Numbers drawn from: Joint Council for Qualification, 2021. https://www.jcq.org.uk/examination-results/

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ORCID

Henriette Holmegaard http://orcid.org/0000-0003-4245-3983

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