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A Missing Piece of the Puzzle? Exploring Whether Science Capital and STEM Identity are Associated with STEM Study at University

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Abstract

Internationally, there are concerns that more needs to be done to address the inequalities in participation in science, technology, engineering, and mathematics (STEM) subjects at the degree level. In response, research focused on better understanding what influences young people's STEM participation has focused on a range of factors. This paper contributes to the existing research with an analysis of how "science capital" and "STEM identity" relate to STEM participation. We draw on data from 3310 young people aged 21–22 who had undertaken an undergraduate degree, 523 of whom studied a STEM subject. We found that science capital and STEM identity were statistically significantly related to studying a STEM degree (with science capital being weakly and STEM identity strongly associated with STEM study at university). Adopting a Bourdieusian lens, we discuss what our findings mean for higher education and what more could be done to support students, especially those who are currently under-represented in STEM, such as through better recognising and developing their science capital and supporting their sense of belonging in STEM.

Keywords Bourdieu · Identity · Logistic regression · Science capital · STEM participation

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Inequalities in STEM Degree Participation

Internationally, there are concerns that more needs to be done to address the inequalities in participation in science, technology, engineering and mathematics (STEM) subjects at degree level. These concerns reflect predictions of a current and growing future STEM skills gap, with the demand of national economies for STEM-skilled workers exceeding supply. These concerns also reflect social justice goals, bringing into question how the STEM sector does a better job of welcoming some young people than others. In the UK, where this study took place, national figures suggest that more young people are taking STEM subjects at university than ever before (The Education Hub, 2021). Yet, while the last decade has seen an overall increase in the numbers of women, black and minority ethnic, and low-income students taking STEM subjects, overall, these communities remain acutely under-represented in areas such as physics, computing and engineering (University and Colleges Admissions Service [UCAS], 2020), with differences exacerbating further when controlling for prior attainment (Codiroli Mcmaster et al., 2017). Similar patterns of inequalities are found in other contexts around Europe (Hanson & Krywult-Albańska, 2020; McNally, 2020), the USA (Ma & Liu, 2017; Mau, 2016), Australia (Cooper & Berry, 2020) and Asia (Almukhambetova et al., 2023). While some inequalities are fairly consistent, such as gender gaps that are typically linked to the "masculine" nature of STEM (Chavatzia, 2017), the patterns of inequalities, and the reasons influencing these, differ between national contexts (Lingyu et al., 2021; Nanyiti & Sseruyange, 2022).

This paper explores whether and how science capital and STEM identity relate to STEM degree participation, drawing on quantitative data from England, to contribute to the scholarship on STEM participation. We seek to build on a growing body of academic literature about the factors influencing student STEM degree participation (e.g. Codiroli Mcmaster, 2017; Le & Robbins, 2016) and the subject-specific research, e.g. focusing on chemistry (Mujtaba et al., 2018), physics (Bennett & Hogarth, 2009; Danielsson, 2011), computing (Kunkeler & Leonard, 2021; Wong, 2016), engineering (Godwin et al., 2016; Unfried et al., 2014), mathematics (Maple & Stage, 1991; Mujtaba & Reiss, 2016) and broader science (Cleaves, 2005; Cooper & Berry, 2020). Reading across the existing literature, we identified three main themes that are associated with the likelihood (or not) of pursuing a STEM degree: attitudes/interest, capital and identity.

Historically, a major research and policy focus has been on understanding young people's attitudes to STEM. There is an extensive body of research that considers how intrinsic and extrinsic attitudes towards STEM are associated with degree participation. For example, subject interest is one of the two main factors identified by Le and Robbins' (2016) longitudinal study of factors shaping student subject choices, and Venville et al.'s (2013) retrospective study of scientists' reasons for pursuing science has similarly identified interest as playing a key role. Interest has been found to play an important role for progression across different subjects (see Hazari et al.'s (2017) study on biology, chemistry and physics;

Mujtaba and Reiss' (2016) study on mathematics and physics). The focus on attitudes and interest has been central to several studies concerned with inequalities. Saw et al. (2018) found that levels of STEM subject interest appear to mirror post-compulsory participation patterns, as women, Black and Hispanic students, and students from lower socioeconomic backgrounds were less likely to show, maintain and develop an interest in STEM during high school years.

While the association between attitudes towards a subject and degree participation is widely recognised, debates exist over the extent to which subject attitudes constitute a discrete factor — or whether they are part of, and/or mediated by other factors (e.g. Hazari et al., 2010). Our previous research found that having an interest in science does not necessarily translate into post-compulsory science participation. DeWitt et al. (2011) report that while over two-thirds of a nationally representative sample of 10–14-year-olds in England found science interesting, under a fifth aspired to be a scientist in the future. Attitudes and interests, thus, while playing an important role in influencing STEM participation, are themselves likely not enough to explain the participation patterns.

Increasing attention has been paid to how social factors, such as family and out-of-school experiences, influence young people's aspirations and trajectories. The concept of "science capital"—understood as encompassing a range of science-related social, cultural and economic resources—has proved compelling in this regard. Science capital is composed of multiple dimensions that research has found influenced an individual's relationship with science. These dimensions include dispositions (e.g. whether science is seen as useful and relevant to everyday life), behaviours (e.g. how people engage in science activities out of school, such as reading science books or visiting science museums), social capital (friends or family members with science jobs or qualifications) and scientific knowledge and literacy (e.g. understanding a scientific method) (Archer et al., 2015).

Both quantitative and qualitative research have found that science capital significantly relates to science aspirations and participation (Ceglie, 2021; Cooper & Berry, 2020; Du & Wong, 2019) and pursuing STEM after the end of the compulsory education (Gonsalves et al., 2021). Disciplinary-specific studies within STEM have also found a positive relationship between capital and aspirations/participation, such as in relation to mathematics capital (Williams & Choudry, 2016) and chemistry capital (Rüschenpöhler & Markic, 2020). Further support for the explanatory power of science capital is given by the research proximal to the concept (i.e. focusing on the factors included within science capital without explicitly mentioning the term). For instance, studies have found that having family members working in science and positive out-of-school science experiences play an important role in supporting young people's science and STEM trajectories (Adamuti-Trache & Andres, 2008; Cheryan et al., 2017; Martin et al., 2013; Codiroli Mcmaster, 2017; Walker, 2012). Capital-related resources appear to be particularly important for young people from backgrounds historically underrepresented in science and STEM. For example, having an engineer in the family has been found to be especially important in supporting Hispanic women's progression into engineering majors (Martin et al., 2013).

There has been a burgeoning interest in understanding identity and belonging in STEM, especially within scholarship on educational inequalities. This drive is in part fuelled by a growing recognition of the structures and power relations that make it easier for some people to "feel at home" in STEM and see these subjects are "for them". Numerous studies have found that having a "science identity" (seeing science as "for me") is significantly associated with an increased likelihood of expressing science aspirations (Aschbacher et al., 2010; Cleaves, 2005), which has been echoed across the different STEM disciplines including computer science (Kunkeler & Leonard, 2021) and engineering (Godwin et al., 2016). Identity is particularly important for under-represented communities (Ireland et al., 2018; Wong & Copsey-Blake, 2023). Vincent-Ruz and Schunn (2018) found that developing a strong science identity was especially critical for girls' participation in STEM, and Chen et al. (2021) report how science identity is more closely associated with a degree trajectory among racial-minority students.

A particularly interesting "component" of identity is competence/self-efficacy (alongside performance and recognition, see Carlone & Johnson, 2007). The notion of feeling "good at" a particular subject is a salient aspect of one's learner identity in relation to that subject and is particularly relevant for STEM subjects that are typically regarded as "hard". While there is indeed an association between attainment and STEM degree participation (Crisp et al., 2009; Le & Robbins, 2016), research has found that self-efficacy (the perception of one's own capabilities) is a better predictor for STEM progression that straightforward attainment. This is particularly important for girls, who typically report feeling less good at STEM subjects even when achieving similarly or better than their male peers (Cheryan et al., 2017; Ireland et al., 2018). As with other factors we outlined above, the role of self-efficacy in fuelling inequalities in STEM participation was reported across the disciplinary studies, including in physics (Bennett & Hogarth, 2009), chemistry (Avargil et al., 2020), engineering (Godwin et al., 2016; Capobianco et al., 2011) and mathematics (Boaler, 2002; Grootenboer et al., 2006).

Research on science capital and STEM identity is not new. Yet, important gaps exist in the current scholarship that this paper seeks to address. In this paper, we consider the role that both science capital and identity play in STEM participation. We contribute to existing literature in the following ways: (i) through an analysis of the role of science capital (and its relationship to study a STEM degree) for young adults — extending previous work that has predominantly focused on younger groups (notably, 11–18); (ii) through a quantitative approach with a dual focus, exploring the relationship between science capital and STEM identity, and STEM participation, building on the wealth of subject-specific research as well as research focusing on one of the concepts in relation to STEM participation; (iii) comparing STEM and non-STEM students (most studies with degree-level students we referenced above focused only on those doing STEM degrees); and (iv) discussing the results through a Bourdieusian lens to develop non-deficit interpretations of the role of identity and capital in relation to young people's STEM trajectories. Our research question is: to what extent (if any) are science capital and STEM identity associated with STEM study at university?

We look at *science* capital and *STEM* identity (a shorthand descriptor encompassing the four disciplinary identities, i.e. science identity, tech identity, engineering identity and mathematics identity). Our decisions about what concepts to include were based on the previous literature, and the data that were viable to collect via a survey. The rationale for using science capital was that among school-aged students, science capital has been found to relate not only to science aspirations and post-16 science participation (Archer et al., 2015) but also to aspirations and attitudes in engineering, computing and mathematics (Moote et al., 2020). Hence, we wanted to investigate whether science capital might also correlate with actual progression to degrees in these STEM disciplines. It was also not straightforward to "translate" science items to technology/engineering/maths capital items; developing a STEM capital composite would require further research and validation to give confidence in how to work with this construct, which was beyond the scope of our current work.

Our decision to use a composite of STEM identity (i.e. treating it as a top-level amalgam of separate disciplinary identities) was informed by a growing body of research on STEM identity. There is no one approach; studies have worked with a single STEM-specific item (Cohen et al., 2021; Dou et al., 2019), expanded models of STEM identity (Dou & Cian, 2022) and treated STEM as a shorthand for or interchangeably with specific disciplines (Seyranian et al., 2018; Singer et al., 2020). At the same time, researchers have called for a critical consideration of how useful it is to ask about "STEM" rather than specific disciplines, recognising that people might relate differently to some areas of STEM than they might to others (Grimalt-Álvaro et al., 2022). Not only might people relate differently to different areas of STEM, but who participates in what beyond the compulsory school years also varies significantly, such as between biology and engineering. In our cognitive interviews, furthermore, we also found that to some young people, STEM (despite its growing popularity, see Dou & Cian, 2022) was not self-explanatory. These factors all led us to use STEM identity as a composite item of four disciplinary identities, each composed of four survey items based on the literature (see "Data and Methods" section for details).

Theoretical Framework

Our study is concerned with inequalities in STEM participation. We have a particular interest in the role played by capital and identity, and how they operate within the field of STEM. Drawing on Bourdieu's (1977, 1984) work, particularly his writing on capital, habitus and field, is a useful way to understand how unequal patterns of STEM participation are produced and maintained. Following Bourdieu (1986), capital refers to cultural, social, economic and symbolic resources that individuals can accrue and possess. Science capital, introduced above, is an extension of Bourdieusian capital that specifically relates to science-related forms of capital. Habitus refers to a set of embedded and internalised dispositions acquired through social experiences, including what people consider to be possible, thinkable and desirable for "people like them" (such as whether they see a career in STEM for people like them, or not). We see habitus as conceptually close to identity, and given the prevalence of the latter within the science and STEM education scholarship, we have chosen to work with identity rather than habitus. Like much identity literature (e.g. Avraamidou, 2020; Butler, 2002), habitus relates to what is intelligible for a particular person within a specific environment (Bourdieu, 1977).

When considering science capital and habitus/identity, it is important to attend to the culture and power relations within STEM. The value of science capital is determined by the specific context. For instance, a typical science classroom might value narrow, canonical science knowledge, but disregard other, everyday forms of knowledge and skills — with implications for how young people recognise their own science-related resources and experiences. Similarly, someone's identity is likely to be more desirable and "fit" better in one context than in another; it is often the norms and expectations of a particular context that determine who gets to be recognised and feel they belong. That is, some identities tend to be more highly valued (considered a "celebrated subject position", see Carlone et al., 2014) than others, which has implications for who sees themselves as a "science person". Everyday pedagogical, institutional, disciplinary and interpersonal practices continually exclude and marginalise those who do not fit the "ideal" (typically, in the UK, white, male and middle-class) student image, creating a "chilly climate" for those who do not fit dominant identities, norms and values.

Bourdieu's third concept, field, is useful for thinking about the contexts and their norms and expectations. We see both capital and identity as interacting with a field of STEM and see the field as a system of power and social relations that determines what is recognised and valued, and what is at tension with or holds a limited value within a particular context. As pointed out by Harker (1984, p. 118), education settings often normalise specific forms of (middle-class, dominant) capital as "the natural and only proper sort of capital" and, as a result, misrecognise children's differential access to capital as reflecting "natural" differences between students. Hence, dominant norms and expectations within a given field can profoundly shape young people's experiences and trajectories.

In this study, science capital and identity were a key focus of the survey, and the analysis presented below explores how these two concepts are associated with STEM degree participation. The field, which is the third part of Bourdieu's (1984) conceptual "equation", was not explicitly part of the survey, but informed our analysis and interpretations of the results, helping us make sense of the data and think about the implications of our findings.

Data and Methods

About the Sample

The survey sample was recruited on the basis that participants lived in England aged 14–16, were born between 1st September 1998 and 31st August 1999 and registered on the Open Electoral Roll. The survey sample was not representative with regard to official government population estimates in England; in line with the study's interest, the sample was over-representative for populations who tend to be under-represented in STEM (e.g. women and young people from the least privileged IMD quintiles) or were in/completed higher education. The analysis in this paper uses unweighted responses.[1] In this paper, we draw on survey data from a sample of 3310 young people aged 21–22 who had taken an undergraduate degree. This sample of young people is drawn from a wider online postal survey sample of 7635 young people who took part in the Aspires3 study (4325 of whom were excluded from the current analysis on the basis that they had not taken an undergraduate degree). The overall questionnaire was wide-ranging and explored young people's aspirations, influences on destinations post-18, demographic data and numerous other areas. It builds on previous surveys, the initial development and validation of which have been described elsewhere (Archer et al., 2015; Moote et al., 2021). The research received ethics approval from the University College London.

Outcome Variable: Undergraduate STEM Study

The focus of this paper is on undergraduate degree-level STEM study, versus a non-STEM subject, drawing on data from participants who were studying or had completed the degree at the time they took part in our study. In this paper, we use "STEM" as an umbrella term for undergraduate degrees in the disciplines of science, technology/computer science, engineering, and mathematics. In this way, our operationalisation of STEM differs from some of the "STEM education" research that has been critiqued for implying an unfounded level of similarity and homogeneity between the constituent disciplines (Tan, 2018).

We recognise that categorising degrees at the university level is neither neat nor straightforward and that there have been several attempts to do this previously (e.g. Mellors-Bourne et al., 2011; U.S. Department of Homeland Security, 2021). Our coding process was informed by existing categorisations within our national context (e.g. The Higher Education Statistics Agency's JACS 3.0: Detailed (four-digit) subject codes [HESA, 2012]) and our study's focus on "elite" STEM degrees where there tend to be particularly large inequalities in terms of who participates (which we defined as requiring at least one maths or science A level, qualification typically taken at age 18, as an entry requirement[2]). We first coded open-text responses into specific degree codes matching JACS 3.0: Detailed (four digit) subject codes (HESA, 2012) (e.g. Biochemistry, Chemical Engineering). We then organised these codes into the seven categories (see Supplementary material 1). There were a handful of degrees that did not fit neatly into a single category (crossed disciplinary boundaries), and these were allocated to what we called "Interdisciplinary science". In addition to using literature to inform our categorisation of subjects, we consulted with UK learned societies to confirm all our groupings, calling on specialists for each subject area (e.g. consulting with the Institute of Physics for the Physics subject

[1] We decided against weighting the student data because there was no directly comparable dataset. The closest potential dataset was Higher Education Statistics Agency (HESA). However, their figures are for specific academic year, and the data set is made up of young people in different academic years.

[2] Entry requirements vary between universities.

Table 1 Percentage of respondents studying or completed degrees across specific STEM disciplines

	%	*n*
Chemistry	14.1%	74
Biology	15.5%	81
Physics	6.7%	35
Computing	19.7%	103
Engineering	20.1%	105
Maths	15.3%	80
Interdisciplinary STEM	8.6%	45
Total STEM	100%	523

codes). Of the participants who had completed or were at the time of the survey studying an undergraduate degree ($n = 3310$), 15.8% (523) were in STEM, and the remaining 84.2% (2,787) were in non-STEM areas. Table 1 shows a breakdown of individual STEM degree disciplines.

Explanatory Variables

First, we introduce the variables that we controlled for, which helped us isolate the size of the association between science capital and STEM identity, and degree-level STEM study (descriptive statistics are presented at the start of the "Results" section, before we focus on logistic regression). Table 2 shows the questions we asked, the response options, and how we grouped some of the responses before carrying out further analysis.

Our main explanatory variables of interest are science capital and STEM identity, which were included (as composite variables) in addition to the above in the logistic regression models. Building on previous science capital work (Archer et al., 2015; Department for Business, Energy & Industrial Strategy [BEIS], 2020), we developed nine items to construct a science capital composite appropriate for young adults (see Supplementary material 2 for the list of items). The adult science capital composite had a Cronbach's alpha of 0.784 (an acceptable range, see George & Mallery, 2003). In line with previous science capital studies (Moote et al., 2021), the scores were transformed along a scale from 0 to 100 for ease of interpretation and put into three groups: high (scores > 67), medium (33 < scores ≤ 67) and low science capital (scores ≤ 33).

To produce the STEM identity composite, our survey asked a set of four questions for each of the four subject areas that make up STEM. We combined the 16 items to create a measure of STEM identity. The specific questions drew on the science and STEM identity literature (Chen et al., 2023; Cribbs et al., 2015; Hazari et al., 2010; Mahadeo et al., 2020; Simpson & Bouhafa, 2020; Vincent-Ruz & Schunn, 2018). The STEM identity composite included items relating to (i) self-identity (e.g. "I see myself as a science person."), (ii) recognition by others (e.g. "Other people see me as a science person."), (iii) interest (e.g. "I am interested in learning more about science.") and (iv) competence/self-efficacy (e.g. "I am good at science."). Survey

Table 2 Explanatory variables included in the analysis

Category	Survey question	Survey response options	Data manipulation for analysis
Gender	Which of the following BEST describes how you identify?	"Man", "Woman", "Non-binary", "Other" and "Prefer not to say"	"Non-binary", "Other", "prefer not to say" and skipped the question grouped into "Other genders"
Ethnicity	Which of these BEST describes how you identify?	"Black"; "Asian"; "White", "Chinese or East Asian", "Middle Eastern"; "Other (including mixed and multiple ethnic groups)" and "Prefer not to say"	"Chinese or East Asian", "Middle Eastern" and "Other" grouped into "Other ethnicities"
Index of Multiple Deprivation (IMD*)	Determined by the participants' postcode (where the invitation letter was sent)	Not applicable	The IMD values grouped into quintiles based on national thresholds and reduced into three groups for modelling ("IMD 1 or 2", "IMD 3", "IMD 4 or 5")
Science route at GCSE	Which science did you complete at GCSE?	"Double science (e.g. 2 GCSEs, Core and Additional)", "Triple science (e.g. 3 GCSEs, Core, Additional and Extra or Biology, Chemistry, Physics)", "Applied science (e.g. 1 GCSE)", "I did not take GCSE science" and "Don't know"	"Applied science (e.g. 1 GCSE)", "I did not take GCSE science" and "Don't know" grouped into "Other"
Highest GCSE science/maths grade	What was the highest grade you achieved in science at GCSE?	"A* and/or A", "B", "C", "D", "Lower than a D", "Other (including other qualifications)" and "Do not remember"	The responses were coded into "A*-A", "B-C" and "D and lower" (also including do not remember and skips)
GCSE attainment	How many of the following qualifications or equivalent did you get? asking about "GCSE grades A*-C"	Participants typed in the number of GCSE at the specified grade	The responses were coded into "At least 5 A*-C GCSEs", "Less than 5 A*-C GCSEs" and "No Details", following a common approach taken for analysing educational achievement at age 16 (e.g. Strand, 2015)

*Index of Multiple Deprivation (IMD) is a measure of relative deprivation commonly used in England, based on a postcode of home address. IMD 1 represents the least privileged/most deprived quintile (Ministry for Housing, Communities and Local Government [MHCLG], 2019) participants were asked to rate their agreement on a 5-point Likert scale. The four subject-specific identity composites were statistically significantly correlated, and we also saw that the 16 individual items were statistically significantly correlated (see Supplementary material 3). The Cronbach's alpha for the 16 items was within an excellent range at 0.906 (George & Mallery, 2003) and would not increase by removing any of the items. Based on this analysis, we concluded that combining the 16 items would give us a good enough proxy for STEM identity. After combining the 16 items, we followed the approach akin to that used in data preparation for science capital. That is, the scores were transformed along a scale from 0 to 100 for ease of interpretation and put into three groups: strong (scores > 67), medium (33 < scores ≤ 67) and weak STEM identity[3] (scores ≤ 33) (see Chen et al., 2021 for a similar approach).

Logistic Regression

After conducting descriptive analysis, we carried out a multivariable logistic regression to assess the probability of studying a STEM undergraduate degree. Our statistical modelling approach was determined by the binary nature of the outcome of interest (studying for a STEM degree vs. studying a non-STEM degree). Drawing on our conceptual lens described above, we focused on science capital and STEM identity. In model 1, we included all demographic and educational variables from the survey that, according to the literature, would likely influence the outcome of studying a STEM degree. In the next step (model 2), we added the science capital composite, and in the final step (model 3), we further added STEM identity. Our approach enabled us to examine the effect of science capital and STEM identity on STEM degree participation after controlling for demographic and educational variables. In other words, this approach allowed us to better isolate the relationship between science capital and STEM identity, and studying a STEM subject at the degree level, after accounting for other variables that could also be related. The results of the logistic regression models are presented with coefficients (B or log-odds) and standard errors.

Results

We focus on the role of science capital and STEM identity and how they explain STEM degree participation. As Table 3 shows, the distribution for science capital across the paper sample ($N = 3299$; 11 respondents did not respond to all

[3] We recognise that our labelling (using terms "low" and "weak") is somewhat problematic and in tension with our wider equity focus, as these terms imply a deficit perspective and do not recognise the breadth of resources, experiences and identities. Yet, quantitative approaches are essentially limited in that they only give respondents a certain set of options (see Taylor, 2016). To mitigate the limitations, we offer interpretations of our results using the Bourdieusian perspective, highlighting that concepts like capital and identity should not be seen as holding absolute value but examined within a specific context or "field".

Table 3 Variables of interest by STEM vs non-STEM undergraduate degree (UG) students

	STEM UG students		Non-STEM UG students		All UG students		
	n	%	*n*	%	*n*	%	*N*
Overall	523	15.8	2787	84.2	3310	100	
Gender							
Man	305	58.3	770	27.6	1,075	32.5	
Woman	197	37.7	1912	68.6	2,109	63.7	
Other genders	21	4.0	105	3.8	126	3.8	3310
	χ^2 (2, $n = 3310$) = 193.921, $p < 0.001$, Cramer's $V = 0.242$						
Ethnicity							
White	345	66.0	1963	70.4	2308	69.7	
Black	26	5.0	144	5.2	170	5.1	
Asian	83	15.9	388	13.9	471	14.2	
Other ethnicities	63	12.0	252	9.0	315	9.5	
Unknown/skip	6	1.1	40	1.4	46	1.4	3310
	χ^2 (4, $n = 3310$) = 6.907, $p = 0.14$						
Index of multiple deprivation (IMD)							
IMD 1 or 2	218	41.7	1185	42.5	1403	42.4	
IMD 3	119	22.8	512	18.4	631	19.1	
IMD 4 or 5	186	35.6	1090	39.1	1,276	38.5	3310
	χ^2 (2, $n = 3310$) = 5.945, $p = 0.051$						
Science route at GCSE							
Double science	127	24.3	1202	43.1	1329	40.2	
Triple science	380	72.7	1282	46.0	1662	50.2	
Other	16	3.1	303	10.9	319	9.6	3310
	χ^2 (2, $n = 3310$) = 129.170, $p < 0.001$, Cramer's $V = 0.198$						
GCSE science grade							
A*-A	372	71.1	1217	43.7	1589	48.0	
B-C	135	25.8	1371	49.2	1506	45.5	
D and lower	16	3.1	199	7.1	215	6.5	3310
	χ^2 (2, $n = 3310$) = 133.372, $p < 0.001$, Cramer's $V = 0.201$						
GCSE maths grade							
A*-A	356	68.1	956	34.3	1312	39.6	
B-C	163	31.2	1706	61.2	1869	56.5	
D and lower	4	0.8	125	4.5	129	3.9	3310
	χ^2 (2, $n = 3310$) = 212.718, $p < 0.001$, Cramer's $V = 0.254$						
Overall GCSE attainment							
At least 5 A*-C GCSEs	500	95.6	2,558	91.8	3,058	92.4	
Less than 5 A*-C GCSEs	19	3.6	208	7.5	227	6.9	
No details	4	0.8	21	0.8	25	0.8	3310
	χ^2 (2, $n = 3310$) = 10.117, $p = 0.008$, Cramer's $V = 0.055$						
Science capital							
Low	20	3.9	480	17.3	500	15.2	

Table 3 (continued)

	STEM UG students		Non-STEM UG students		All UG students		
	n	%	*n*	%	*n*	%	*N*
Medium	297	61.5	1,958	70.4	2255	68.4	
High	202	34.7	342	12.3	544	16.5	3299*
	χ^2 (2, $n = 3299) = 221.351$, $p < 0.001$, Cramer's $V = 0.259$						
STEM identity							
Weak	17	3.3	917	33.1	934	28.4	
Medium	264	50.8	1648	59.6	1912	58.2	
Strong	239	46.0	202	7.3	441	13.4	3287*
	χ^2 (2, $n = 3287) = 630.943$, $p < 0.001$, Cramer's $V = 0.438$						

*Of the 3310 survey respondents, any respondents who had skipped some of the science capital and STEM identity items were excluded from the final composite scores, and models 2 and 3. Eleven respondents were excluded from the science capital models and descriptive analysis (leaving $n = 2299$ participants) and further 12 respondents from the STEM identity models and descriptive analysis (leaving $n = 2287$ participants)

nine items) was low science capital, $n = 500$ (15.2%); medium science capital, $n = 2255$ (68.4%); and high science capital, $n = 544$ (16.5%). While these results suggest that a high science capital group is larger than in previous work (DeWitt et al., 2016; Moote et al., 2021), this is likely due to investigating an undergraduate sample, who we would expect to have high science capital (Moote et al., 2021). The distribution of STEM identity across the paper sample ($N = 3287$; 23 participants did not respond to all 16 items) was weak STEM identity, $n = 934$ (28.4%); medium STEM identity, $n = 1912$ (58.2%); and strong STEM identity, $n = 441$ (13.4%).

Table 3 shows the breakdown by subject (STEM vs. non-STEM) and demographic and educational variables. It shows that the following variables, when taken on their own, were significantly related to STEM undergraduate degree participation: STEM identity (large effect size), gender, science capital, GCSE Maths grades (medium effect size), GCSE Science grades, science route at GCSE, and overall GCSE attainment (small effect size, see Pallant, 2013). Ethnicity and IMD were not significantly related to STEM degree participation.

Looking at the differences in science capital and STEM identity between STEM and non-STEM students, we see that a third (34.7%) of STEM students recorded high science capital, meaning that, somewhat surprisingly, two-thirds of STEM students did *not* register high science capital. It is also interesting to note that, for both STEM and non-STEM students, the large majority had medium science capital (61.5% vs. 70.4%, respectively). Nearly half (46.0%) of STEM students fell into a strong STEM identity group, meaning that over half of STEM students did *not* have a strong STEM identity.

Now, we turn to the logistic regression and to the extent to which science capital and STEM identity explained STEM degree participation. Table 4 shows the results for models 1–3, where model 1 includes all demographic and educational variables,

Table 4 Logistic regressions predicting STEM undergraduate degree participation with model coefficients (B) and standard errors (SE)

	Model 1: demographic and education		Model 2: model 1 + science capital		Model 3: model 2 + STEM identity	
	Coeff	SE	Coeff	SE	Coeff	SE
Reference for gender: man						
Woman	−1.27***	(0.11)	−1.24***	(0.11)	−0.79***	(0.12)
Other genders	−0.48	(0.27)	−0.54	(0.28)	−0.26	(0.30)
Reference for ethnicity: white						
Black	0.19	(0.24)	0.23	(0.25)	0.20	(0.26)
Asian	0.21	(0.15)	0.21	(0.15)	0.10	(0.16)
Other ethnicities	0.30	(0.17)	0.21	(0.17)	0.19	(0.18)
Unknown/skip	−0.25	(0.47)	−0.26	(0.52)	−0.30	(0.54)
Reference for index of multiple deprivation (IMD): IMD 1 or 2						
IMD 3	0.09	(0.14)	0.08	(0.14)	0.11	(0.15)
IMD 4 or 5	−0.33**	(0.12)	−0.33**	(0.13)	−0.26	(0.13)
Reference for science route at GCSE: double science						
Triple science	0.62***	(0.12)	0.46***	(0.13)	0.40**	(0.13)
Other	−0.45	(0.30)	−0.37	(0.30)	−0.51	(0.31)
Reference for GCSE science grade: A*-A						
B-C	−0.40**	(0.14)	−0.17	(0.14)	−0.19	(0.15)
D and lower	−0.06	(0.34)	0.26	(0.34)	0.36	(0.35)
Reference for GCSE maths grade: A*-A						
B-C	−0.91***	(0.13)	−0.91***	(0.14)	−0.66***	(0.14)
D and lower	−2.01***	(0.56)	−1.89**	(0.57)	−1.52**	(0.58)
Reference for overall GCSE attainment: at least 5 A*-C GCSEs						
Less than 5 A*-C GCSEs	0.32	(0.30)	0.14	(0.31)	0.01	(0.32)
No details	0.10	(0.62)	0.18	(0.63)	−0.12	(0.71)
Reference for science capital: low						
Medium			0.91***	(0.24)	0.26	(0.25)
High			1.96***	(0.26)	0.86**	(0.27)
Reference for STEM identity: weak						
Medium					1.60***	(0.26)
Strong					3.11***	(0.28)
Constant	−0.68***	(0.16)	−1.78***	(0.28)	−3.13***	(0.36)
Observations	3310		3299		3287	
−2 Log likelihood	2454.84		2338.81		2115.83	
Cox & Snell *R* square	0.12		0.15		0.20	

Standard errors in parentheses

Coeff. Coefficient (B, log-odds), *SE* standard error

*** $p<0.001$; ** $p<0.01$; * $p<0.05$

model 2 adds the science capital composite, and model 3 further adds STEM identity composite.

We observe a robust gender difference across models 1–3, which shows that identifying as a woman is consistently negatively associated with STEM degree participation, compared to men, although the size of the coefficient is attenuated once ethnicity, IMD, prior attainment, science capital and STEM identity are included in the model (model 3). We can see in Table 4 that in model 3, women have the log odds of − 0.79 of STEM degree participation compared with men. Ethnicity was not significantly associated with STEM degree participation over and above gender, deprivation and prior attainment (using white as a reference category). Being from the most socioeconomically privileged backgrounds (IMD 4 or 5) was significantly negatively associated with participation in a STEM degree compared to being from the least privileged backgrounds (IMD 1 or 2), a result that merits further exploration. However, this result does not hold when STEM identity is included in the model (Table 4, model 3).

The results for model 2 indicate that science capital was significantly positively associated with studying a STEM undergraduate degree after controlling for educational and demographic factors. Having high or medium science capital was associated with a significant increase in the odds of taking a STEM undergraduate compared to having low science capital (in the presence of education and demographic factors). Those with high science capital have the log odds of 1.96 of STEM degree participation compared with those with low science capital (see Table 4, model 2).

The results from the logistic regression in model 3 show that strong and medium STEM identity were positively associated with studying a STEM undergraduate degree compared with those who have weak STEM identity, even after controlling for educational and demographic variables and science capital. Those with strong STEM identity have the log odds of 3.11 of STEM degree participation compared with those with weak STEM identity (Table 4, model 3). Science capital remained significantly associated with STEM degree participation when STEM identity was introduced in model 3 — those with high science capital have the log odds of 0.86 of STEM degree participation compared with those with low science capital.

There are other interesting results to note. For example, science and maths attainment at the age of 16, and the science route taken at the age of 14–16, were significantly associated with STEM degree participation when considered in the presence of other demographic and educational variables. In model 1, as we might expect, getting a grade B or C in maths or science was negatively associated with studying a STEM undergraduate degree, in comparison to getting top grade (grade A* or A). While maths GCSE grades remained significant when we introduced science capital into the model (Table 4, model 2) and STEM identity (Table 4, model 3), science GCSE grades were no longer significantly associated with STEM degree participation once science capital was added to the model. In other words, when science capital was introduced into the model, science GCSE grades were no longer significant, suggesting that science capital could explain some of the association between STEM degree study and science GCSE grades. Furthermore, taking a selective Triple Science route was positively associated with STEM undergraduate degree, and this predictor remained significant even when science capital and STEM identity were introduced (see also Francis et al., 2023 for discussion of Triple Science as a predictor of science degree participation).

Discussion

Our findings add another piece to the puzzle of understanding young people's STEM trajectories. Our analyses suggest that both science capital and STEM identity are significantly related to studying a STEM subject at the degree level. That is, science capital and STEM identity variables were significant explanatory factors for the variance in STEM undergraduate degree participation among students in England.

Science capital had a small, significant effect on STEM degree study, and STEM identity had a large, significant effect (Table 4, model 3). In our models, the reference category was low science capital; it is thus important to remember that across the sample of degree students, only 15.2% (Table 3) recorded low science capital (compared to 27% of the cohort recording low science capital in previous research using younger cohort and a nationally representative sample; see Archer et al., 2015). We found it especially interesting, as noted above, that only a third of STEM students recorded high science capital, which means two-thirds of STEM students recorded medium or low science capital. Given that the majority of both STEM and non-STEM students had medium science capital, we could also conclude that differences between these two groups of students perhaps are not as wide as we had expected. One interpretation for this finding is that the cohort of students that we looked at, across STEM and non-STEM, had a higher science capital than a broader sample that involved those who did not progress to university degrees to begin with. From an equity perspective, we could interpret this finding as somewhat encouraging, in that it suggests that people do not necessarily need to have high science capital to be taking STEM degrees. At the same time, we recognise that, as previous research has also highlighted (Archer et al., 2015; Moote et al., 2021), those with low science capital are more likely to experience other intersecting inequalities, which also influence the likelihood of those young people not continuing at degree level. We think it is also important to consider the complexity of grouping different subjects under the umbrella of STEM. Previous work with a younger cohort has shown that science capital was more strongly related to attitudes and aspirations in science and engineering, but somewhat less so to maths and computing (Moote et al., 2020). Hence, we might expect that science capital is potentially less strongly related to STEM overall trajectories than if we had looked at specific disciplinary trajectories. It was beyond the scope of the present study to collect data to perform subject-specific analysis, which would also allow a necessary validation of the STEM capital construct, but this could be a fruitful area for future research.

Our findings suggest that it was the combination of science capital and STEM identity that had a particularly important effect on STEM degree participation (echoing other international research about the importance of identity for young people STEM degree participation, see Chang et al., 2023). The difference between STEM and non-STEM students in terms of STEM identity was more pronounced than for science capital, with nearly half of STEM students versus under one-tenth of non-STEM students falling into a strong STEM identity group. Yet again, a notable percentage (over half, Table 3) of STEM students did not have a strong STEM identity. While we might hope and expect that students would identify with the subject of their study, we also acknowledge that how we worked with an identity composite of different STEM areas may have contributed to these results. For instance, a biology undergraduate could score highly on the "science identity" items but lower on "tech identity" and "engineering identity" items, which would bring down their overall STEM identity score (potentially resulting in being categorised into "medium" rather than "strong" grouping). Regardless of these methodological limitations, we suggest that our result provides evidence of the importance of identity for STEM trajectories, in line with what previous studies have found (Danielsson, 2011; Godwin et al., 2016; Steegh et al., 2021; Wong, 2016).

Our findings—that STEM identity and science capital are associated with STEM degree trajectories—could be interpreted as in line with the Bourdieusian (1984) conceptual framework, in which Bourdieu explains that outcomes are shaped by the interaction of both habitus (identity) and capital. The paper thus contributes quantitative evidence to existing findings regarding the significance of these phenomena for young people's STEM degree trajectories. Our finding that STEM identity was more strongly related to degree participation than science capital could be interpreted as adding new insights to Bourdieusian scholarship regarding the potential relative and differential "weight" of habitus (identity) versus capital in terms of shaping educational trajectories. However, we suggest that further research would be needed to clarify whether this relationship was to hold if measures of "STEM capital" (i.e. disciplinary-specific forms of capital in relation to science, technology, engineering and mathematics) were to be used.

Of course, it might be argued that the relationship between STEM identity and STEM degree participation we observed could be explained by the very experience of studying for a STEM degree at a university level. STEM identity could be regarded as an outcome, rather than a precursor, of a STEM degree trajectory. However, following our Bourdieusian framework (Bourdieu, 1984; Bourdieu & Passeron, 1990) and prior work in the field, we suggest that there may be a more recursive relationship and interaction between STEM identity (along with science capital) and young people's trajectories. That is, while following a STEM trajectory would likely reinforce and augment STEM identity, STEM degree aspirations would be much less likely in the absence of prior capital and identity resources. Specifically, our own previous research has shown that many young people do not see science-related subjects as "for me" and even when interested in the subject, do not aspire to continue with it and do not imagine themselves as future science professionals (DeWitt et al., 2016).

We are mindful that quantitative approaches can give only partial insight into the complexity of identity, capital and the interactions of these within and across fields — as both of the main explanatory variables we used are highly context-dependent. That is, (science) capital is often understood from a dominant perspective, by both the participants themselves and as captured by quantitative research instruments, with only specific science-related resources "counting" as valuable, as having an exchange value (Skeggs, 2004). As such, some potentially useful resources and experiences have likely gone under-recognised in our study, as they also tend to get under-recognised, ignored and unleveraged within the dominant field of education (Nasir & Hand, 2008; Walker, 2015).

The focus on science capital and identity, despite their growing interest and evidence-base within the research community, is somewhat scarce in the UK policy discussions about how to attract, retain and support STEM students. To date, policy and practice interventions still overwhelmingly focus on encouraging STEM participation through raising interest and aspiration, and doing so largely through deficit-oriented approaches, seeking to address a "lack" in the potential students. In one respect, our findings could be interpreted as suggesting that existing approaches simply need to be repurposed to increase and strengthen young people's science capital and strengthen their sense of STEM identity. However, in ensuring that we support and cultivate young people's STEM identity effectively *and* equitably, we must consider how current dominant practices within science and STEM education operate to provide a welcoming space for young people within STEM (Calabrese Barton & Tan, 2020; Dawson, 2019). We thus call for policy attention to not only be paid to "building" young people's science capital and STEM identity (Lane & Id-Deen, 2023) but do so equitably through changing the contexts within which people engage to better recognise and develop their science capital and support their sense of belonging in STEM (an approach that would be more asset-based). Science capital and STEM identity might not be the ultimate "missing piece of the puzzle" to supporting equitable STEM participation, but they might help policymakers and educators consider the persistent challenges of inequitable STEM participation at degree level from a more complex perspective that will hopefully open productive new avenues for better supporting more and more diverse young people to continue with STEM.

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Data Availability Data is currently not publicly available.

Declarations

Ethical Approval and Informed Consent The study received ethical approval from the University College London (REC1300) and follows the ethical code of the British Educational Research Association (BERA), ensuring free and informed consent (and offering right to withdraw data) from all participants and complying with UK data protection legislation for data treatment and storage.

Conflict of interest The authors declare no competing interests.

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