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Dimensions of science capital: exploring its potential for understanding students' science participation

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ABSTRACT

As concerns about participation rates in post-compulsory science continue unabated, considerable research efforts have been focused on understanding and addressing the issue, bringing various theoretical lenses to bear on the problem. One such conceptual lens is that of 'science capital' (science-related forms of social and cultural capital), which has begun to be explored as a tool for examining differential patterns of aspiration and participation in science. This paper continues this line of work, attempting to further refine our conceptualisation of science capital and to consider potential insights it might offer beyond existing, related constructs. We utilise data from two surveys conducted in England as part of the wider Enterprising Science project, a broader national survey and a more targeted survey, completed by students from schools generally serving more disadvantaged populations. Logistic regression analyses indicated that science capital was more closely related than cultural capital to science aspirations-related outcome variables. In addition, further analyses reflected that particular dimensions of science capital (science literacy, perceived transferability and utility of science, family influences) seem to be more closely related to anticipated future participation and identity in science than others. These patterns held for both data sets. While these findings are generally in alignment with previous research, we suggest that they highlight the potential value of science capital as a distinct conceptual lens, which also carries particular implications for the types of interventions that may prove valuable in considering ways to address disparities in science engagement and participation.

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Science capital; participation; survey

Despite years of research and initiatives aiming to address the issue, participation rates in post-compulsory science, particularly the physical sciences and engineering, continue to be unequal and seemingly resistant to change (e.g. Gorard, See, & Davies, 2012; Smith, 2010, 2011). These inequalities are of concern not just to science educators but to policy-makers and industry as well (e.g. ACOLA, 2013; House of Lords, 2012; US President's Council of Advisors on Science and Technology, 2010). Although stakeholders may differ in their reasons for concern, with some eager to ensure the supply of future scientists while others are more motivated by equity and/or the need for a scientifically

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literate population, there seems to be strong consensus that more must be done to widen participation in areas such as the physical sciences, particularly by those from under-represented groups, including women and individuals from working-class and some minority ethnic backgrounds. Our own research, including that discussed in this paper, is primarily motivated by an interest in equity – namely the importance of public scientific literacy for social mobility and agency, especially among socially disadvantaged communities. Our position is also informed by the strategic value of science qualifications in educational and labour markets (Claussen & Osborne, 2013) as well as the wage premiums often commanded by science qualifications (Savage, Bagnall, & Longhurst, 2001). That is, the symbolic and exchange value of science within contemporary society drives our concerns that the distribution of these resources be more equitable. Current differentials in post-compulsory participation in science mean that not all groups have equal access to these resources.

Efforts to explain and address disparities in post-compulsory science participation have often focused on students' (purported) declining interest in science, concluding that if science, particularly school science, is made more interesting, more students will continue to pursue it (Osborne, Simon, & Collins, 2003). However, considerable research has reflected that students are generally interested in science – lack of interest is not the problem (e.g. Butt, Clery, Abeywardana, & Phillips, 2009; DeWitt & Archer, 2015), begging a further, more nuanced explanation for these disparities in participation than is offered by interest alone.

A more fruitful line of research, in our view, focuses on how participation and engagement with science are mediated by identity. As Carlone and Johnson (2007) explain, science identity captures both the extent to which a person sees themselves, and is recognised by others as being, a 'science person'. The extent to which a student feels their identity is recognised and valued within science education will shape their engagement with science (e.g. Calabrese Barton & Tan, 2010) and will impact on their sense of whether post-16 science is 'for me', or not (Archer & DeWitt, 2016). From a Bourdieusian perspective, we understand identity as part of habitus, that is, a layering of dispositions, produced through socialisation which guide a person's sense of what is normal, possible and desirable for 'people like me'.

How capital influences student science participation

In this paper, we draw on Bourdieu's theory of social reproduction (e.g. 1984, 1986), with particular emphasis on his concept of *capital*, as a tool for understanding inequalities in science participation. Bourdieu proposes that social life can be understood as produced through interactions of *habitus* (an internal matrix of dispositions, produced through socialisation, which guides behaviour and produces a 'feel for the game') and capital within the context of field (social context). Substantial previous research has illuminated the ways in which interactions of capital and habitus can generate academic achievement and, relatedly, the reproduction of relations of privilege or domination. For instance, studies have highlighted the ways in which the middle classes are often able to combine economic, cultural and social capital to produce academic achievement (Dika & Singh, 2002) and secure the 'best' school places for their children (e.g. Reay, David, & Ball, 2001; Vincent & Ball, 2006). Moreover, through the interaction of capital and habitus, families may produce values, attitudes, expectations and behaviours in children that promote academic attainment and post-compulsory educational participation (e.g. Israel, Beaulieu, & Hartless, 2001; Lareau, 2003; Martin, 2009; Perna & Titus, 2005; Sandefur, Meier, & Campbell, 2006) and, as our previous research has shown, foster engagement with science (Archer & DeWitt, 2013).

Bourdieu identifies four main types of capital: cultural capital, social capital, economic capital and symbolic capital. Cultural capital refers to qualifications, dispositions, knowledge/understanding and cultural 'goods'. Social capital refers to social networks and relations and economic capital denotes financial and economic resources. Symbolic capital denotes the forms of capital that have the highest social prestige and exchange value – that is, they can generate value across different social contexts. However, the value of capital is not fixed but is determined by the field. That is, capital has no permanent 'intrinsic' value of its own, its value is produced through the field in which it is being realised. For instance, knowing about and having a 'taste' for fine art does not have an inherent value in and of itself – the value of such knowledge and dispositions is only realised within contexts that would value this as, for instance, a marker of high social class or as legitimate knowledge during an art examination.

Previous research has also applied Bourdieu's construct of cultural capital to the field of science education. For instance, Claussen and Osborne (2013) use cultural capital as a lens to critique science education, including the way in which it argues for its worth, concluding that it fails to communicate the value of science qualifications for future employment. Other work has utilised cultural capital as an analytical lens to explore student engagement and participation in science, exploring what components of students' cultural capital they bring to the science classroom (Elmesky & Tobin, 2005). Research has also drawn on Bourdieu's theorisation to examine why some individuals remain in the 'science pipeline' while others do not, identifying the way in which families' cultural capital powerfully shapes access to post-compulsory science (Adamuti-Trache & Andres, 2008). Other work, although not directly referencing Bourdieu as such, shares its concern with exploring how students' resources from outside the school (e.g. family influences) can be leveraged as ways of doing science and promoting more equitable science learning (e.g. Calabrese Barton & Tan, 2010; Calabrese Barton, Tan, & Rivet, 2008).

Aligned with such work, we have been drawing on Bourdieu's notions of capital (e.g. 1986), to develop a theorisation of 'science capital' (e.g. Archer, Dawson, DeWitt, Seakins, & Wong, 2015), as a way of conceptually collating science-related forms of cultural and social capital, but particularly those forms which have the potential to influence a young person's science identity and prospective science participation. In this respect, we do not see science capital as a separate type of capital – rather we use it as a lens for 'zooming in' on particular science-related configurations of capital that might help us identify the factors promoting, or constraining, science participation between students who, otherwise, appear to share a similar social location.

In order to illustrate how differences in science capital can relate to differences in science participation and to show how we have used the construct in making sense of patterns in qualitative data, we begin by describing some participants in our previous research. Vanessa, Danielle, Gus and Robert M are four students who have been participating in the ASPIRES project – a longitudinal study exploring the development of attitudes and aspirations in science among a cohort of students from age 10–18

(Archer & DeWitt, 2013, 2016). As part of that research, students (including these four) were interviewed three times – at ages 11, 13 and 14. At age 14, 2 of the 4 had science-related aspirations, which had been maintained since the age of 11, while 2 did not. Gus and Robert M both attend an independent boys' school which provides engaging science teaching and ample science enrichment opportunities. Both boys are White, come from comfortable, upper middle-class backgrounds and have parents in professional positions (e.g. public relations, finance and architecture). Robert M aspires to become an aeronautical engineer (as he has since at least the age of 10), while Gus does not see himself as 'scientific' and is primarily leaning towards becoming an author or journalist. Vanessa and Danielle do not attend the same school (Vanessa goes to an inner city all-girls school, while Danielle attends a suburban mixed school) and both are in middle sets (or groups) for science. While neither is high attaining, they both consistently enjoy science, with Danielle frequently remarking how much she likes the subject. Unlike Gus and Robert M, Vanessa and Danielle are both from working-class backgrounds. Danielle is White and Vanessa is Black African. Vanessa hopes to pursue forensic science (and has consistently maintained STEM-related aspirations since at least the age of 10), but Danielle drops science after the age of 16 and is considering becoming a humanities teacher.

While there are multiple reasons that might lead to the differences in aspirations between the boys and between the girls, it would appear that cultural capital alone is an insufficient explanation (particularly for the difference in aspirations between Vanessa and Gus). It would also appear that neither attainment nor interest/enjoyment alone can account for these differences. While we acknowledge that this is an oversimplification and that aspirations are shaped by multiple, interacting and idiosyncratic factors, the prevalence of such differentials in patterns of aspirations in data from the ASPIRES project (Archer & DeWitt 2013) motivated our interest in developing the concept of science capital.

Our understanding of science capital goes beyond a focus on 'science literacy', science content knowledge and skills, and/or attitudes to science, although we would see all of these as components within science capital. More specifically, our initial analysis of data (Archer et al., 2015) from a survey of over 3600 students aged 11–15 identified a number of different dimensions within science capital: scientific forms of cultural capital (including scientific literacy and science dispositions, knowledge of transferability of science skills and qualifications); science-related behaviours and practices (e.g. engagement with science-related media, informal science experiences), and science-related social capital (e.g. parental scientific knowledge, talking with others about science, receiving encouragement from others to continue with science).

We are also mindful that the value of capital is not fixed but is determined by field (Bourdieu, 1984). With this in mind, our quantitative measure of science capital was derived to highlight those science-related cultural and social resources which, empirically, would seem to be endowed with the most value in relation to the field of science education, particularly in relation to promoting science participation. This is not to say that we consider these to be the *only* resources that relate to a student's science identity and likelihood of participating in post-16 science. For instance, what happens in the school (e.g. science lessons, school science 'culture', teachers and so on) would all be important in terms of shaping both student habitus and capital and – of course – are also constitutive of the field of school science. Indeed, the original (longer) survey from which the key dimensions of science capital were derived included, for instance, a range of items relating to students' experiences of science teachers and teaching (e.g. My teachers explain how science qualifications can lead to different jobs; I learn interesting things in science lessons) and some of these items group under the key dimensions of science capital that our analyses identified as being most strongly related to student science identity and post-16 science aspirations. Additionally, we felt that there could be value in trying to identify the most transferable and valued forms of capital as a means of trying to better understand the ways in which social reproduction occurs and also to inform attempts to intervene and develop more targeted approaches aimed at widening science participation (as we are attempting in our wider study). That is, we attempted to identify forms of science capital that seem to have value across various fields, including the science classroom and the wider field of science education, that enable individuals to engage and participate in science while they are in school as well as after.

In very simple terms, the notion of science capital and its constituent dimensions can be summarised by the visual metaphor of a 'holdall' (Figure 1), with the various dimensions grouping under four main 'pockets' (what science you know, who you know, how you think and what you do). Although admittedly losing a lot of the subtlety, nuance and complexity of the concept, this is a tool that we have found useful for conveying and exploring the concept of science capital with a range of practitioners (e.g. teachers, museum educators).

In our current work, we have been further developing the construct of science capital, both empirically and methodologically, in part because we felt that it would be interesting and potentially useful to be able to 'measure' levels of science capital at a broader scale than is possible with more qualitative (e.g. interview) approaches. Our previous qualitative work (e.g. Archer & DeWitt, 2016) highlighted a link between science capital and the maintenance of science-related aspirations, and our current survey analyses explore this relationship with broader, quantitative data. We view the survey work (the focus of this paper) as a complement to, not a substitute for, the in-depth perspective qualitative research affords. However, we also hope that the breadth afforded by quantitative measures may not only advance our understandings of the parameters of science capital but may also enable practical explorations of outcomes of interventions on participants' engagement and aspirations in science. The analyses which form the basis of the current paper, then, reflect attempts to further refine our understandings of science capital and focus on the following questions:

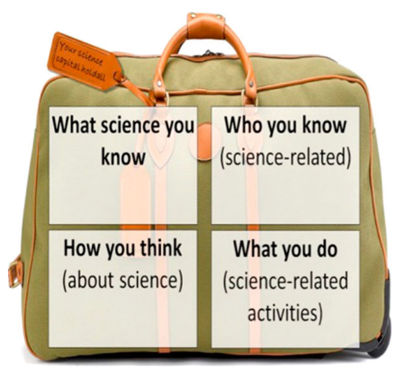

Figure 1. Simple visual metaphor: the science capital 'holdall'.

(1) What new insights, if any, might the concept of science capital offer beyond existing, related constructs (e.g. cultural capital)?
(2) How do the component elements of science capital relate to (anticipated/future) science participation and science identity? Are some more closely related than others?

We utilise survey data to address the above two questions and then use the findings to consider which aspects of science capital might usefully form a focus for intervention efforts.

Methods

The data on which the findings reported in this paper are based were collected in the context of a wider, ongoing research project, involving ongoing theorisation and development of the concept of science capital. Our analyses utilise data from two surveys: a broader national survey conducted in spring/summer of 2014 and a more recent survey (from the 2014 to 2015 school year) completed by schools participating in the Enterprising Science project. For ease of reference, the first survey is referred to as the 'national survey' and the second as the 'targeted survey' throughout.

Instrument development

Broadly, the initial development of the survey was informed by findings from the (previous) project (cf. DeWitt et al., 2011; DeWitt & Archer, 2015), which explored children's aspirations in science from ages 10–14, as well as our theorisation of science capital. The current survey has been refined through successive iterations, beginning with an initial pilot phase during the summer of 2013, involving 1463 students in Years 7 and 9 (ages 11 and 13). A subsequent trial during the 2013–2014 school year involved over 6000 students in Years 7, 8 and 9. Those two iterations were conducted as part of the Enterprising Science current project, a research and development project which focuses on engaging students from underprivileged or under-represented communities with science. Consequently, the students completing those surveys were from schools that were not intended to be nationally representative but rather to reflect groups who have historically been more likely to be marginalised from science. A third iteration of the survey, for comparison, was conducted in the spring and summer of 2014 and involved a more nationally representative sample of students in Years 7–10 (ages 11–15). Although the first two iterations were used to refine the survey instrument, it was the third iteration that formed the basis of the development of an 'index' of science capital. Details of the development and trial of this index, including the way in which it reflects various dimensions of science capital, are reported elsewhere (Archer et al., 2015).

The survey instrument itself consists of items corresponding to dimensions of science capital, namely, scientific literacy, scientific-related dimensions/preferences (e.g. attitudes to science and scientists, perceptions of school science and teachers), knowledge about the transferability of science qualifications (in the labour market), consumption of science-related media, participation in out-of-school science learning activities, and science-related social capital (i.e. knowing individuals working in science-related jobs, talking with others about science). In addition to items about knowing individuals who work in science, the survey also contains items about parental attitudes towards science.

Previous work has highlighted that young people with science capital were more likely to maintain aspirations to continue with STEM, in terms of interest in future study and in the maintenance of science-related aspirations (Archer et al., 2012; Archer & DeWitt, 2016). Consequently, the survey also includes a number of items intended to capture intentions for future science participation. It also contains a measure of science identity, whether or not science is 'for me' (e.g. 'Other people think of me as a science person'). Finally, items are included which capture a range of demographic/background information, such as gender, ethnicity,[1] cultural capital, parental employment, set (or track) in school subjects (as a proxy for attainment).

Index of science capital

As noted above, our measure of science capital was refined using data from the third iteration of the survey, the 'national survey'. Details of how this index was measured are detailed elsewhere (Archer et al., 2015), but, in brief, logistic and linear regression analyses were employed to identify which items from the full survey were most closely related to a dependent measure of future science affinity and science identity. That is, although our survey contained items corresponding to our *conceptual* model of science capital, we used regression analyses to identify which items *in particular* were most predictive of our outcome measures and should thus form an index or measure of science capital. Fourteen questions comprise this measure: two questions about (i) who students speak with about science and (ii) who they know who has a job using science, and 12 individual items:

- A science qualification can help you get many different types of job.
- When you are NOT in school, how often do you talk about science with other people?
- One or both parents think science is very interesting.
- One or both parents have explained to me that science is useful for my future.
- I know how to use scientific evidence to make an argument.
- How often do you go to an after-school science club?
- When not in school, how often do you read books or magazines about science?
- When not in school, how often do you go to a science centre, science museum or planetarium?
- When not in school, how often do you visit a zoo or aquarium?
- My teachers have specifically encouraged me to continue with science after GCSEs.
- My teachers have explained to me science is useful for my future.
- It is useful to know about science in my daily life.

These items were used to create a composite measure of science capital, which could be used in further analyses.[2] Students' scores were also used to divide students completing each survey into three groups – possessing low, medium, and high levels of science capital. For conceptual ease, we did so by dividing the scores into thirds, defining low science capital as the bottom third (0–34), medium science capital as scores of 35–69 and high science capital as scores of 70–105. We acknowledge that only a subset of these 14 items relate to experiences of school science. However, such items do form part of the larger survey – the 14 items comprising the index were those that, statistically, were most closely related to the outcome measures of science identity and intentions to participate in science in the future. While more items (e.g. related to school science) could have been included, our intention was to create a tool which would be both concise and reflect that much of science capital does come from outside the classroom.

Participating students and schools

Data from two surveys are reported in this paper, with 3658 students participating in the (2014) national survey and 6861 in the targeted survey. The students in the national survey attended 45 secondary schools across England. The schools represented the various types of secondary schools found in England, including state schools (under varying degrees of local and governmental control), independent schools and faith-based schools. Five were all girls, two were all boys and the remaining schools were mixed. Schools also reflected a range of achievement on national standardised tests and a range of proportions of students eligible for free school meals (1.3–60.5%).

Due to difficulties students had on previous surveys responding to questions about parental occupation, we simply asked students whether or not their parents were in employment. Additionally, we employed a measure of cultural capital (based on parental university attendance, leaving school before age 16, number of books in the home and museum visitation), which had been developed and utilised in multiple surveys in the current project and others. As a proxy for attainment, students were asked which sets (or tracks) they were in for science, mathematics and English. (The distribution of top/middle/bottom/no sets was similar for English and mathematics.)[3]

Compared with the national survey, a greater number of students participated in the more targeted survey included in these analyses – 6861. Due to the design of the wider project and its focus on students from groups traditionally marginalised from science, these participants were drawn from a smaller group of 18 schools who generally serve such communities. Because of our project partner, the schools were situated in four cities in England: London, Bradford, York and Manchester. All but one (all girls) were mixed sex and all were state-supported schools. The schools tended to have lower ranges of achievement on national tests and greater student eligibility for free school meals, compared with the national average (as well as compared with the schools participating in the national survey). Background/demographic information about students participating in each survey is summarised in Table 1.

Analyses

To address our first research question (what new insights science capital might have to offer), we explored differences between science capital and cultural capital, comparing the ability of our science capital variable to predict science aspirations-related outcomes with the ability of a measure of cultural capital to do so. In other words, we asked which measure is more closely related to particular survey outcomes (Recall that previous qualitative research had highlighted the link between science capital and science aspirations and here we explore this relationship quantitatively.) The survey contained two questions that we would expect, conceptually, to be related to science capital and that had not been used in the creation of that measure: (1) Do you think you might want to work in a science-related job in the future?

Table 1. Background information/details for participating students.

	National survey (2014)	Targeted survey (2014–2015)
Number of participants	3658	6861
Year groups	Year 7 (age 11–12) – 31.5% (1153)	Year 7–32.1% (2238)
	Year 8 (age 12–13) – 24.4% (891)	Year 8–25.9% (1804)
	Year 9 (age 13–14) – 22.4% (820)	Year 9–23.7% (1653)
	Year 10 (age 14–15) – 21.7% (794)	Year 10–18.3% (1279)
Gender	Female – 54.3% (1988)	Female – 54.1% (3775)
	Male – 45.7% (1670)	Male – 45.8% (3196)
Ethnicity (self-identified)	White – 73.8% (2701)	White – 37.7% (2626)
	South Asian – 8.4% (307)	South Asian – 23.6% (1642)
	Other or mixed race – 5.5% (201)	Other or mixed race – 10.2% (711)
	Black – 4.4% (161)	Black – 15.5% (1082)
	Middle Eastern – 0.8% (31)	Middle Eastern – 2.6% (182)
	East Asian – 1.1% (42)	East Asian – 0.9% (61)
	(Prefer not to say – 5.9%, 215)	(Prefer not to say – 9.6%, 667)
Parental employment	Father employed – 86.4% (3160)	Father employed – 76.2% (5317)
	Mother employed – 76.1% (2785)	Mother employed – 55.6% (3880)
Cultural capital	Very low – 5.3% (195)	Very low – 6.9% (474)
	Low – 25.9% (949)	Low – 33.4% (2293)
	Medium – 28.2% (1031)	Medium – 26.8% (1965)
	High – 19.6% (718)	High – 17.6% (1209)
	Very high – 20.9% (765)	Very high – 13.4% (920)
Attainment (Science set/grouping used as proxy)	Top set – 44.2% (1618)	Top set – 41.9% (2897)
	Middle set – 28.8% (1055)	Middle set – 37.0% (2553)
	Bottom set – 7.4% (270)	Bottom set – 8.6% (594)
	No sets for science – 19.5% (715)	No sets for science – 12.5% (964)

(Yes/No) and (2) a question about how far they might want to pursue the study of science in the future (at university, A-level, not past GCSE* and so forth).

With regard to the first (Y/N) question, two logistic regression models were created, one with science capital as the predictor (or independent) variable and the other with cultural capital as the predictor variable. The program used for analysis was SPSS, which produces a summary for each model, containing −2loglikelihood, Cox & Snell R^2 and Nagelkerke R^2 scores. While there is some debate about the R^2 measures, there is agreement that the smaller loglikelihood scores indicate better fits (indicate that there is less unexplained variance) and, similarly, larger R^2 (whether Cox & Snell or Nagelkerke) indicate better fits (demonstrating that the model explains more of the variance in an outcome) (Field, 2013). Put simply, if the −2loglikelihood is smaller and R^2s larger for science capital, it means that it is a better or more accurate predictor than cultural capital of how a student will answer the question about whether they would like a science-related job in the future (so is more closely related to aspirations).

For the second question (concerning future science study), responses were combined into two groups in order to perform the logistic regression. One group included responses consistent with greater pursuit of science (I would like to study a science subject at university; I would like to study one or more sciences at A-level) and the other reflected less extensive (or no) anticipated participation (I would like to study some science after GCSE but not A-level biology, chemistry or physics; I do not want to study any science

*General Certificate of Secondary Education (GCSE) is the last point at which students are required to study science in England. GCSE exams are sat when students are approximately 16 years old.

after GCSE; None of the above or I do not know). Again, the same measures described above were used to compare how closely related science capital and cultural capital each were to outcomes on this question.

Next, and in response to our second research question, we investigated whether some items are more central to our conceptual model of science capital than others. To do so, we conducted a linear regression (backward stepwise), utilising the same dependent variable used in the initial creation of our science capital measure (detailed in Archer et al., 2015), a composite comprised of five items reflecting intentions for future participation in science (primarily science-related aspirations) and science identity.[4] In creating this outcome measure, we took science-related aspirations (three items) as consistent with intentions to participate in science in the future, as well as indicative of science identity (in that individuals who hold science-related aspirations often identify with science or see it as 'for them'). This measure also included a further two items related to science identity, concerning perceived similarity with those who work in science and perceptions of themselves as a 'science person'. To further check the model, linear regressions using the enter and forward stepwise methods were also utilised.

Findings

In order to frame our analyses of science capital, we begin by providing an overview of the distribution of science capital and providing a brief summary of the background characteristics of the students in each group. Data from the national survey provides a broad overview of the distribution of science capital. However, given our particular concern with groups historically marginalised from science, we compare the impression emerging from the national survey with that provided by the more targeted survey. In the national survey, 5.2% (190 students) fell into the high science capital group, while 67.6% (2472) had medium levels of science capital and 27.2% (996) were in the group with low science capital. These proportions were largely mirrored in the data from the targeted survey, where the proportions having high, medium and low levels of science capital were 4.9% (334 students), 66.9% (4588) and 28.3% (1939), respectively. Likewise, students' science capital scores, a scale of 0–105, were quite similar for both samples, with those from national survey having a mean of 43.65 (SD = 15.45) and those from the targeted survey having a mean of 42.99 (SD = 15.38). These similarities between samples, despite the demographic differences between them (i.e. in ethnicity and cultural capital in particular), suggest that science capital is not simply reducible to other characteristics.

Despite the demographic differences between the samples, students with high science capital from both surveys (national and targeted) were slightly more likely to come from South Asian or Middle Eastern ethnic backgrounds (compared with the overall samples of respondents to each survey). They were also likely to have higher levels of cultural capital and to be in a top set for science.

In contrast, students in the low science capital group from each survey were more likely to have low or very low levels of cultural capital and were somewhat more likely to be White. They are also more likely to be in middle or bottom sets for science. Perhaps not surprisingly, students with middle levels of science capital tended to be reflective, demographically, of the broader sample (for each survey).

Comparing science capital and cultural capital

In order to address our first research question (concerning what new insights science capital might have to offer, in comparison to the existing construct of cultural capital), we compared our science capital variable with a measure of cultural capital, exploring the ability of each to predict students' responses on two survey questions. These two questions were both related to science aspirations, one focusing on science-related jobs and a second about future science study.

As described previously, for each question, two logistic regression models were created, one with science capital as the predictor variable and the other with cultural capital as the predictor (or independent) variable. The scores in Tables 2 and 3 indicate that for each question, science capital is a better predictor than cultural capital of the outcome (concerning interest in science-related jobs or concerning intentions for future science study). Moreover, this was the case for both sets of data – that from the more national survey as well as from the more targeted survey (involving a group from a set of more disadvantaged schools). Recall that smaller −2loglikelihood scores and larger R^2 scores indicate better fits.

The lower −2loglikelihood score for science capital (compared with cultural capital) reflects that there is less unexplained variance in the model when science capital is used to predict students' responses to a yes/no question about whether they would be interested in a science-related job in the future. Additionally, the higher R^2 scores for science capital indicate that it explains more of the variance in the outcome (in students' responses) than cultural capital does. Table 3 highlights that, likewise, science capital would seem to be a better predictor than cultural capital of students' intention to study science in the future.

In summary, science capital is a better predictor than cultural capital of how students will respond on each of these two questions. Moreover, this is the case not only for data from a broader, national survey but also for a survey of students from a more disadvantaged set of schools. Of course, the regression models reflect that both cultural capital and science capital are related to science aspirations-related outcomes and that neither perfectly predicts the outcomes but the two constructs, statistically at least, would not seem to be interchangeable. The differences between the two variables reinforce our argument that there is value in considering science capital as a construct distinct from cultural capital, and one that might offer fresh insights into science-related aspirations and choices for a range of students – beyond that offered by cultural capital alone.

Exploring the dimensions of science capital

Against this backdrop, we turn to address the question as to whether some of the component dimensions of science capital – as encapsulated in individual survey items – are more closely related to (anticipated/future) science participation and science identity.

Table 2. Model summary information indicating relative goodness of fit for science aspirations (scores in brackets are from the targeted survey).

Independent variable	−2loglikelihood	Cox & Snell R^2	Nagelkerke R^2
Science capital	3747.952 (7141.445)	.257 (.237)	.343 (.316)
Cultural capital	4659.397 (8701.198)	.032 (.027)	.042 (.036)

Table 3. Model summary information indicating relative goodness of fit for interest in future science study (scores in brackets from targeted survey).

Independent variable	−2loglikelihood	Cox & Snell R^2	Nagelkerke R^2
Science capital	3845.986 (7363.029)	.212 (.193)	.286 (.259)
Cultural capital	4472.605 (8530.867)	.055 (.031)	.073 (.042)

As the students completing the survey were still in secondary school, we had to use a proxy for future (post-16 and beyond) science participation – that of intentions to participate in science in the future (generally via work). Linear regression was used to investigate how closely related the items comprising the science capital variable were to a composite dependent variable reflecting intentions for future participation in science and science identity. That is, future science participation and science identity are operationalised in a composite variable described previously. The outcomes of this analysis (showing which items are most closely related to our dependent measure) are found in Table 4, which presents the beta weights from the linear regression analysis (backward). Part correlations, which reflect the unique relationship between each item and the dependent variable, are also included. Note that the data in brackets are that from the targeted survey.

Across both surveys, the items that emerge as most closely related to the outcome measure are remarkably similar. The order varies slightly but the items themselves are nearly identical, helping to crystallise a picture of the items that are key to our developing ideas around science capital. Broadly speaking, it appears that science literacy[5] would be quite central to our conceptual model of science capital, as the corresponding item is most closely related to our outcome measure (concerning science participation and identity) in

Table 4. Science capital items most closely related to indicator variable (data in brackets from targeted survey).

Item	Coefficient (B)	SE	Standardised beta (β)	Part correlation
I know how to use scientific evidence to make an argument	.151 (.132)	.012 (.009)	.187 (.162)	.151 (.137)
(Parents) think science is very interesting	.115 (.236)	.025 (.019)	.076 (.152)	.056 (.114)
(How often when not in school) read books or magazines about science	.103 (.110)	.011 (.008)	.133 (.145)	.107 (.120)
When not in school, how often talk about science with other people.	.099 (.082)	.010 (.007)	.163 (.135)	.118 (.106)
(Parents) Have explained to me that science is useful for my future	.074 (.079)	.012 (.009)	.099 (.105)	.074 (.079)
A science qualification can help you get many different types of job	.103 (.086)	.013 (.009)	.110 (.098)	.095 (.085)
My teachers have specifically encouraged me to continue with science after GCSEs	.065 (.057)	.012 (.009)	.082 (.074)	.066 (.059)
(In school, how often) go to an after-school science club?	.049 (.043)	.011 (.007)	.061 (.059)	.055 (.055)
Extended family member works in science[a]	.090 (.107)	.025 (.020)	.044 (.052)	.042 (.049)
It is useful to know about science in my daily life.	.159 (.081)	.026 (.019)	.094 (.049)	.072 (.038)
Go to a science centre, science museum or planetarium[b]	.039 (.023)	.013 (.009)	.048 (.029)	.035 (.023)

[a]This item did not appear as closely related (not in the top 10 items) in the national survey.
[b]This item did not appear as closely related (not in the top 10 items) in the targeted survey.

data from both surveys. Notions of transferability of science qualifications and usefulness of science would also seem to be quite key, in that three items related to these science capital dimensions (parents have explained to me that science is useful for my future; A science qualification can help you get many different types of job; A science qualification can help you get many different types of job) did emerge as relatively closely related to the outcome measure for both surveys as well. Family would also appear to have an important role to play, although the item about parental interest seems less central in the national survey (with a beta of .076) compared with the targeted survey (beta = .152). What might be considered unstructured science-related activities (i.e. activities that can potentially take place in the home and certainly can happen in un-designed environments, such as reading books/magazines or simply talking about science), would also seem to be related to – and perhaps supportive of – science aspirations and identity. However, more structured informal science experiences do not appear to be quite as central. For instance, the item about going to a science centre, science museum or planetarium was in the top 10 only in the national survey (and was number 10) and the item about visiting a zoo or aquarium was actually negatively related to the outcome measure in both surveys. Although this particular finding may be surprising to some, it does not necessarily mean that such institutions have no role to play in supporting the development of science capital. For instance, it is possible that zoos are visited by a range of individuals, including many with lower levels of science capital. Such a visitation pattern could account for a negative relationship between that item and our outcome measure (which increases and decreases in correspondence with science capital). A weak relationship between visitation and the outcome measure could also be due to the relative infrequency with which most individuals visit such institutions, compared to, for instance, how often they may have conversations about science with others. Nevertheless, this intriguing pattern does have bearing on the implications of this research, as we discuss subsequently.[6]

Discussion

In this article, we have built upon previous theorisation and research around science capital (Archer et al., 2015), with the aim of exploring in more detail, quantitatively, what potential this construct might offer for understanding science engagement and participation. In many ways, our analyses confirmed findings from previous surveys, as well as being consistent with other work around aspirations and participation in science (c.f. Archer & DeWitt, 2016; Costa, 1995; Gilmartin, Li, & Aschbacher, 2006). For instance, the data highlighted the small proportion of students with high levels of science capital (who are, critically, also most likely to want to pursue science in the future). We also found that these students were, ethnically, more likely to be Asian or Middle Eastern and tended to occupy quite a privileged position in other ways, with high levels of cultural capital and being in top sets at school.

Broadly speaking, we regard science capital as what may help transform positive attitudes and interest in science into decisions and choices – actions – that make future science participation more likely. Thus, this paper investigated (1) what new insights the concept of science capital might offer beyond existing, related constructs, and (2) how the component elements of science capital relate to (intended) science participation and identity. These questions were explored using data from two administrations of the (project) survey – one conducted with a broader national sample and one with a more targeted sample of students from schools that, on the whole, tended to serve individuals from more disadvantaged communities. Given the similarity in results from both surveys, the data could have been combined for analysis. However, we have kept them separate because the two samples were distinct and we felt that it was important to investigate our research questions for both samples. Indeed, we argue that the similarity in findings for both samples strengthens our argument that there is value in considering science capital as distinct from cultural capital – this holds for different groups of students.

In response to our first research question, our analyses compared science capital with cultural capital on their ability to predict responses related to questions about anticipated future science participation. We found that science capital was a better predictor than cultural capital of students' responses to such questions. Thus, there would seem to be value in conceptualising science capital as something distinct from cultural capital, not only for theoretical reasons, but because doing so may also point to different implications – or provide new insights into issues around science engagement and participation, including choices to continue with science or not. Likewise, our finding that some elements of science capital would seem to be more closely related to future/anticipated science participation than others is not simply of interest theoretically, but rather also has implications for practice, as we describe subsequently.

The linear regression analyses used to address our second research question highlighted the centrality of science literacy, as well as family, to science capital. In addition, the analyses indicated that knowledge of transferability and usefulness of science qualifications (and of studying science generally) are also important. That is, we found that science literacy, family attitudes and unstructured science experiences, as well as awareness of the transferability/utility of science, were most closely related to our dependent variable, a composite reflecting elements of (future/anticipated) science participation and science identity. While these findings are not necessarily surprising, they also align with previous research around who does and does not continue to participate in science. For instance, Mujtaba and Reiss (2014) found that perceived *utility* of science qualifications (for a desired career) was very strongly predicted students' choice to continue with physics (or mathematics) after it was no longer compulsory. In addition, substantive previous work also emphasises the key role of family support in students' continued pursuit of science (e.g. Costa, 1995; Gilmartin et al., 2006). Our own previous work (e.g. Archer et al., 2012; Archer & DeWitt, 2016) also reflects the way in which science social capital – knowing someone (especially parents) who work in a science-related job – can facilitate the development and maintenance of science aspirations.

We now return to the four cases we described at the beginning in order to exemplify the way in which science capital may play out in the lives of individual students. Recalling Vanessa and Robert M, who did plan to continue in science and hoped to pursue STEM-related careers (forensic science in the case of Vanessa and aeronautical engineering for Robert M), compared to Gus and Danielle, who did not, science capital would seem to provide more insight than cultural capital alone in understanding why some students are able to continue to participate in science, while others do not. For instance, both Gus and Robert M have similar levels of cultural capital and access to the same (rich) science lessons in their all-boys independent school. The differences between them would seem to do with the science social capital provided by their respective families –

with Gus's family not particularly engaged in science pursuits, while Robert M has a family friend who is an engineer and a father who has a keen interest (though not a career) in maths and science, once even taking him to visit the lab at Cambridge where Frank Whittle developed the jet engine.

Turning to the girls, neither Vanessa (whose parents have immigrated from Nigeria) nor Danielle (from a working-class background) comes from families with high levels of cultural capital. Although they attend different schools, neither is in top sets for science and although both aspire to continue with science past GCSE, Danielle ultimately ends up not pursuing science post-16. In contrast, Vanessa has an advantage, from a science capital perspective, in that her father possesses a university degree in pharmacy and, perhaps even more importantly, is a science technician in a secondary school (not Vanessa's). Thus, he is able to support Vanessa's science literacy very directly and he is also well positioned to use his knowledge of the school system to ensure that Vanessa is permitted to continue with science at A-level (in addition to being keenly aware of the value that such qualifications could have for his daughter).

Conclusions and implications

Drawing on the findings from our analyses, we argue that science capital can serve as a useful construct in accounting for the development and maintenance of science aspirations, adding a greater degree of specificity and explanatory power than cultural capital alone. Considering the key dimensions of science capital – such as science literacy and attitudes, knowledge of the transferability of science qualifications, science-related practices and science-related social capital – would seem to help shed some new light onto why some students are able to continue their participation in science while others are not. Put differently, when looking at the field of school science (including the field of the science classroom), we expect these dimensions of science capital to help students engage more, identify with science and plan to continue with science because of the alignment between their capital and that field, experiencing it as a 'fish in water'. Thus, we recognise the importance of the experience of school science, but the point of exploring science capital and attempting to identify its constituent dimensions is to understand the actual knowledge, practices, dispositions, contacts and so forth that students can acquire (through school science, out of school, family, etc.) In this sense, school science issues and factors are more part of the field (that mediates capital) rather than the actual capital itself.

The notion of science capital also has further implications for theory and practice. For instance, aspirations in science tend to be classed (Archer & DeWitt, 2016), as those with high cultural capital are more likely to maintain science aspirations. However, our quantitative comparison of science capital and cultural capital suggests that there is added value in using science capital as a lens with which to examine aspirations and, in particular, the translation of engagement and interest in science into later participation, as science capital can provide more insight than simply looking at cultural capital or social class. In the same way that using a microscope can contribute to deeper understanding of scientific phenomena through the magnification of particular features, the tool of science capital offers a finer grain of analysis than cultural capital alone, although the two constructs are related. While our previous qualitative analyses indicated that this was the case, the analyses in the present study suggest that science capital can also be a useful analytic lens on a larger scale. The capacity to do this offers the potential not only to continue to refine the construct of science capital, but also to explore questions such as its distribution across larger groups of individuals or to track how it develops, perhaps in response to an intervention or even to systemic changes.

The identification of key elements within science capital also has implications for practice, both in school and out. Our findings suggest that what happens at school and at home (and other unstructured environments out of school) is of primary importance, with designed spaces (e.g. science centres) having, perhaps, a less key role.[7] Moreover, given the time spent in such environments, as well as their centrality to science capital, it would seem that they might be important foci for intervention. Similarly, particular elements of science capital – such as parental understanding of the utility of science qualifications – are also more likely to be amenable to intervention than others (such as having family members working in a science-related job). For instance, parents and other family members could be encouraged to share intentionally any interest or valuing that they have for science with their children. Perhaps via work with schools, it would also be important to highlight to parents the utility and transferability of science qualifications and to encourage them to communicate this to their children in turn, particularly when it comes to choice points in their education (e.g. around GCSE choices). Likewise, teachers should be encouraged to highlight the relevance of science skills and utility/transferability of science qualifications for a wide range of jobs, not just in science. While doing so would necessitate some pedagogical shifts, they could be integrated into the existing curriculum and assessment structure.

A number of recent interventions have been developed along these lines, focusing on the relevance of science to students' lives, with the rationale that if students perceive science to be relevant to their current and, perhaps more importantly, future lives, they will be more inclined to continue to pursue science after it is no longer compulsory. One such initiative is CareerStart (Orthner, Jones-Sanpei, Akos, & Rose, 2013; Rose, Woolley, Orthner, Akos, & Jones-Sanpei, 2012; Woolley, Rose, Orthner, Akos, & Jones-Sanpei, 2013), which focused on integrating links to jobs in all areas of the middle school curriculum (including science). While it is too soon to explore outcomes around adult participation, this work did find that the intervention had positive results for school valuing and mathematics attainment. Other interventions have focused supporting the engagement of students from disadvantaged backgrounds with science through leveraging these students' funds of knowledge within the context of doing science, often leading to increased identification with science (Calabrese Barton & Tan, 2010; Calabrese Barton et al., 2008; Furman & Calabrese Barton, 2006; Gonsalves, Rahm, & Carvalho, 2013).

Designed spaces (such as science museums and zoos) also have the potential to nurture the development of science capital of their visitors, such as via the messages they provide about the variety of ways to engage with science and about the utility and relevance of science. However, the visitor demographics of some of these spaces are currently skewed towards the more privileged (those with more science and cultural capital), suggesting that in order for their intervention effects to be successful, they need to do more to include those from disadvantaged communities.

The current system is not ideal for supporting science capital. While science literacy (e.g. knowledge and skills) is key and should, of course, continue to be supported and improved in schools, the education system (including learning environments inside and outside the classroom) is rife with missed opportunities to build on dimensions of science capital such as emphasising the transferability and utility of science knowledge, skills and qualifications. Such awareness is potentially at least as important as science literacy in helping students to translate their interest (and even attainment) in science into decisions to participate in science in the future and to supporting the engagement and identification with science across the breadth of our communities, inside the pipeline and beyond.

Notes

1. We fully acknowledge that these characteristics and terms are problematic and contested. However, collecting such data is helpful in providing an overview of the sample and in enabling us to explore how science capital may be unevenly distributed among groups. In addition, the scale of the survey (as well as the ages of the individuals completing it) necessarily precludes a more nuanced collection of data.
2. Items were initially weighted according to their theoretical centrality to the notion of science capital (for instance, having a parent who worked in science was weighted more heavily than having a neighbour who worked in science). We then compared these with a weighting derived from the logistic regression (which indicated which items were stronger predictors of the outcome variable). As the distribution of scores was virtually identical, we decided to keep our initial weightings for clarity and simplicity.
3. That over 40% of students reported being in the top sets suggests that there was some tendency on the part of schools to ask students in top sets to complete the survey. However, we are unable to weight the data for set, as there is no way of knowing what proportion of students, nationally, are in top sets. This situation is further complicated by the fact that different schools have different proportions of students in their top set (some might have two classes of top sets, while others might have one, or three) and different schools place students in sets based on different criteria.
4. These five items were: when I grow up, I would like to be a doctor or work in science; I want to become a scientist; I would like a job that uses science; people who are like me, work in science; and other people think of me as a science person.
5. Ideally, we would have preferred to have multiple measures of science literacy (including items that measured science content knowledge and skills), but this was unfeasible within the constraints of this survey (not least due to the different ages/year groups involved). However, this item does map onto our science capital dimension of science literacy.
6. A principal components analysis was also conducted to explore whether – and if so, how – the items in our measure of science capital grouped together statistically into any interesting or interpretable dimensions. Details are not included due to space limitations but it would seem interesting to note that the four components emerging did map back broadly to key dimensions of science capital, as reflected by the holdall in Figure 1: What science you know and how you think about science (Valuing and understanding science); Who you know (Science-related social capital); What you do (Talking about science; Participation in science-related activities).
7. This does not mean that what people experience in such spaces is irrelevant but rather that other environments may be more influential on science participation and identity (Of course, this is not necessarily surprising, given the relative amounts of time spent in schools and at home, compared with the amount of time spent in designed informal science environments).

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