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Research Article

"Science Capital": A Conceptual, Methodological, and Empirical Argument for Extending Bourdieusian Notions of Capital Beyond the Arts

Louise Archer,[1] Emily Dawson,[2] Jennifer DeWitt,[1] Amy Seakins,[1] and Billy Wong[3]

[1]*Department of Education and Professional Studies, King's College London, Waterloo Road, London SE1 9NH, UK*
[2]*University College London, London, UK*
[3]*School of Education, Roehampton University, London, UK*

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Abstract: This paper sets out an argument and approach for moving beyond a primarily arts-based conceptualization of cultural capital, as has been the tendency within Bourdieusian approaches to date. We advance the notion that, in contemporary society, scientific forms of cultural and social capital can command a high symbolic and exchange value. Our previous research [Archer et al. (2014) *Journal of Research in Science Teaching* 51, 1–30] proposed the concept of "science capital" (science-related forms of cultural and social capital) as a theoretical lens for explaining differential patterns of aspiration and educational participation among young people. Here, we attempt to theoretically, methodologically, and empirically advance a discussion of how we might conceptualize science capital and how this might be translated into a survey tool for use with students. We report on findings from a survey conducted with 3658 secondary school students, aged 11–15 years, in England. Analysis found that science capital was unevenly spread across the student population, with 5% being classified as having "high" science capital and 27% "low" science capital. Analysis shows that levels of science capital (high, medium, or low) are clearly patterned by cultural capital, gender, ethnicity, and set (track) in science. Students with high, medium, or low levels of science capital also seem to have very different post-16 plans (regarding studying or working in science) and different levels of self-efficacy in science. They also vary dramatically in terms of whether they feel others see them as a "science person." The paper concludes with a discussion of conceptual and methodological issues and implications for practice. © 2015 The Authors. *Journal of Research in Science Teaching* Published by Wiley Periodicals, Inc. J Res Sci Teach 52: 922–948, 2015
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Inequalities in post-16, science participation remain a matter of international policy concern. There is a broad consensus among governments, industry, and the science education community that more needs to be done to increase and widen participation in post-16 science, particularly in areas such as the physical sciences and engineering and among those from under-represented groups, such as women, working-class, and some minority ethnic groups (e.g., ACOLA, 2013; House of Lords, 2012; US President's Council of Advisors on Science and Technology, 2010).

Correspondence to: L. Archer; E-mail: louise.archer@kcl.ac.uk
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The imperative to improve (widen and increase) participation reflects both national economic concerns, namely to ensure a sufficient talent pool and supply of future scientists, and social justice concerns, to promote equity and ensure a scientifically literate general population who can be active citizens within a scientifically advanced contemporary society. Yet despite decades of attempts to understand and solve the problem, and considerable resource being devoted to the issues, participation rates remain stubbornly resistant to change (e.g., Smith, 2011). This paper seeks to offer a potential new lens (''science capital'') for understanding uneven patterns in science participation, with the hope that this might also offer some fresh ideas for how the issue might be tackled. We begin by setting out an argument as to why sociological measures of cultural capital (designed to elicit social class) could usefully also include some science-related aspects. We then outline our (ongoing) conceptual approach to theorizing ''science capital'' and how we have translated this into a survey tool for use with school students.

Bourdieu's Theorization of Capital

Capital is a key component within Bourdieu's theory of social reproduction. Bourdieu (1977, 1984, 1986) conceptualizes capital as the legitimate, valuable, and exchangeable resources in a society that can generate forms of social advantage within specific fields (e.g., education) for those who possess it. In *The Forms of Capital* (1986), Bourdieu identified four key types of capital—economic, social, cultural, and symbolic capital—which through interactions with habitus (a person's internalized matrix of dispositions, which guides behavior) within fields (social contexts), produce relations of privilege or subordination within society. Economic capital relates to money and financial resources, social capital refers to social networks and relations, and cultural capital, as discussed in more detail below, refers to qualifications, dispositions, and cultural goods. Symbolic capital refers to those forms of capital that are accorded the highest social prestige and legitimation, and hence which may be the most powerful in accruing social advantage. These four forms of capital do not operate in isolation, but interact together to determine a person's position within any given field.

Capital—as embodied, institutionalized, and/or objectified resources—has been likened to different types of skill and resource. It has also been compared to the "cards" that a player possesses (and their knowledge of the "rules") within a particular "game," which will shape their ability to play and their chances of "winning" or "losing" (Lareau & Horvat, 1999). The value of any form of capital must be understood in relation to the fields within which it operates. This is because field governs the "rule of the game," determining the value of particular forms of capital within a given context. As Bourdieu and Wacquant (1992, p. 101) noted, "capital does not exist and function except in relation to a field," In this respect, as Khan (2014) argues, capital is a resource that has both an amount and a trajectory, with its value being socially defined (by field/context).

There has been a proliferation of work that has developed and extended notions of capital further—both within and beyond the Bourdieusian framework, from more Bourdieusian—inspired conceptualizations of social capital (''resources based on connection, networks, and group membership: who you know, used in pursuit of favor and advancement,'' Skeggs, 2004, 17), to emotional capital (Reay, 2000) and linguistic capital (e.g., Stanton-Salazar & Dornbusch, 1995), through to social psychological notions of identity capital (e.g., Côté, 2002) and economics-based conceptualizations of human capital (Becker, 1993). It has also been argued that the extent of overlap between forms of capital can lead to them being treated synonymously (Robbins, 2000). In this paper, we make a case for the useful augmentation of existing Bourdieusian conceptualizations of capital, through the recognition of scientific forms of cultural and social capital (institutionalized and/or embodied through knowledge, consumption, credentials, and social networks), which as we explain below, have, to date, been absent or marginal within most Bourdieusian conceptualizations of capital.

The Relationship Between Capital and Educational Outcomes

There is a substantial literature illuminating the various ways, in which capital can be deployed to promote educational achievement and the reproduction of relations of privilege or domination. In particular, attention has been drawn to the ways in which the middle-classes often successfully combine economic, cultural, and social capital to produce academic achievement (Dika & Singh, 2002). For instance, through the interaction of capital and habitus, families may produce values, attitudes, expectations, and behaviors in children that promote academic attainment (e.g., Israel et al., 2001; Martin, 2009; Perna & Titus, 2005; Sandefur et al., 2006). Families may deploy their resources to purchase additional benefits and advantage, such as through private schooling, private tuition, and extensive enrichment activities for children (e.g., music lessons, swimming clubs, and additional language clubs) to enhance and distinguish their children within the field of education (Vincent & Ball, 2007). Research shows that middle-class families often engage in a sustained ''CV-building'' of their children from a young age, a process akin to ''hot housing'' that is designed to reproduce social privilege process, and which Annette Lareau (2003) terms ''concerted cultivation.'' Middle-class families may use their capital to act strategically and ''play'' the marketized education system, for instance through ''school choice'' (e.g., Ball, Maguire, & Macrae, 2000, 2003; Reay, David, & Ball, 2005). Families with higher levels of science-related resources (capital), have also been found to actively promote, develop, and sustain their children's science interest and aspirations, through the foregrounding of science within everyday family life, for instance, by providing science kits, watching science TV together, discussing science in everyday conversations, going to science museums, and so on (Archer et al., 2012). Research also suggests that capital can generate (more) capital. For instance, studies conducted within the field of informal science learning have found that museum visitors with higher levels of cultural capital can use this capital to leverage further capital and science learning from their visits (e.g., Archer, Dawson, Seakins, & Wong, in press, 2015; Dawson, 2014a, b).

While more prevalent among privileged groups, the deployment of capital to promote educational advantage is not solely restricted to the White middle-classes. Studies indicate how middle-class minority ethnic families (e.g., Archer, 2010; Lareau, 2003) and some working-class/minority ethnic families (e.g., Archer & Francis, 2007; Zhou & Lin, 2005) may also strategically use cultural, social, and economic capital to facilitate social mobility for their children through the production of educational attainment and strategic educational choices. Indeed, findings suggest that where minority ethnic families are able to draw on science-related capital, this may help promote and sustain science aspirations among minority ethnic young people, irrespective of their class background (Archer, DeWitt, & Osborne, in press, 2015).

Questions have been raised as to whether all forms of cultural capital are equally useful for producing social privilege. For example, a survey of 1,653 respondents aged 25 or over in the Netherlands by De Graaf, N. D., De Graaf, P. M., and Kraaykamp (2000) found ''parental reading behavior'' (e.g., frequency of reading, genre of literature), rather than parental participation in the ''beaux arts'' (e.g., going to art/history museums, classical music concerts, opera/musical performances), to be positively associated with children's higher educational achievements, such as university degrees. Sullivan (2001) reported similar findings in the context of 465 year 11 (typically age 16) English students and their attainments at GCSE (the national examinations taken at age 16, at the end of compulsory schooling). De Graaf et al. and Sullivan considered the practice of reading as central in children's development of linguistic, cognitive, and analytic skills. The authors argued that participation in ''beaux arts'' may only develop ''middle class'' communication skills, which appears to have little or no direct relationship with children's measurable

educational achievement. That is, while some forms of cultural capital (e.g., consumption of ''high'' culture) may have a symbolic social status, they may not translate as directly into the reproduction of educational advantage as compared to specific behaviors and practices, such as regularly reading with children.

Yet, as Skeggs (2004) reminds us, it is the process of legitimation of capital—rather than the actual content or form of the capital itself—which is key to the production of advantage/privilege. That is, within any given field, the most powerful forms of capital will be those whose intrinsic value can be most readily and precisely converted into symbolic forms that match the requirements of the field. For instance, families and young people may engage with science in a wide range of ways, but, from a dominant perspective, some forms of engagement (e.g., doing experiments, going to a science museum) may be valued as more ''scientific'' than others (e.g., cooking or ''tinkering''). Criticisms have been leveled at mainstream science for its tendency to privilege and legitimate only particular, narrow versions of ''expert'' scientific knowledge, marginalizing other forms of scientific knowledge, which may have ''use value'' but are often not accorded exchange value within dominant relations (see Irwin, 2001; Leach, Scoones, & Wynne, 2005; Michael, 2006; Wynne, 1991, 1996). As Claussen and Osborne (2013) argue, currently science education values and reflects the needs and values of the dominant scientific elite (privileging the production of the next generation of professional scientists for the ''pipeline,'' rather than seeking to produce scientifically literate citizens). They argue that school science also prioritizes academic language, which advantages dominant cultural groups and excludes or marginalizes others. Hence those who can engage with and ''do'' science in ways closest to the version of science that is privileged and taught at school are more likely to find that their capital translates into educational advantage. Hence, the value of capital is not fixed and changes according to who embodies it and the field within which it is located. For instance, Carlone's (2004) research exemplifies how the scientific ''ability'' of students on an advanced physics course was judged differently by teachers depending on the gender of student, with boys being typically described as being ''naturally talented'' at physics yet ''lazy,'' whereas the higher attainment of their female peers was explained away as due to the girls being ''hard working.''

Moving Beyond an Arts-Based Conceptualization of (Cultural) Capital: The Increasing Relevance of Science-Related Forms of Capital in Contemporary Society

Bourdieu conceptualized cultural capital as existing in three main states/formations: institutionalized (e.g., educational qualifications and credentials), embodied (socialized forms of knowledge, enduring dispositions of the mind and body), and objectified (e.g., cultural goods, artefacts).

Cultural capital has been predominantly framed by Bourdieu, and those who have since developed his work, in relation to the arts. For instance, in his classic work, *Distinction* (1984), in addition to collect data on educational qualifications, employment, and household composition and income, Bourdieu empirically determined cultural capital through the collection of data on:

- Arts-related aesthetic dispositions (e.g., survey items such as ''which of the following would make a beautiful photo?'' and questions about preferred painters; opinions on art, pp. 528);
- Aesthetic preferences (''taste'') and consumption (e.g., items about preferred musical works, composers, film directors, books, favorite singers; items about speech; activities, and pastimes; where respondents purchase furniture; items asking to select three adjectives/statements to describe a desired home interior, clothes that best express your taste; qualities most appreciated in friends; types of meal preferred to serve to friends)

- Leisure consumption and cultural practices (e.g., participation in spectator sports; car maintenance; DIY, stamp collecting, library membership, evening classes, historic places visits, cultural activities per week/year).

Replications and contemporary updating of Bourdieu's work, such as the very useful work by Bennett et al. (2009) have also predominantly explored cultural capital, ''taste'' and consumption through the lens of the arts, albeit while pointing to the emergence of a broader cultural spectrum and forms of consumption, for instance combining both traditional ''high'' culture (e.g., opera) and more contemporary/emergent forms of culture, such as hip hop.

We propose that a rethinking of Bourdieusian arts-based forms of capital is timely, not least because, as Prieur and Savage (2013) write, ''Given the scale of technological and social change, it would be remarkable if Bourdieu's account of cultural capital continued to exist in an unchanged form'' (p. 249). Indeed, as Prieur and Savage (2013) argue, ''the meaning of cultural capital may be changing, so that it is different to that which he [Bourdieu] analyses in *Distinction*'' (p. 247). As Savage (2010) discusses, since Bourdieu wrote *Distinction*, there have been radical advances in science and technology, which have increased their importance within contemporary society and affected all areas of cultural life and practice:

> We suggest that these shifts should lead us to understand contemporary cultural capital less through its association with the traditional canon of humanities orientated high culture, but more through an association with scientific expertise, technology, information systems, and more generally, the capacities to handle methods of various kinds (Prieur & Savage, 2013; p. 261).

Moreover, Prieur and Savage argue that ''scientific and technical forms of expertise [in Bourdieu's arts-based] model embody different kinds of claims to legitimacy and superiority'' (Prieur & Savage, 2013; p. 261).

We suggest that science-related resources should be legitimately considered as important contemporary forms of capital, which play a role in the production of social relations of advantage/disadvantage. This is not least because they command a high symbolic and exchange value within contemporary society. For instance, across numerous international contexts, science is widely framed as a national priority within government policy and rhetoric (e.g., CBI, 2012; Treasury, 2011; Perkins, 2013). Scientific industries are positioned as closely linked to national economic competitiveness, and the need to widen and increase the level of science-qualified and scientifically literate individuals within society is routinely cited as a priority to meet the needs of the ''knowledge economy'' (e.g., CBI, 2012; CiHE, 2009; UKCES, 2013), under-lining the exchange value of scientific forms of cultural capital. Moreover, science disciplines enjoy a high social and cultural status in society. As Claussen and Osborne (2013) argue, science qualifications command a strategic value in educational and labor markets. At an individual level, it has also been argued that the scientifically literate, ''science citizen'' (Irwin, 2001) is better placed to play an active role in modern society. For instance, knowledge and understanding of scientific concepts, processes, and ''how science works'' can enable individuals to interpret the scientific information that they come across in their everyday lives, make better informed choices (e.g., around personal health) and enable them to access, understand, respond to and even contribute to shaping scientific developments in society. It has been argued that science is a powerful and pervasive aspect of people's lives and that the possession (or lack) of scientific knowledge and resources can translate into increased (or decreased) social agency/power (e.g., Michael, 2006). Research by Savage and colleagues (2001) also suggests that science qualifications

can command a wage premium (e.g., Greenwood, Harrison, & Vignoles, 2011), and that a person's chances of being in an elite social class are higher for those with a science degree than those with an arts degree. In other words, science qualifications may confer a personal instrumental benefit alongside a cultural and social advantage to those who possess them.

Bourdieu was not entirely ignorant or dismissive of such changes. Indeed, in his later work, notably *The Social Structures of the Economy* (2005), Bourdieu acknowledged the existence of ''technical'' capital—although arguably these ideas were never really fully expanded nor were they integrated into his arts-based conceptualization of cultural capital. For Bourdieu, technical capital is ''a particular kind of cultural capital'' (p. 29) which can be built up through schooling, vocational qualifications and the acquisition of ''hands on skills'' (''the capital of the DIYer,'' *ibid*) and which Bourdieu links to particular ''ascetic dispositions.'' Bourdieu also mentions a range of technical forms of capital, including technological, commercial, financial, bureaucratic, and organizational capital. For instance:

> Technological capital is the portfolio of scientific resources (research potential) or technical resources (procedures, aptitudes, routines, and unique and coherent know-how, capable of reducing expenditure in labor or capital or increasing its yield) that can be deployed in the design and manufacture of products. (Bourdieu, 2005; p. 194).

He understands these ''technically-based'' forms of capital as being ''acquired more quickly by more rationalized, formalized procedures—such as the statistical survey [...] and mathematical modelling ...'' (*ibid*, p. 117). Yet, while Bourdieu shows some awareness that scientific, technical, and mathematical skills may be useful (and carry exchange value) within particular fields (for instance in relation to the context of home ownership, which he explores in *The Social Structures of the Economy*), the concepts remain comparatively undeveloped in his work as a whole. Indeed, only a few subsequent studies have sought to expand these notions of technical capital. For instance, Emmison and Frow (1998) argue that, in contemporary western society, being knowledgeable about, and positively predisposed toward, information technology should be considered a form of capital because it can advantage those families that possess these attributes.

In his final writing, Bourdieu (2004/2001) made brief reference to the existence of scientific capital, which he defined as follows:

> Scientific capital is a set of properties which are the product of acts of knowledge and recognition performed by agents engaged in the scientific field and therefore endowed with the specific categories of perception that enable them to make the pertinent distinctions, in accordance with the principle of pertinence that is constitutive of the *nomos* of the field [...] Scientific capital functions as a symbolic capital of recognition that is primarily, sometimes exclusively, valid within the limits of the field (although it can be converted into other kinds of capital, economic capital in particular). (Bourdieu, 2004/2001; p. 55).

In other words, Bourdieu conceptualized scientific capital as symbolic capital in the form of scientific authority, residing either within particular, high status scientists (the ''weight'' of their scientific authority) or as power over the scientific field (which may be exercised by governments, organizations, and other agencies, not just scientists).

> ... the field is a site of two kinds of scientific capital: a capital of strictly scientific authority, and a capital of power over the scientific world which can be accumulated through channels that are not purely scientific ...'' (*ibid*. p. 57).

However, he never managed to develop the concepts beyond this couple of brief pages.

In this paper, we suggest that there may be a value in taking a broader view of scientific forms of capital, going beyond the individualized, knowledge and skills-based ''know-how'' encapsulated by Bourdieu's notion of technical capital and taking a broader perspective than his somewhat narrow, authority-based conception of scientific capital. As we discuss next, we seek to stretch the concept of science capital so that it both includes, and goes beyond, scientific literacy, to also encompass forms of science-related social capital.

Developing the Concept of Science Capital

In an earlier project, the ASPIRES study, which explored children's science and career aspirations (age 10–14), we noticed that children whose families possessed more science-related resources (such as parents with scientific qualifications and/or careers) seemed more likely to aspire to a science-related career and/or plan to study at least one science post-16 (e.g., Archer et al., 2012; Archer, Dewitt, & Willis, 2014). Longitudinal tracking within the ASPIRES project also suggested that these patterns became stronger over time. We proposed the term ''science capital'' as an analytic concept to help make sense of the patterns:

> ... a conceptual tool for understanding the production of classed patterns in the formation and production of children's science aspirations. We propose that ''science capital'' is not a separate ''type'' of capital but rather a conceptual device for collating various types of economic, social and cultural capital that specifically relate to science—notably those which have the potential to generate use or exchange value for individuals or groups to support and enhance their attainment, engagement and/or participation in science (Archer et al., 2014).

We felt that the concept had some value for helping to explain the differential patterns of aspiration that we were observing, but we also recognized that it remained theoretically underdeveloped and weakly specified (e.g., are all science-related resources equally valuable/influential? What other sorts of science-related forms of capital might shape science aspirations?) The current *Enterprising Science* project was developed as a means to attempt to further flesh out the concept of science capital and to see whether it could be developed methodologically, into a generalizable tool that others might also use. This paper reports our initial attempts to conceptualize and measure science capital.

Our starting point for the current work—in which we seek to develop a first iteration of an index of science capital—is the belief that it may be interesting and useful (both conceptually and in practice) for the science education community to be able to ''measure'' and determine levels of science capital at scale. This exercise may be of interest not only to researchers, but also for the myriad of science education organizations which deliver programs and interventions designed to engage and inspire young people to better understand and/or continue with science. In other words, our attempts to define and measure science capital are as much driven by a theoretical desire to explore the parameters of capital, as by a wish to help science educators and delivery organizations to be able to delineate what they are seeking to change through their practice and why and to assess to what extent they have been successful, or not, in these efforts. For instance, we hope that this work will contribute to efforts to understand whether a given scheme or intervention has had any effect on participants in terms of their identification, engagement, or aspirations to participate in, science—and their capacity to do so. Importantly, we see the index as a potential complement to (not a substitute for) qualitative research, providing breadth and the ability to assess patterns at scale to sit alongside the equally important in-depth perspective provided by qualitative approaches.

Drawing across the literature outlined in the previous sections, our understanding of science capital is broader than (and substantively different in approach from) existing instruments which seek to measure how much people know about science and/or how science works (e.g., Bauer, Allum, & Miller, 2007; Ipsos Mori Public attitudes to science surveys, Relevance of Science Education questionnaire, e.g., Sjøberg & Schreiner, 2010) in that it goes beyond science-related cultural capital and knowledge, and beyond attitudes to science, to also encompass science-related social capital and behaviors and practices. Our first iteration of a theoretical model of science capital combines the following: scientific forms of *cultural capital* (scientific literacy; science dispositions, symbolic forms of knowledge about the transferability of science qualifications), science-related *behaviors and practices* (e.g., science media consumption; visiting informal science learning environments, such as science museums), science-related forms of *social capital* (e.g., parental scientific knowledge; talking to others about science). These are now discussed in turn.

Science-Related Cultural Capital

Scientific Literacy. There are many competing definitions of scientific literacy (e.g., see Holbrooke & Rannikmae 2009; Norris & Phillips 2003) but here we draw on broad notions of scientific literacy, incorporating scientific knowledge, skills, and an understanding of how science ''works'' and the ability to use and apply these capabilities in daily life for personal and social benefit. We consider scientific literacy to be a vital (and essential) subcomponent within a broader index of science capital yet, as discussed below, we also see science capital as going beyond scientific literacy. We are influenced by Claussen & Osborne's argument that the most (intrinsically and extrinsically) valuable forms of scientific cultural capital are the aspects of scientific literacy that concern

> ...the disciplinary habits of mind which the practice of science develops—that is, the analytic ability to make logically deductive arguments from simple premises, to identify salient variables, patterns in data, numerical fluency, and the critical disposition of mind that is the hallmark of the scientist (Claussen & Osborne, 2013; p. 68).

In designing survey items to capture scientific literacy, we used a mixture of self designed items and items from sources such as Bauer et al. (2007); Ipsos MORI ''Public attitudes to science'' survey (2011).

Scientific-Related Dispositions/Preferences. Our delineation of science-related forms of cultural capital also includes items that seek to measure science dispositions and preferences, such as the valuing of science in society (e.g., ''it is useful to know about science in my daily life''). Our rationale for including this dimension comes from Bourdieu's (1984) original quantitative measure of cultural capital from *Distinction* and Bennett et al.'s (2009) UK replication/updating and critique of this work—namely that artistic aesthetic dispositions are a key component of an arts-based cultural capital, hence we might expect there to be a similar rationale for including a component that measures the extent of science-based valuing/dispositions. Moreover, research conducted in Australia by Lyons (2004) found that students who went on to study post-compulsory physical sciences tended to have supportive parents or family members with favorable views towards science education. To develop items for measuring science-related dispositions, we combined self-designed items with items on attitudes to science and scientists and views of school science and teachers from ASPIRES surveys (e.g., DeWitt et al., 2011; DeWitt, Archer, &

Osborne, 2014), the Public Attitudes to Science survey (2011); the BIS learner panel survey on pupils' attitudes to science.

Symbolic Knowledge About the Transferability of Science in the Labor Market. This is a specific component which seeks to ascertain the extent of the respondent's appreciation of the transferability of science qualifications in the labor market (e.g., "a science qualification can help you get many different types of job"). This component seeks to tap what we consider to be a particular form of symbolic scientific cultural capital, which our previous qualitative work suggested seemed to be related to differential patterns of aspiration and was unevenly spread across different families (Archer et al., 2012). As Claussen and Osborne (2013; 69) explain:

> ...when making decisions about future educational pathways and possible careers, it is a knowledge of the forms of institutionalized cultural capital that count that play a key role (Adamuti-Trache & Andres, 2008). However, students from different socioeconomic backgrounds have access to "unequal knowledge about courses and the careers they lead to [and] the cultural models which associate certain occupations and certain educational options" (Bourdieu & Passeron, 1979, p. 13). Such knowledge is then a valuable form of cultural capital, for "knowing the current and future worth of various types of academic credentials is key in the transmission of cultural capital from parents to their children" (Adamuti-Trache & Andres, 2008, p. 1576)."

This view is also supported by empirical findings from the UPMAP project (e.g., Mujtaba & Reiss, 2014) which found that one of the strongest predictive factors of a student's plans to take physics or mathematics post-16 is the extent to which they think it will be useful for their future career. Similarly, Brown, B. A., Brown, C. A., and Jayakumar (2009) suggest that an understanding of the extrinsic value of science qualifications can be considered a "high" form of cultural capital—which is unevenly socially spread due to inequities between families and schools. In other words, we treat this component as capturing the distribution and possession of culturally valued forms of knowledge which can be strategically used to their advantage by those who possess it. For these items, we drew on self-designed items and some items from the ASPIRES surveys.

Science-Related Behaviors and Practices

Consumption of Science-Related Media. This component seeks to capture the extent to which respondents consume science through various forms of media, such as via science-related TV programs, books/magazines, and online. For instance, drawing on PISA data from Hong Kong adolescents, Ho (2010) found that watching TV programs about science, reading books on scientific discovery and watching, reading, or listening to science fiction were found to be highly effective activities for promoting children's science achievement and self-efficacy. For these questions, we drew on items from a range of pre-existing surveys, including the Wellcome Monitor survey and the ASPIRES surveys.

Participation in Out-of-School Science Learning Contexts. This component seeks to capture the extent to which respondents participate in informal science learning contexts, including designed spaces (such as science museums, zoos/aquaria), community spaces (such as after-school science clubs), and everyday contexts (such as doing experiments/using science kits at home; fixing/building things at home; going on nature walks; programming computers). Our rationale for this component is that informal science learning contexts may provide forms of science capital (e.g., enhanced scientific literacy and/or dispositions) through the science learning

opportunities they provide. Evidence also suggests that these forms of participation may be socially structured, for instance, the Ipsos MORI Public Attitudes to Science survey (2011) found that in the 12 months preceding the study, half the public (50%) had engaged in at least one of the science activities asked about in the survey. The most popular of these were visiting a zoo (26%) or science museum (22%). But whereas zoos may attract visitors from across the class spectrum, evidence suggests that the visitor profile for science museums tends to be overwhelmingly white and middle-class (Bell, Lewenstein, Shouse, & Feder, 2009; Department for Culture Media and Sport, 2011; Falk et al., 2012; IPSOS MORI Public Attitudes to Science survey, 2011; OECD, 2012). This suggests that ''taste'' and consumption of science-related phenomena may be relevant components within measures of social class and capital. We drew largely on items from the Wellcome Monitor survey and the ASPIRES surveys for this component.

Science-Related Social Capital

Knowing Someone Who Works in a Science Job. This component seeks to capture the science-related social capital (social contacts and networks) that a respondent might have. As Bourdieu's conceptual framework proposes, social capital is a key form of capital. Moreover, our previous work found that children aged 10–14 who have close family members who work in a science-related job are far more likely to aspire to science-related careers than those whose parents do not work in these fields (e.g., Archer et al., 2012). The UPMAP study (Mujtaba & Reiss, 2014) also found that being motivated and encouraged to study maths or physics by a ''key adult'' (usually a teacher or family member) over time was an important predictor of a student's decision to study physics or math post-16. Using a mixture of self-designed items and those from Bourdieu and the Office for National Statistics (2002), we extended these questions to explore a range of potential social contacts (parents, family members, neighbors, and friends).

Parental Science Qualifications. Ideally, we wanted to explore the range, nature, and extent of parental science qualifications[1] because we hypothesize that parental post-16 STEM qualifications might be an important source of capital for young people. We attempted to capture parental science qualifications in previous pilot versions of the survey. However, students struggled to answer this question and response rates for these items were very low—perhaps due the age of students and because few seem to know what qualifications (and in what subject areas) their parents possess. Hence, although parental science qualifications remain in our conceptual model of science capital, we are yet to find a reliable way to capture these among school students at sufficient scale within our actual survey.

Talking to Others About Science. This component seeks to capture the frequency and number of people whom students talk about science in their daily lives (e.g., parents, teachers, family members, friends, extended family, and scientists). Lyons (2006) found that parents using scientific discourse and talking about science at home is form of scientific cultural capital that can advantage students at school. For these items we extended existing items from the [name] surveys.

Dependent Variables. As discussed above, our conceptualization of science capital comprises various subsets of cultural and social capital which form a Bourdieusian perspective, we would see as mediated by field and as interacting with personal and family habitus and wider forms of capital to create a set of science-related dispositions within the individual. For this iteration of the survey, we specified our dependent variables as: future science educational and occupational aspirations (''future science affinity'') and the sense of whether science is ''for me,'' or not (''science identity'').

Future Science Affinity. This variable seeks to capture the extent to which the respondent aspires to continue with science in the future, both educationally (e.g., studying one or more sciences post-16) and occupationally (e.g., aspiring to a science career). For these items we drew largely on items from the [name] survey and combined these with self-designed items.

Science Identity. This variable seeks to capture the extent to which someone recognizes themselves and/or is recognized by others as being ''scientific.'' It draws on Carlone and Johnson's (2007) conceptualization of science identity as comprising both self-identification and recognition by others (e.g., ''other people think of me as a science person'') and findings from Carlone and others which show that science identity is important for young people's science engagement and learning (e.g., Calabrese Barton & Tan, 2010; Calabrese Barton, 2014). This variable is also informed by Mujtaba and Reiss' (2014) findings that motivation from others is a key factor promoting post-16 participation in Physics and math (e.g., ''my teacher has specifically encouraged me to continue with science after GCSE''). This variable draws on a range of self-efficacy and identity-based items from the UPMAP and [name] studies.

Other Items. We also included a range of demographic and background items in the survey, such as ethnicity, gender, social class (via the proxy of general cultural capital), parental occupation, set (track) in school subjects, in order to be able to investigate patterns in the possession of science capital and potential interactions between variables (See supplementary materials for full survey.)

In sum, our conceptual model proposes that scientific forms of cultural capital (comprising scientific literacy, a cultural appreciation of science, particular symbolic forms of capital regarding the transferability of science qualifications), behaviors and practices (including consumption of science-related media and out-of-school science learning contexts) and social capital (knowing people with science-related jobs, qualifications, talking to others about science) can have a significant use-value and/or exchange-value within society. We hypothesize that the possession of science capital will influence a young person's science-related educational and occupational aspirations and their science identity. We also suggest that these forms of capital may also be as important markers of social class as arts-based forms of capital. Moreover, we suggest that developing a better understanding of young people's ''science capital'' (and how it may be leveraged, generated, and differentially embodied and valued across time and different learning contexts) may be a useful and valuable part of ongoing efforts to improve agency, social mobility, and social justice science education work with underserved communities. In other words, we are interested in the various ways that science might constitute a form of capital that can be activated and mobilized through different learning contexts to reinforce, perpetuate, or even challenge social inequalities

Having set out our conceptual and methodolological operationalization of science capital, we now discuss our findings, namely how young people's science career aspirations and their science identities might be influenced (or not) by their possession of science capital. Drawing on survey data from the first phase of a new 5 year project (Enterprising Science), we present our attempts to develop an instrument for ''measuring'' science capital and discuss preliminary findings from our piloting of the instrument. We ask: what might the components of a ''science-based'' measure of cultural capital include? How might we ''measure'' science capital? What light might a science capital analytic lens shed on our understanding of young people's science aspirations and the role played by social inequalities?

Testing Out the Index: Participating Students and Schools

Two pilot runs of the questionnaire were conducted with intervention and comparison schools[2] for the wider project: 1,463 students in Summer 2013 and 6,000+ students in Autumn 2013[3]). In this paper, the analysis focuses on data from a third iteration of the survey, conducted with a more nationally representative sample of 3,658 students in Spring/Summer 2014. These students were drawn from 45 schools across England. Of these, 3,431 responded to the final question—a dropout rate of 6.2%, (a considerable improvement on the Autumn survey, in which the drop-out rate was 21%).

Geographically, the schools came from across England. More specifically, six were from the Southwest, nine from the Southeast, seven from the Northeast, five from the Northwest, three from the East Midlands, three from the West Midlands, three from the East of England, four from Yorkshire and the Humber, and five from London. In the UK, secondary schools fall into a variety of types, depending on how they are governed and whether they finish at age 16 or 18. The schools in our survey represented this variety of types (eleven schools were 11–16 academies[4], eleven were 11–18 academies, eight were 11–16 comprehensives, five were 11–18 comprehensives, six were independent (privately funded) schools, two were grammar[5] schools, one was a junior high school, and one was a middle school, age 9–13). Ten schools were Christian faith schools. Five schools were all girls, two were all boys, and the remainder were mixed. Schools also represented a range of achievement on national standardized tests and range of proportions of students eligible for free school meals (1.3%–60.5%).

Overall, there were 1,153 (31.5%) students in Year 7, the first year of secondary school when students are aged 11/12; 891 (24.4%) in Year 8, aged 12/13 years; 820 (22.4%) in Year 9, aged 13/14 years; and 794 (21.7%) in Year 10, aged 14/15 years. Of the participating students, 1,988 (54.3%) were female and 1,670 (45.7%) were male. A total of 74% of participating students self-identified as White, 8% as Asian, 6% other/mixed, 4% Black, 1% Chinese or other East Asian, and 1% Middle Eastern (and 6% ''prefer not to say'').

We also gathered data on parental occupation, which was used in analyses of previous surveys as a proxy for their socio-economic classification or ''social class'' (while recognizing that social class is a complex and contestable concept). However, students had considerable difficulty answering this question despite piloting it over multiple years, so drawing on previous surveys (DeWitt et al., 2011, 2014), we calculated a measure of ''cultural capital'' (based on parental university attendance, leaving school before 16, number of books in the home, and visits to museums), and created five cultural capital groups, which had the following percentages of students within them: very low (5%), low (26%), medium (28%), high (20%), and very high (21%)[6].

Students were asked to report which sets (if any) they are in at school for science, math, and English. Science set (track) membership was as follows: one of the top sets: 44%; one of the middle sets: 29%; one of the bottom sets: 7%; there are no sets for this subject/in my school: 20%.

Analyses

We began by conducting reliability and validity analyses, using principal components analysis (PCA) and Cronbach's alpha to determine the unidimensionality and internal validity of the survey scales. Principal components analysis revealed the following nine resolvable components:

- Everyday science (media) engagement;

- Future science job affinity (aspirations);
- ''Informal'' Science activities;
- Parental attitudes and practices (including attitudes to science);
- Science teachers and lessons;
- Self-efficacy in science;
- Utility of science qualifications;
- Valuing museums/museum experiences;
- Valuing science and scientists.

Cronbach's alphas for these components ranged from 0.729 to 0.854, all within an acceptable range for attitudinal instruments. For details of items comprising the components, as well as their corresponding alphas, please see Appendix 1 and 2.

The components emerging from the PCA were then used to create composite variables. The variables were calculated by scoring each student's responses as follows: Strongly disagree = 1, disagree = 2, neither = 3, agree = 4, and strongly agree = 5. For items about ''how often,'' never = 1 and very frequently = 5. Scores were then added together and divided by the number of items in the variable. (The only exceptions are negative items, which were reverse-scored before the mean was calculated). Table 1 details the means for each composite variable.

Calculating a Science Capital "Score"

In order to calculate a science capital ''score'' for each student, it was necessary to identify a dependent (or outcome) variable, to which science capital could be compared. In other words, if a student has high science capital, what might we expect them to score highly on? To assist us in this, we drew on two main bodies of work: first, we drew on qualitative findings from our previous ASPIRES work, which indicated that students whose families possess higher levels of science qualifications, interest, science-related jobs, and high levels of scientific literacy, are more likely to aspire to continue with science post-16 and maintain STEM aspirations over time. In this respect, a measure in some way connected with science aspirations seemed most plausible as a measure of something that we might expect to increase as science capital increases. If we had been constructing an index for use with adults, we might reasonably suggest using a measure of post-16 science participation and/or a more robust measure of scientific literacy or understanding of ''how science works.'' But given that our current sample is drawn from Years 7–10 (age 11–15), these measures were not possible. Consequently, we judged the composite variable ''future science job

Table 1
Means and standard deviations for composite variables

Variable	Mean	SD
Future science job affinity (aspirations)	2.50	0.888
Valuing science and scientists	3.53	0.778
Parental attitudes and practices (including attitudes to science)	3.56	0.822
Utility of science qualifications	3.85	0.861
''Informal'' science activities	2.36	0.827
Everyday science (media) engagement	2.51	0.921
Valuing museums/museum experiences	3.01	1.09
Science teachers and lessons	3.44	0.867
Self-efficacy in science	3.15	0.831

affinity'' (as discussed above from the principal components analysis) to be a reasonable candidate for an outcome measure. This measure consisted of four items (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). Second, we drew on literature pertaining to science identity, particularly the notion that identification with science involves not only a personal identification with science, but also a sense that one is recognized (as ''a science person'') by others. For this, we also added a fifth item to the outcome measure: ''Other people think of me as a science person.'' A further principal components analysis indicated that doing so was justified as the five items together could form a single component. That is, we base our analyses on the proposition that students with higher levels of science capital are more likely to aspire to continue with science post-16 and are more likely to feel that others recognize them as being ''science people.'' Hence students with higher levels of science capital should score more highly on this measure, while those with lower science capital should score less highly. This combined measure was utilized as the dependent variable (outcome measure) for our subsequent investigations regarding which items should form part of our index of science capital.

We then divided scores on this outcome measure into three groups—corresponding to high, medium, and low scores on that variable. The rationale for this was that students with higher levels of science capital would be more likely to fall into the ''high'' group and those with lower levels to fall into the ''low'' group. We then employed logistic regression analyses to identify which survey items were most predictive of whether a student would fall into the high or low grouping.

The logistic regression identified 14 questions: 12 individual items plus two larger questions (concerning who students speak with about science and who they know who has a job using science) as the strongest predictors of whether a student would fall into the high or low group on the outcome variable (future science affinity plus recognition). The 12 individual items are:

- 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 of my parents think science is very interesting.
- One or both of my parents have explained to me that science is useful for my future.
- I know how to use scientific evidence to make an argument.
- 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?
- How often do you go to after school science club?
- 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.

Next, these items were used to create a composite measure of science capital, which could be used in further analyses (such as the multivariate analyses incorporated below). Items were 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 neighbor who worked in science). The scores were then summed across items, to generate a single science capital score for each young person. In order to assess the utility and reasonableness of the conceptually-derived weightings, we also compared these with a weighting derived from the logistic regression (which indicated, which items were stronger predictors of the outcome

variable). The distribution of scores was virtually identical, giving us confidence in our use of the original, theoretically-derived weighting system.

Students' science capital scores fell along a scale from 0–105 with a mean of 43.65 and a standard deviation of 15.45. Finally, we used this distribution of science capital scores to divide students into three groups—possessing low, medium, and high levels of science capital. We decided to simply group these into thirds, for conceptual ease, defining low science capital as the bottom third of scores on the 0–105 scale (0–34), medium science capital scores as 35–69 and high science capital scores as 70–105 (the top value). These resulted in the following percentages of students within each of the groupings:

High science capital: 5%

Medium Science Capital: 68%

Low Science Capital: 27%

Hence ''high science capital'' refers to those who should have a good level of scientific literacy and access to plentiful, high quality, science-related cultural, and social resources. These students are confident in their scientific skills and are recognized by others as being ''a science person.'' They do science-related activities in their spare time and have family/friends (particularly parents) who work in science-related jobs. In comparison, ''low science capital'' refers to those students with lower levels of scientific literacy, less confidence in their skills and abilities, less engagement with out of school science activities, and whose family/social networks tend not to include people with science-related jobs.

Patterns in Level of Science Capital by Social Characteristics

As detailed above, the majority of our sample (68%) are classified as having ''medium'' levels of science capital. Over a fifth (27%) have low science capital and just 5% have high science capital. As we now discuss, the likelihood of a student having high, medium, or low science capital is not a matter of chance, but is strongly patterned by social characteristics. In particular, the likelihood of a student having a particular level of science capital differs significantly by their cultural capital, gender, ethnicity, and appears, to some extent, to align with school attainment (as measured by the proxy of science set/track). As we shall also discuss, levels of science capital appear correspond to the likelihood of being seen by others as being a ''science person,'' student aspirations and post-16 plans.

Cultural Capital. Science capital appears to align closely with cultural capital, with a one-way analysis of variance (ANOVA) showing significant differences among the three groups $F(43,653) = 245.79$, $p < 0.001$), such that the higher a student's level of cultural capital, the higher their level of science capital (means science capital scores for the different cultural capital (cc) groupings were as follows: very low = 27.72, low = 36.63, medium = 43.23, high = 46.92, very high = 53.94.) Students with very low cultural capital are proportionally overrepresented among students with low science capital (14% vs. 5% of students in the overall sample). Likewise, students with very high cultural capital are proportionally overrepresented among students with high science capital (58% vs. 21% in the sample).

Gender. Higher levels of science capital appear to be concentrated more among boys. According to a one-way ANOVA, boys had significantly higher means on the science capital

variable (44.39) than girls (43.04) $F(13,656) = 6.94$, $p < 0.01$. Likewise, the proportion of boys was higher in the high science capital group, relative to their representation in the overall sample (54% vs. 46%).

Ethnicity. Science capital appears to vary significantly between ethnic groups $F(63,651) = 9.07$, $p < 0.001$. For instance, the science capital mean scores for different ethnic groups were: South Asian = 47.58, Black = 43.04, Chinese/East Asian = 45.52, Middle Eastern[7] = 54.13, White = 42.96, Other ethnicity = 47.25, prefer not to say = 42.02). South Asian students are proportionally over-represented in the high science capital group (14% vs. 8% in the overall sample). Although White students were numerically the largest ethnic group within the high science capital group, proportionally they were actually under-represented (63% White students had high science capital vs. 74% White students in the overall sample).

School Set for Science. Levels of science capital appear to vary significantly according to whether a student is in a top, middle, or bottom set and for those in schools that do not set for science. Significant differences $F(33,654) = 111.00$, $p < 0.001$ (one way ANOVA) were found among students according to which set they reported being in at school for science. Students in top sets (and those whose schools do not set for science) had higher mean science capital scores than those in middle and bottom sets (means for top sets = 47.29, middle = 39.80, bottom = 32.46, no sets = 45.32). Students in top sets are over represented among those with high science capital (60% vs. 44% in whole sample). Conversely, students in bottom sets are overrepresented among those with low science capital (15% vs. 7% of sample). Students who are not set for science were the most evenly spread group (their location in low or medium science capital groupings being very similar to overall sample percentages). If anything, these students were slightly over-represented in the high science capital group (23% vs. 20% in whole sample).

Post-16 Science Aspirations. Science capital also appears to have a significant relationship to student aspirations and post-16 plans. As detailed in Table 2, overall, 19% of students said that they would like to study a science subject at university; 23% would like to study one or more sciences at A level, 15% would like to study some science after GCSE but not A level; 19% do not want to study any science after GCSE (25% said none of these/don't know). Significant differences were found between the science capital means for students aspiring to the various different future science study paths $F(43,426) = 314.96$, $p < 0.001$. The means for these groups were: University = 54.00, A-level = 50.83, after GCSE but not A-level = 45.66, no post GCSE science = 34.22, none of the above/don't know = 35.20.

Table 2
Student post-16 plans by level of science capital (% students)

	Overall sample	High science capital	Medium science capital	Low science capital
Would like to study a science subject at university	19%	50%	22%	6%
Would like to study one or more sciences at A Level	23%	37%	28%	9%
Would like to study some science after GCSE but not A Level	15%	7%	17%	10%
Do not want to study any science after GCSE	19%	2%	14%	34%
None of the above/don't know	25%	5%	19%	42%

Table 3
Students' responses to a yes/no question about working in a science-related job in the future by science capital group

Science capital group	Percentage responding "yes"	Percentage responding "no"
High	20.1% (195 students)	79.9% (777 students)
Medium	61.0% (1391)	39.0% (891)
Low	93.1% (175)	6.9% (13)
Total sample	51.2% (1761)	48.8% (1681)

The percentage of students agreeing "I would like to study a science subject at University" also varies considerably according to level of science capital, with high science capital students significantly proportionally over-represented and far more likely to aspire to study science at University level (50%). Students with low science capital are proportionally over-represented among those not wanting to study any science after GCSE (34%).

Unsurprisingly, these trends were also found within students' aspirations in relation to science-related future jobs. As can be seen from Table 3, the sample were roughly equally divided as to whether they wanted to work in a science-related job in the future (51%) or not (49%). Within these, high science capital students were massively over-represented among those aspiring to work in science-related jobs (93%) and conversely low science capital students were over-represented among those *not* aspiring to such jobs (80%). That is, only 20% of students with low science capital agreed with the statement "I would like to work in a science-related job in the future."

A significant difference was also found between the science capital means scores of those who want to work in a science related job in the future ("yes" = 51.44) and those who do not ("no" = 35.51)[8]. This suggests that even before they complete their GCSEs, students with low science capital already seem to perceive science as "not for me." In other words, a student's level of science capital appears to align predictably with whether they see post-16 science (post-compulsory plans regarding the study of science and working in science or STEM-related jobs in the future) as being "for me," or not.

Science "Identity". Our analysis also reflected that on the individual item "other people think of me as a science person" (which was part of the indicator variable against which the science capital variable was constructed), the percentage agreement differed hugely by science capital group. The percentages agreeing/strongly agreeing with this item in each of the three groups are as follows: Low science capital: 3.3%; Medium science capital: 22.7%; High science capital: 79.5%. That is, students with high science capital are overwhelmingly secure in their science identity, feeling that this identity is clearly validated by others. Hardly any students with low science capital feel that others see them as a science person.

Self-Efficacy. We also calculated a measure of self-efficacy to get an approximation of whether science capital relates to self-efficacy, or not. The three items included in this measure are: I am confident giving answers in science lessons; I know quite a lot about science; I don't think I am clever enough to study any of the sciences at A-level (reverse scored). The means for this variable by science capital grouping were: low = 2.7037; medium = 3.4825; high = 4.2275, which were significant $F(23,458) = 293.68$, $p < 0.001$ (one way ANOVA). In other words, students with high science capital are significantly more confident in their science abilities than students with medium or low science capital (and students with medium science capital are more confident in their abilities than those with low science capital).

Summary and science capital pen portraits

Overall a picture emerged in which the likelihood of a student having a particular level of science capital appears to relate to their cultural capital, gender, ethnicity, and science set. Students with high, medium, or low levels of science capital also seem to have very different post-16 plans (regarding studying or working in science) and different levels of self-efficacy in science. They also vary dramatically in terms of whether they feel others see them as a ''science person.'' We developed the following ''pen portraits'' as an illustrative tool to help convey these patterns:

High Science Capital (5% of Students Surveyed). Our survey shows that only a small proportion of students surveyed had high science capital. High science capital students are more like to be male, Asian (and other/mixed) and come from the most socially advantaged homes, with very high levels of cultural capital. They are more likely to be in the top set for science at school and are interested in a science-related future career (e.g., 93% of high science capital students aspire to a science-related job, compared to 51% of the whole sample). These students are much more interested than other students in studying a science subject at university (50% of high science capital students vs. 19% of the whole sample) or at least to A-level (37% vs. 23% of the whole sample). They are confident in their science abilities and overwhelmingly secure in their public identity as a ''science person.''

Medium Science Capital (67.6% of Students Surveyed). The majority of students surveyed were categorized as having medium science capital. They are largely representative of the wider sample in terms of gender, ethnicity, and cultural capital (although slightly more likely to have medium/higher levels of cultural capital and less likely to have lower levels of cultural capital). They are marginally more likely to report being in the top set at school compared to the overall sample. They are slightly more likely to be interested in pursuing science at A level and a science-related job compared to the overall sample, but are less interested in future science-related jobs than those with high science capital (and are more interested than those with low science capital). They have medium levels of confidence in their abilities but are not that secure in their science identity (less than a quarter of medium science capital students feel that others see them as a ''science person'').

Low Science Capital (27.2% of Students Surveyed). Over a fifth of the students surveyed fell into this category. These students were more likely to be female and to come from less socially advantaged backgrounds (possessing low or very low levels of cultural capital). They are more likely to be in the middle or bottom sets for science at school. They are noticeably less likely than other students to want to work in a science-related job in the future (20%, as compared with 51% of the whole sample). They are far less likely to want to pursue science post-16—only 6% aspire to study a science subject at degree level and just 9% are interested in studying a science subject at A level. Students with low science capital are far more likely to want to drop science after GCSE (34% vs. 19% of the whole sample). They have little confidence in their science abilities and overwhelmingly do not feel that others see them as a ''science person.'' These young people may find science interesting, but are particularly unlikely to consider post-16 science or science careers as being ''for me.''

Discussion

In this paper, we have detailed our ongoing conceptual modelling of what science capital ''is'' (how it might be theorized) and how it might be ''measured'' via a survey instrument. We have also presented some emergent findings from our analyses of a survey conducted with a nationally

representative sample of 3,658 students in England aged 11–15 to illustrate the potential scope, and workings, of the concept and the survey instrument. Our aim is to contribute to knowledge about how science related resources are unevenly socially spread within society—and the implications of this uneven spread for youths' access to, participation in, and engagement with science. With these aims in mind, it is our hope that the work on science capital discussed in this paper might help to provide an additional lens on equity concerns and help promote further thinking within the field, particularly in relation to how we might better understand and measure the impact of work designed to increase participation in science. We see this as still very much work in progress, but our hope is that sharing our current findings might both help advance our thinking in useful ways and stimulate further conceptual and methodological work in this area.

Our analysis indicates that science capital aligns with other forms of cultural capital and, as such, might be considered part of the contemporary reproduction of relations of privilege/disadvantage (and classed forms of ''distinction'') within society. We agree that there is a strong conceptual argument for the relevance, importance, and utility of including scientific and technical forms of capital within wider measures of cultural capital in contemporary society—yet to date there has been no concerted attempt to theorize or operationalize this. This paper makes a first step towards redressing this oversight.

We have detailed how science capital is unevenly socially spread, with relatively few students possessing ''high'' science capital and around 27% being classified as having ''low'' science capital. We suggest that our findings reinforce Claussen & Osborne's (2013) arguments that school science is currently failing to provide young people with the most valuable forms of scientific cultural (and, we would add, social) capital. Claussen & Osborne (2013) identify three main ways in which science education is failing to deliver, including the failure to convey a meta-picture of the major achievements of Western science and its cultural value; a failure to develop key scientific ''critical habits of mind'' and a failure to communicate the extrinsic value of a science education for future employment within and beyond science. They suggest that the latter could be used to better engage and motivate students—a message that we concur with, but we would further add that this form of knowledge might also be considered a valuable component of science capital. Hence, in addition to motivating students to engage with science, messages conveying the wide transferability of science skills and qualifications might also be used to generate advantage/social mobility. As Claussen & Osborne argue, these are forms of (science) capital that schools should be, but are currently not, developing:

> A healthy democracy [...] is dependent on the capability of its institutional structures to identify both the valued forms of cultural capital that exist and to ensure that all students are provided the opportunity to acquire as much as possible.'' (Claussen & Osborne 2013; p. 66).

Perhaps unsurprisingly, because our conceptualization of science capital attempts to capture symbolic forms of science-related capital (those forms with the greatest potential exchange value), our data shows that science capital is strongly socially patterned, being concentrated in more privileged social groups. Moreover, we found a relationship between science capital and outcomes/behaviors, particularly in relation to propensity towards post-compulsory STEM participation—which would appear to offer a plausible explanation for continued uneven participation rates in post-compulsory STEM.

We suggest that it is unsurprising—yet conceptually reassuring—that science capital appears to align with students' science identities and their science-related post-16 work and study plans and aspirations. However, we feel that our findings add useful empirical support for existing

assumptions and claims which have, to date, been made based primarily on qualitative data (e.g., Archer et al., 2012). That a student's level of science capital relates to their science identity and/or post-16 aspirations and plans would suggest that there is an urgent task in hand, particularly for those concerned with improving post-16 STEM participation rates. Yet post-16 science STEM participation is not the only reason to be concerned by inequalities in science capital. We suggest that the findings regarding the dramatic differences between students with high, medium, and low science capital in terms of whether they feel that others see them as a ''science person'' are particularly concerning from a social justice perspective. Indeed, research has drawn attention to the importance of ''science identity'' for student engagement with science. As Carlone and Johnson (2007); propose, science identity comprises both the extent to which a student personally identifies with science and whether they are recognized by others as being a ''science person.'' Our findings suggest that girls and those with low cultural capital are particularly likely to be over-represented among those students with low science capital who lack confidence in their science identities and feel that others do not see them as ''science people.''

As we have emphasized throughout this article, we consider this work as very much being a beginning point in our exploration of the concept of science capital. Our conceptual work and analyses inevitably raise a further set of questions and theoretical entanglements. First, by constructing an index that largely attempts to measure more symbolic forms of capital, is there a danger that we are missing (rendering invisible and/or marginalizing) other forms of science capital? For instance, our survey does not capture the various resources (and funds of knowledge) that young people from under-privileged backgrounds may possess, and which—given an appropriate, equitable context (field)—may be cross-leveraged to produce science capital (e.g., see Tan & Barton, 2010; Rahm, 2014)

Second, there is the question of field: How, and in what contexts, might different sorts of capital be mobilized and used to increase science capital? As Khan (2014) argues, given that the value of capital is determined by field, how is the value of science capital socially defined across different contexts? Can an index of science capital have any value (can it really ''work''), given that the value of capital is defined by the field? We suggest that in this latter respect, perhaps it is better to treat the instrument as a way of capturing changes that may occur due to intervention in a particular field? For instance, the task of science education interventions may not be to provide students with ''more'' or ''better'' science capital, but may instead need to focus on shifting relations within/across particular fields to better enable activation of facilitating forms of capital and/or changing which components of science capital are symbolically valued within particular fields. The latter clearly calls for a more radical shifting of power relations, calling into question, for instance, what is/counts as ''science?'' Whose science counts? (Harding, 1991) If the value of science capital lies in the processes that make it valuable, then perhaps the key task for science educators is to act on these to create contexts within which different forms of (science) capital are valued, activated, and able to be converted into symbolic forms of capital (see also discussions by Carter, 2003; Yosso, 2005).

Third, there are issues of embodiment. While we have attempted to some extent to construct an index which can reveal the hidden imprint of social inequalities, given that the value of capital is contingent on the person who deploys it, how does embodiment (and associated power dynamics) affect the possession, and activation, of science capital (Calabrese Barton, 2014)—and how/might this be captured in a quantitative tool? At a descriptive level, our tool currently enables us to report at scale on, for instance, the proportion of girls and boys who feel that others recognize them as being a ''science person,'' the degree of motivation and encouragement that they feel they receive from teachers and parents, and any differences in self-efficacy. However, we feel there is

still more scope to develop a more sophisticated understanding of the relationship between embodiment and science capital.

Fourth, can a quantitative tool, such as this survey, really capture the complexity of capital? How might it be used to explore how capital exists within webs of interrelationships? We also need to be alert not to assume linear trajectories for science capital—youth may move horizontally, as well as vertically (Calabrese Barton, 2014; Rahm, 2014) within fields. How can we explore the ways in which science capital relates to other sorts of capital? And, as Crowley (2014) reminds us, how might we identify which combinations of variables, or contexts within the science ''ecosystem'' generate resilience, resistance, or motivation?

Fifth, how might science capital vary across national contexts? Our Bourdieusian conceptualization assumes that capital is structured by field, hence we would expect the meaning and value of science capital to change across fields—hence not all the components we have identified may have relevance or currency in different national contexts and/or at different time points. For instance, in a society with an education system that strongly promotes messages about the transferability of science qualifications, this component may carry less ''weight.'' Equally, the availability and accessibility of science-related media and/or a high financial cost for accessing out-of-school science learning contexts, such as museums, may differentially weight these items in different national contexts. However, given that many countries face roughly similar issues in science participation, some cross-national comparisons might be informative. For instance, could the instrument be developed to provide an indication of the ''equity health'' of a particular system, in terms of mapping the in/equitable distribution of science capital across different populations and social groups?

Finally, there is the question of practical application. Given that our work is under-pinned and driven by a commitment to equity, we are centrally concerned with how science capital might be used as a transformative concept within science education. The wider project, which this work forms part of, is trying to develop and test out ways of creating conditions within which wider forms of science capital might be valued and enabled, in order to help more young people from under-privileged backgrounds to find science relevant and engaging, and to use this engagement to improve their lives. In this respect, we see science capital as a tool or device that can be used by educators to help improve young people's lives and foster social mobility. That is, science capital is more a means to an end, rather than an end in itself. So what might this look like in practice? If, as Lawler (2014) reminds us, symbolic capital is a ''denied capital'' (one which disguises its own status and appears naturalized rather than being the product of hard work, money, privilege, etc), then one implication might be for science education interventions to seek to ''reveal'' the workings of privilege in the production of science capital.

The 27% of students within the survey who were identified as having low science capital would seem to constitute a key group deserving of (urgent) resources and intervention—but what clues might our science capital lens give us regarding how/where to deploy resources to this effect? Many aspects of science capital (and the variables that are closely related to it) may be fairly ''fixed'' and difficult to change. However, we suggest that some attitudinal aspects may be easier to influence and more amenable to intervention than behavioral or structural variables. To this end, the aspects of science capital concerned with ''valuing science/scientists'' and ''utility of science qualifications'' may be obvious first targets. There would seem to be a value in supporting students to understand the transferability of STEM qualifications in the labor market, the relevance of science in everyday life, and the potential utility of science for their future lives. There would seem to be scope to address this both though schools and via work with families. This suggestion is, of course, only one aspect of a wider project. In line with the wider literature, our findings would support a view that it is an urgent and valuable task to support student self-efficacy (both their own,

and others', confidence in their science capabilities), particularly in relation to girls, low cultural capital students and those in lower school sets. In other words, our analysis would lend support to the value of developing and supporting students to perform a positive ''science identity,'' to see themselves (and to be recognized by others as being) a ''science person'' (Carlone & Johnson, 2007). Our analyses also lend support for work to promote empowering (Tan & Calabrese Barton, 2012), democratic (Basu, Calabrese Baron, & Tan, 2011) science teaching, learning, and participation within schools, ''informal'' science learning contexts, and within families.

In UK, considerable resource has been invested to date in supporting a plethora of STEM interventions aimed at improving young people's engagement with and participation in STEM. Yet, to date, many organizations have used fairly vague/inconsistent criteria with which to evaluate the ''success''/effectiveness of their interventions (e.g., Department for Education/ National Audit Office 2010). We suggest that, perhaps a more theoretically considered notion of ''science capital'' (and appropriate methodological tools with which to capture key elements of science capital) might offer a useful step forward in this respect.

Conclusion

As we have emphasized throughout the paper, our conceptual, methodological, and empirical exploration of science capital is very much ongoing work that remains in development. As we move forward in this project, we will continue to develop, refine, and test out the survey instrument with successive cohorts of young people (and adults) over the coming years. Our work with science capital is not solely quantitative—indeed a key aspect of the wider project involves applying our science capital conceptual lens to qualitative data from the students, parents, and teachers who are taking part in the wider study. So an imminent challenge will be the conceptual and analytic integration of these different methods. In this paper, we hope to have set out a case for the value of the concept of science capital—and an outline of potential ways in which this might be taken forward within the field. We conclude by reflecting on an interesting conundrum raised by Savage (2014); is science capital a ''good'' or ''bad'' thing? Many sociologists regard capital as negative and problematic, in that it is integral to the reproduction of inequalities. Yet many educationalists may see it as a hopeful concept, in that it offers the promise of changing social inequalities. From our own perspective, we feel that the value of science capital lies in its potential to provide a way of understanding the reproduction of inequalities in science participation—and a potential vehicle for dismantling and re-structuring current unequal relations of power: to help create contexts within which other (wider, different) forms of capital might be valued while also re-distributing and sharing out privileged forms of science capital more fairly between social groups. In this respect, we hope that science capital might offer a useful new, or additional, way of promoting social justice within science education.

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Notes

[1]Parental post-16 STEM qualifications are an important source of capital, which we attempted to capture in previous pilot versions of the survey. However, students struggled to answer this question and response rates for these items were very low—perhaps due the age of students and because few seem to know what qualifications (and in what subject areas) their parents possess.

[2]In the wider Enterprising Science project, we are working with seven ''intervention'' schools to develop, pilot, and test our interventions aimed at increasing students' science capital and their engagement with science). Intervention schools are ''matched'' with 13 comparison schools, and surveys are conducted annually to provide a comparative baseline data. Schools were selected to represent socially disadvantaged backgrounds (in line with the study aims to focus on improving science engagement among under-represented groups).

[3]The analysis does not focus on the 6,000+ students who undertook the previous survey because (1) this sample is not nationally representative, but over-represents students from disadvantaged backgrounds, in line with the wider study remit and (2) the previous survey had a high drop-out rate (21%)

[4]In England, academies are government funded schools that are also often co-funded by a private organization or individual, and which are outside of local authority control.

[5]Grammar schools are state secondary schools to which pupils are admitted on the basis of ability.

[6]This distribution is quite similar to ASPIRES (e.g., in the Year 9 survey, the percentages from very low to very high were 4.1%, 30.2%, 30.3%, 18.8%, and 16.6%).

[7]Note that there were only 31 students in this group, so results need to be treated with extreme caution.

[8]Not surprisingly, given the way the science capital variable was constructed, a one-way ANOVA highlighted significant differences between high, medium, and low science capital students in relation to the composite variable ''Future Science Job Affinity'' $F(23,631) = 603.19$, $p < 0.001$. (Post-hoc Bonferroni comparisons also showed that high science capital students scored significantly higher than students with medium science capital, who in turn scored significantly higher than those with low science capital). The means on this variable for each group were low = 1.8604; medium = 2.6733; high = 3.6079.

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