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Who Aspires to a Science Career? A comparison of survey responses from primary and secondary school students

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There is broad international agreement about the importance of increasing participation in science once it is no longer compulsory in school, particularly among groups who have been historically underrepresented in science. Previous research reflects that despite broadly positive attitudes to science in and outside of school, there is limited translation of these attitudes into later aspirations and participation in science. The ASPIRES project, a five-year longitudinal study, has sought to understand students' science and career aspirations between the ages of 10 and 14 and to identify factors that contribute to, or hinder, the development of aspirations in science. Utilising data from two cross-sectional surveys conducted with students in their last year of primary school (9300 students) and in their third year of secondary school (4,600 students), we explore who is most likely to hold science aspirations and what factors seem to be connected to those aspirations at both time points. Descriptive, multivariate and multilevel modelling analyses of the data reflect consistency in who holds science aspirations, as well as highlighting that the factors connected to these aspirations—attitudes to school science and parental attitudes—are similar at both times. However, for many students, positive attitudes to school science and positive parental attitudes to science are not translating into children wanting a career in science. We suggest that differences in 'science capital' may help explain this persistent gap.

Keywords: Aspirations; Science capital

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Despite any political or popular consensus over what science education is *for* (e.g. creating the next generation of scientists versus producing a scientifically literate population) (Millar, 2014), there is broad agreement in many quarters around the importance of increasing participation in science once it is no longer compulsory, particularly among groups who have been historically underrepresented in science. That this is not merely a historical phenomenon is reflected in current participation rates, which remain low despite prolific efforts over the years aimed at increasing participation in post-compulsory science. Indeed, particularly in the physical sciences, the ‘typical’ graduate in most Western countries continues to be male, White and middle-class (National Center for Education Statistics, 2009; Smith, 2010, 2011).

In Britain, the predominant option for post-compulsory participation in science is via A-levels. Those pursuing science at A-level tend to be high attaining and from higher social class backgrounds (Smith & Gorard, 2011; Strand, 2007, 2011). However, once attainment is taken into consideration, the impact of socioeconomic status (SES) becomes negligible (Smith & Gorard, 2011). Nevertheless, the intractable nature of the links between SES and attainment (Demack, Drew, & Grimsley, 2000; Homer, Ryder, & Donnelly, 2013) highlights the way in which post-compulsory participation in science is patterned by social class. Post-compulsory participation is also patterned by ethnicity (e.g. Elias, Jones, & McWhinnie, 2006; Lewis, Menzies, Najera, & Page, 2009; Strand, 2007, 2011; The Royal Society, 2008) and by gender (Hazari, Tai, & Sadler, 2007; Homer et al., 2013; Korpershoek, Kuyper, van der Werf, & Bosker, 2011; The Royal Society, 2008).

Considerable attempts have been made to disrupt these patterns (Smart & Rahman, 2009) and a variety of interventions have been trialled over the years attempting both to increase and to broaden participation rates in post-compulsory science (e.g. Calabrese Barton & Tan, 2010; Daly, Grant, & Bultitude, 2009; Darke, Clewell, & Sevo, 2002; Haussler & Hoffmann, 2002; Luehmann, 2009). Despite these efforts, participation remains patterned by gender, ethnicity and social class. Part of the reason for the intractable nature of this pattern seems likely to be due to the multiplicity of factors that contribute to its maintenance. For instance, longitudinal data collected in England reflected that students from some minority ethnic backgrounds (Black Caribbean) were less likely than their White British peers to be entered for higher tier test papers, regardless of prior attainment, thus capping their possible attainment (Strand, 2012). The lower attainment that inevitably results (because higher grades are unavailable at the lower levels) in turn restricts their options for post-compulsory subjects.

Another reason for the apparent lack of impact of these interventions on patterns of post-compulsory participation in science may also be their focus on students’ ages: fourteen and older. Many interventions target students who are already well into secondary school and are at a point where their aspirations are unlikely to change dramatically (Archer et al., 2012, 2013; Aschbacher, Li, & Roth, 2010; Maltese & Tai, 2010, 2011; Tai, Liu, Maltese, & Fan, 2006). Indeed, a substantial body of accumulated evidence points to the 10–14 age period being a critical time during which aspirations are

formed, particularly in relation to science (Lindahl, 2007; Tai et al., 2006). For instance, Tai et al (2006) found in their longitudinal tracking that students who aspired to science-related careers at age 14 are almost three and a half times more likely to end up later studying for a degree in the physical sciences or engineering. In the UK, Croll's (2008) analysis of longitudinal large-scale survey data sets also suggests that, on the whole, categories of student aspiration at age 15 map broadly on to later occupational outcomes. Thus, we argue that there is a link between aspirations and the choices students make—such as whether or not to pursue post-compulsory science—and that these aspirations are formed from an early age. It then follows that the factors that influence choices, and ensuing participation, are also already in play at an early age. This argument leads to the aim of the current paper—to explore whether it is possible to detect the seeds of later participation patterns at an earlier age than has been previously been explored and, secondarily, to investigate whether these patterns continue up to age 14.

Conceptual Framework

Against this context of concern around patterns of participation in post-compulsory science, [project name] set out to investigate how children's educational and occupational aspirations are formed over time and how aspirations, particularly those related to science, may be shaped by gender, ethnicity and social class, as well as influenced by peers, families and experience of school science. By studying aspirations, the project hoped to gain insight into not only their development and related factors but also into how they may or may not translate into later participation, particularly via the educational choices students make. In so doing, we drew upon a wide range of previous research on aspirations which highlighted, for instance, the way in which parental attitudes can support the development of aspirations in science (Gilmartin, Li, & Aschbacher, 2006; Keller & Whiston, 2008; Turner, Steward, & Lapan, 2004). There is also a considerable body of work identifying the way in which positive experiences in school science, including supportive relationships with teachers and pedagogy which highlights the relevance of science, can nurture science aspirations (Aschbacher, Li, & Roth, 2010; Barmby, Kind, & Jones, 2008; Bennett & Hogarth, 2009; Lyons, 2006; Lyons & Quinn, 2010). It seems that such experiences contribute to interest in and enjoyment of science which, in turn, exerts a positive influence on students' decisions to pursue post-compulsory science (e.g. Lyons et al., 2012). In our own earlier research on this project, we also found similar close relationships between aspirations in science and family attitudes to science (DeWitt et al., 2011, 2013; Archer et al., 2012) and attitudes to school science (DeWitt et al., 2011, 2013).

Additional research has explored the interrelationships between aspirations and structural factors such as gender (e.g. Eccles, 1994; Francis, 2002; Gutman, Schoon, & Sabates, 2012; Sikora & Pokropek, 2012; Turner & Lapan, 2005), ethnicity (e.g. Fouad & Byars-Winston, 2005; Riegle-Crumb, Moore, & Ramos-Wada, 2011; Strand & Winston, 2008) and social class (e.g. Atherton, Cymbir, Roberts, Page, &

Remedios, 2009; Flouri & Panourgia, 2012; St Clair & Benjamin, 2011). These studies highlight that aspirations seem to be patterned by gender, ethnicity and social class, but also make salient that the relationships between structural factors and aspirations are complex. Moreover, despite these patterns, factors such as interest and experience of school science may be more influential on aspirations and participation than structural factors alone (Maltese & Tai, 2011; Rieggle-Crumb et al., 2011). At the same time, other research reflects that an individual's experience in school and within the family are inherently interconnected with structural factors (e.g. Calabrese Barton & Tan, 2009; Calabrese Barton et al., 2013; Carlone, Kimmel, Lowder, Rockford, & Scott, 2011; Lareau & Horvat, 1999), suggesting that these factors, and their influence on aspirations, are deeply intertwined.

A key factor that has been identified in previous work by others (e.g. Aschbacher et al., 2010; Gilmartin et al., 2006; Stake, 2006) and ourselves (e.g. Archer et al., 2012) is the role of the family. For instance, Aschbacher et al. (2010) found that higher science achievers tend to come from more affluent families possessing strong scientific social capital and a range of economic, social and cultural resources to support achievement. Likewise, we have found that parents or, more specifically, parents' *science capital* appears to play a mediating role in relation to children's science aspirations. We see science capital as:

... 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, DeWitt, & Willis, 2014, p. 5)

Yet the distribution of science capital is strongly classed and racialised, being more prevalent among middle class and White and South Asian families. Our work to date has found that the likelihood of a child maintaining science aspirations over time may be strongly mediated by science capital and that children whose families have higher levels of science capital (e.g. parents with science degrees and/or who work in science jobs) are much more likely than their peers to express science aspirations (see Archer et al., 2014).

As noted previously, there are clear relationships between attitudes to science and aspirations in science. Nevertheless, there is also a persistent disparity between these positive attitudes and science aspirations (Archer et al., 2010; DeWitt et al., 2013; National Foundation for Educational Research, 2011), suggesting that many students hold the perspective that science is 'important, but not for me' (Jenkins & Nelson, 2005). We have previously termed this phenomenon the 'being-doing divide' (Archer et al., 2010), noting that many elementary school aged students may enjoy *doing* science, but most do not aspire to *be* a scientist. For many students, their positive attitudes are not translating into aspirations in science and we argue that identity, or sense of self, has a central role to play here. That is, we suggest that the relationship between attitudes and aspirations is likely to be mediated by issues of identity and equalities. Our theoretical approach sees identity (and agency) as shaped by structure. That is, individuals actively construct their identities but they do so within conditions

and constraints that are not of their choosing (e.g. Anthias, 2001). This interplay of agency and structure generates young people's 'horizons of choice', opening up or closing down what is perceived as (un)desirable and/or (im)possible and resulting in a powerful sense of what is 'normal for people like me'.

Identities and aspirations are inherently influenced by social inequalities of 'race'/ethnicity, social class and gender (e.g. Hall, 1990), which can result in particular patterns of aspiration within and between social groups. More broadly, we argue that individuals' senses of self are intimately related to aspirations, or what/who one hopes to be. Put differently, the range of 'possible selves' (Markus & Nurius, 1986; Oyserman & Fryberg, 2006) that a student can envision for themselves will manifest itself in the range of aspirations they hold. Yet while identities influence, they do not determine, future outcomes. In the case of science, aspirations may be nurtured and developed—or not—by the extent to which students can imagine themselves in certain science-related roles and can perceive science careers as possible and achievable (Aschbacher et al., 2010; Boe, Henriksen, Lyons, & Schreiner, 2011; Cleaves, 2005; Lyons & Quinn, 2010; Taconis & Kessels, 2009). While these aspirations may be broadly patterned in socially predictable ways, they are nevertheless always in a process of 'becoming' and hence remain open to the possibility of change. Thus, we see value in examining aspirations as multifaceted, socially indicative phenomena which provide a mechanism for unpacking the complex ways in which social identities, inequalities and contexts intersect and interact to shape the range of students' possible selves, or possibilities that they see as 'for me' or 'not for me' (Archer et al., 2010).

In order to examine the development of aspirations and their influences, we have been conducting a mixed methods study, combining interview and survey data (see Archer et al., 2012; DeWitt et al., 2013). Qualitative data are reported in depth elsewhere (e.g. Archer et al., 2012, 2013, 2014); hence the current paper focuses on a comparison of survey data collected when students were in Year 6 and in Year 9, in order to explore who is most likely to hold aspirations in science, what factors contribute to these aspirations and the extent to which these patterns hold or differ over time. Specifically, the research questions addressed by this paper are:

- (1) Who holds science aspirations?
- (2) What factors seem to be connected to aspirations?
- (3) Are these patterns similar or different at different time points (in primary and secondary school)?

Methods

Although the present paper has a quantitative emphasis, the wider [project name] research employs a mixed methods approach in order to tap both the breadth and depth of participants' aspirations, perceptions and attitudes. The quantitative component (the focus of the present analyses) consists of an online survey administered to children at three time points: in the last year of primary school (Year 6, age 10–

11) and in the second (Year 8, age 12–13) and third (Year 9, age 13–14) years of secondary school. While the three survey samples should be considered as separate, we were able to track some students and 1036 completed both the Year 6 and Year 9 surveys. The current paper focuses on data from the third survey, comparing them with data collected in the first survey, when children were still in primary school. We compare data gathered in Years 6 and 9 because we were interested in maximising the time frame of our analysis, in order to give us the broadest perspective possible on what may be supporting or acting against the development and maintenance of aspirations in science.

Survey Instrument

The survey began with a series of multiple-choice questions to collect background data (e.g. gender, ethnicity and parental occupation). It also contained Likert-type items on a range of attitudinal topics including: aspirations in science and in other fields; participation in science-related activities outside of school; attitudes towards school science; self-concept in science; images of scientists; parental attitudes towards science; and peer attitudes towards school and towards school science. Response options were on a five-point scale from ‘strongly agree’ to ‘strongly disagree’ with ‘neither agree nor disagree’ as a midpoint.

The surveys administered in Years 6 and 9 were very similar, to allow for comparison between age groups, although additional items were added to the latter survey as appropriate (e.g. questions about science teachers and about post-16 plans). Details on the development and validation of the survey instrument have been described elsewhere (e.g. DeWitt et al., 2011), as have the findings from the first and second surveys (DeWitt et al., 2013; DeWitt, Archer, & Osborne, 2014), which also provide further information on the reliability and validity of the survey instrument and particular items. A complete copy of the survey is omitted here due to space limitations. Sample items can be found in the appendix.

Sample

The survey was completed by 9,319 Year 6 students from 279 schools (autumn 2009) and 4,600 Year 9 students from 147 schools (spring 2013). Although the students completing the survey should be regarded as separate groups, we do have a tracked sample of 1036 students, who completed the survey in Year 6 and Year 9. Schools participating in each of the surveys represented all geographic regions in England and were roughly proportional to the overall distribution of schools in England in terms of attainment (as determined by scores on national standardised tests) and proportion of students eligible for free school meals.

Of the students participating in the Year 6 survey, 50.6% were boys and 49.3% were girls. Ninety-one per cent attended state schools and 9% attended independent schools. Ethnicities included: 74.9% White, 8.9% South Asian (Indian, Pakistani and Bangladeshi heritage), 7.5% Black (Black African and Black Caribbean), 1.4%

Far Eastern and 7.8% mixed or other. Respondents to the Year 9 survey were 44.4% male, 55.4% female; 96.5% in state schools; 71.2% White, 13.5% South Asian, 6.2% Black, 1.5% Chinese or East Asian and 7.6% mixed or other. In addition, the 1036 students completing both surveys were 54.2% female, as well as 80.0% White, 9.0% Asian, 5.4% Black, 1.1% Chinese or East Asian and 4.5% mixed or other.

The survey also included a multiple-choice question about parental occupation as a broad indicator of social class and students were assigned to the highest social class indicated by occupation (of the father or mother). Students came from a range of social class backgrounds, with 43.7% of Year 9 children reporting having a parent in a professional or managerial occupation (43.9% in the Year 6–Year 9 matched sample), 26.6% in a skilled occupation (30.8% matched), 12.7% in a semi-skilled or unskilled occupation (12.4% matched) and 9.3% in some other job (8.0% in matched sample). Additionally, 7.3% of children had parents who were homemakers, unemployed or of an unknown occupation (4.2% matched).

The survey also contained a measure of cultural capital (e.g. Bourdieu, 1984) with a scale of -4 through 9, which was calculated based on responses to items about parental education, approximate number of books in the home and frequency of museum visitation. For simplicity, the scores were grouped into categories, with 4.1% of students indicating very low levels of cultural capital (-4 through -1.5), 30.2% with low levels (-1 to 1), 30.3% medium (1.5 to 3.5), 18.8% high levels (4 to 6) and 16.6% very high levels (6.5 to 9) of cultural capital.¹ For the 1036 matched students, the percentages from very low to very high were 3.6%, 29.9%, 31.2%, 18.5% and 16.8%. Note that the social class and cultural capital profiles of the Year 9 sample were similar to those from the first two surveys. (See DeWitt et al., 2013, 2014, for details of those sample characteristics.)

Analyses

Analyses began by exploring reliability and validity—principal components analysis and Cronbach's alpha were utilised to determine internal consistency and unidimensionality of scales. The component structure of the Year 9 survey was nearly identical to that of the Year 6 survey. Both surveys contained the following components: aspirations in science, participation in science-related activities outside of school, parental attitudes to science, peer attitudes to science, attitudes to school science, self-concept in science and images of scientists (positive and negative). Cronbach's alpha values for the Year 9 survey ranged from .665 to .919. (Also see the appendix.)

As with the first survey, student responses to the items in each of the components were used to create composite variables. Due to the addition of items after the first survey (e.g. items about science teachers), some of the components, such as attitudes to school science, changed in composition from the Year 6 survey. For the sake of comparison with the Year 6 results, the composite variables used in the Year 9 analyses were created to contain the same items as those used in the Year 6 analyses. Doing so is not only justified in order to allow for comparisons to be made but also because a principal components analysis based on only those items that were in all three surveys

revealed the same data structure—for example, components such as ‘attitudes to school science’ and ‘self-concept in science’ emerged from both sets of data (Year 6 and Year 9).

The composite variables created were then utilised to explore patterns in children’s responses, including by gender, ethnicity and cultural capital. In order to compose a general picture of who is likely to express aspirations in science, a logistic regression analysis (using a multilevel model with school and student as the levels to account for the nested nature of the data) was performed. This analysis explores which variables most strongly predict a categorical (yes–no) outcome. We transformed the aspirations in science composite variable into a dichotomous variable, where students with scores of 22 or higher (possible range: 5–25) counted as ‘yes’ (for having strong aspirations in science) and those of 21 or lower counted as ‘no’. To obtain a ‘yes’ score, a student would have to agree or strongly agree on all five items comprising this variable (and strongly agree on at least 2). In addition, there is a clear break in the distribution between the number of students scoring 21 and 22. This dichotomous aspirations variable was the outcome (dependent) variable in the analysis.

Finally, multilevel modelling (MLM) analyses were conducted to investigate factors related to children’s aspirations in science. As with regression analyses, MLM analyses are used to identify variables that account for significant proportions of variance in an outcome variable, such as aspirations in science. MLM differs from regression analyses in its capacity to account for the nested structure of the data (i.e. that students are grouped into schools), which results in their using a more accurate measure of standard error than standard regression models. Consequently, the accuracy of the model is increased.

Findings

Who Holds Science Aspirations?

To form a picture of those students most likely to hold science aspirations, we focused on the ‘aspirations in science’ composite variable, which comprised five items. (See appendix.) As described above, students’ scores on this variable were used to divide them into two groups: those with strong science aspirations and those without. At Year 6, 727 of the 9,319 (7.8%) students completing the survey fell into the strong science aspirations group, while at Year 9, 392 of 4,600 (8.5%) were included. At Year 6, students in the group with strong science aspirations were 62.5% male; 60.7% White, 18.2% South Asian, 9.4% Black and 9.5% Other; and 56.5% with high or very high cultural capital. At Year 9, students in this group were 52.4% male; 57.1% White, 21.9% South Asian, 8.4% Black and 11.7% Other ethnicity; and 53.6% with high or very high levels of cultural capital. In addition, 45.9% of these Year 9 students reported having a family member who used science in their work (as compared with 24.8% in the total Year 9 sample) and 48% reported being in the top set—or top grouping—of their school’s science classes (as compared with 33% in the sample). (Students are not put into sets for science in Year 6.)

Logistic multilevel models were also created to explore statistically which of these background variables were most closely related to children's science aspirations. These analyses revealed that the following variables were the strongest predictors of whether or not a child is likely to have strong science aspirations (to fall into the group with a mean on this variable of 22 or higher) at Year 6: gender, ethnicity (Black, Other and Asian), and cultural capital (low, high and very high).

Table 1 displays the coefficients and standard errors for the logistic MLM for aspirations in science—note that this model **ONLY** explored background variables, not other composite variables, to form a 'pen portrait' of these Year 6 students².

Rather than effect size, this analysis produces an 'odds multiplier', which reflects how likely an outcome is for one category of independent variable as compared to the reference categories (male, White, medium cultural capital) and thus gives a perspective of the relative strength of the relationship between an independent variable and the outcome. This means that girls are .57 times less likely than boys to fall into the strong aspirations in science group. Asian students are 2.73 times as likely (or nearly three times as likely) as White students to fall into this group. Similarly students of Other ethnicities are 1.51 times as likely and Black students are 1.44 times as likely to fall into this group, relative to White students. Students with high or very high levels of cultural capital are 1.27 and 2.03 times as likely, respectively, as those with medium levels of cultural capital to have high science aspirations, whereas those with low levels of science capital are less likely.

At Year 9, we were able to incorporate further information about science set and family background into the model (which had not been available for the Year 6 data). The logistic multilevel model for the Year 9 data set revealed that the following most strongly predicted whether or not a child is likely to be part of the group with strong science aspirations: gender, ethnicity (Black, Other and Asian), Cultural capital (low, very low and very high), family member using science in their work and science set (top). **Table 2** displays the coefficients and standard errors for the logistic MLM for aspirations in science at Year 9.

As with Year 6 students, at Year 9 girls and students with low or very low levels of cultural capital are less likely to fall into the strong aspirations in science group. South

Table 1. Characteristics of students with strong science aspirations—Year 6

| | Coefficient | SE | Odds multiplier |
|----------------------------|-------------|------|-----------------|
| Intercept (constant) | -2.53 | 0.09 | N/A |
| Gender (female) | -0.57 | 0.08 | 0.57 |
| Ethnicity—Asian | 1.003 | 0.12 | 2.73 |
| Ethnicity—Black | 0.363 | 0.15 | 1.44 |
| Ethnicity—Other | 0.415 | 0.14 | 1.51 |
| Cultural capital—low | -0.636 | 0.13 | 0.53 |
| Cultural capital—high | 0.239 | 0.11 | 1.27 |
| Cultural capital—very high | 0.71 | 0.10 | 2.03 |

Table 2. Characteristics of students with strong science aspirations—Year 9

| | Coefficient | SE | Odds multiplier |
|--------------------------------------|-------------|------|-----------------|
| Intercept (constant) | -2.85 | 0.13 | N/A |
| Gender (female) | -0.341 | 0.12 | 0.71 |
| Ethnicity—Asian | 0.668 | 0.15 | 1.95 |
| Ethnicity—Black | 0.415 | 0.21 | 1.51 |
| Ethnicity—Other | 0.652 | 0.18 | 1.92 |
| Cultural capital—very high | 0.450 | 0.13 | 1.57 |
| Cultural capital—low | -0.407 | 0.15 | 0.67 |
| Cultural capital—very low | -1.484 | 0.51 | 0.23 |
| Family member whose job uses science | 0.768 | 0.12 | 2.16 |
| Science Set—top | 0.681 | 0.12 | 1.98 |

Asian students as well as those of Black or Other ethnicities are more likely than White students to have strong science aspirations. Students with very high levels of cultural capital are also more likely than those with medium levels to have high science aspirations. Those who have a family member working in a science-related job are 2.16 times as likely to fall into this group as those who do not. Finally, students who are in the top set for science are nearly twice as likely to fall into this group as those who are in middle sets. Taken together, these analyses contribute to our picture of the child most likely to have strong science aspirations (in terms of background or structural variables) at Year 9: a boy, with very high levels of cultural capital, a family member whose job uses science and attaining well in science (as indicated by set). He is also likely to be non-White. Other than the additional information about family members and science set (which was not available for Year 6 students), this picture has changed very little compared with the Year 6 data.

Other Factors Contributing to Aspirations in Science

Despite the consistent picture of who holds strong science aspirations at Years 6 and 9, multilevel modelling analyses conducted at both time periods reflected that although there may be differences between groups (e.g. ethnic groups), other factors are more closely related to aspirations in science.

MLM analyses revealed that the following variables were most strongly related to Year 6 students' aspirations in science: gender, ethnicity, cultural capital, parental attitudes to science, attitudes to school science and self-concept in science. More specifically, students reporting more positive parental attitudes to science tended to have higher aspirations in science, and those whose self-concept in science and attitudes to school science were more positive also tended to have higher aspirations in science. This model, or a combination of variables, explained 49% of the variance in students' aspirations in science in the last year of primary school. (Detailed findings from Survey 1 have been published previously (DeWitt et al., 2013).)

Similar factors (gender, parental attitudes to science, attitudes to school science and self-concept in science) continue to be closely associated with the aspirations in science composite variable in the Year 9 data and in the same direction as in Year 6 (i.e. negative for girls). Participation in science-related activities is also closely related to Year 9 aspirations in science. This model accounted for 56% of the variance in students' aspirations in science at Year 9. Table 3 presents a comparison of the Year 6 and Year 9 models.

The similarity between the Year 6 and Year 9 models is apparent not only in which factors are included but also in the strength of the relationships between these factors and aspirations in science. In both data sets, parental attitudes to science and attitudes to school science had the strongest relationships with aspirations in science, followed by the association between aspirations and self-concept in science. Most other relationships, including that between gender and aspirations, had smaller effect sizes. This pattern suggests that although there are some relationships between demographic factors and aspirations (as also reflected in the logistic multilevel models described previously), these factors may not play as central a role in the formation of science aspirations as parental attitudes towards science or attitudes towards school science. At the same time, differences in participation in post-compulsory science and science careers along structural lines suggest that these factors do merit

Table 3. Effects of structural and latent variables on aspirations in science (Year 6 and Year 9)

| Effect | Year 9 coefficient (Y6) | Year 9 SE (Y6) | Year 9 effect size (Y6) |
|---|-------------------------|----------------|-------------------------|
| Intercept | -5.770 (13.944) | 0.321 (0.072) | |
| Gender (female) | -0.438 (-0.651) | 0.110 (0.074) | -0.09 (-0.13) |
| Ethnicity—Indian | N/A (0.602) | N/A (0.197) | N/A (0.12) |
| Ethnicity—Pakistani | N/A (0.663) | N/A (0.254) | N/A (0.13) |
| Ethnicity—Bangladeshi | N/A (0.833) | N/A (0.283) | N/A (0.16) |
| Ethnicity—'Other' South Asian | N/A (1.253) | N/A (0.424) | N/A (0.24) |
| Ethnicity—Chinese | 1.233 (1.271) | 0.409 (0.424) | 0.24 (0.25) |
| Ethnicity—Black Caribbean | N/A (-0.665) | N/A (0.284) | N/A (-0.13) |
| Ethnicity—Mixed, Black & White | N/A (-0.447) | N/A (0.203) | N/A (-0.09) |
| Ethnicity—Mixed, Asian & White | N/A (0.779) | N/A (0.340) | N/A (0.15) |
| Cultural capital—very low | 0.647 (N/A) | 0.258 (N/A) | 0.13 (N/A) |
| Cultural capital—low | N/A (-0.317) | N/A (0.092) | N/A (-0.06) |
| Cultural capital—very high | N/A (0.298) | N/A (0.098) | N/A (0.06) |
| Family member using science in job | 0.757 (N/A) | 0.118 (N/A) | 0.15 (N/A) |
| Science set—top | 0.510 (N/A) | 0.114 (N/A) | 0.10 (N/A) |
| Parental attitudes to science | 0.519 (0.668) | 0.026 (0.021) | 0.35 (0.44) |
| Attitudes towards school science | 0.320 (0.343) | 0.015 (0.009) | 0.48 (0.53) |
| Self-concept in science | 0.161 (0.134) | 0.013 (0.009) | 0.24 (0.20) |
| Participation in science-related activities | 0.159 (N/A) | 0.013 (N/A) | 0.21 (N/A) |

Note: Year 6 coefficients, standard errors and effect sizes are shown in brackets. 'N/A' is used to indicate when a variable did not form part of a particular model (Year 6 or Year 9).

attention, and implications of these differences will be discussed in more detail subsequently.

In order to further examine the relationship between aspirations in science at Years 6 and 9, a final multilevel model was constructed for Year 9 aspirations in science, using data from the 1,036 students for whom we had matched data from both surveys and including those students' Year 6 aspirations in science as an independent variable.

As seen in Table 4, when data from the 1,036 students who completed both surveys are utilised to create a model, the composite variables most closely associated with Year 9 students' aspirations in science were their attitudes to school science in Year 9 and parental attitudes to science reported in that year. Although other composite variables were sufficiently strongly related to aspirations to be included in the model, their effect sizes were quite small, including the effect size for the relationship between Year 6 and Year 9 aspirations in science. This model thus reinforces the picture of factors associated with aspirations in science provided by the model for the whole Year 9 sample: that students' experience of school science and perceived parental attitudes to science are indeed closely related to aspirations and are likely to play a role in the formation and/or maintenance of science-related aspirations.

The Relationship Between Aspirations, Experiences of School Science and Parental Attitudes to Science

Analyses of our survey data clearly revealed that composite variables such as attitudes to school science and parental attitudes to science are the factors most closely related to aspirations in science. However, although aspirations are only weakly related to structural factors (gender, ethnicity and cultural capital), participation in post-compulsory science is clearly raced, classed and gendered. We next discuss the relationship between aspirations and (i) school science and (ii) parental attitudes, and then

Table 4. Variables related to Year 9 aspirations in science, using matched data

| Effect | Coefficient | SE | Effect size |
|--|-------------|-------|-------------|
| Intercept | -6.806 | 0.685 | |
| Gender (female) | -0.445 | 0.198 | -0.09 |
| Ethnicity—Other Asian | 1.815 | 0.790 | 0.38 |
| Cultural capital—low | 0.562 | 0.234 | 0.12 |
| Cultural capital—high | 0.651 | 0.249 | 0.14 |
| Science set—top | 0.448 | 0.205 | 0.09 |
| Family member whose job uses science | 0.824 | 0.229 | 0.17 |
| Year 6 aspirations in science | 0.110 | 0.020 | 0.16 |
| Parental attitudes to science (Year 9) | 0.560 | 0.058 | 0.35 |
| Attitudes towards school science (Year 9) | 0.348 | 0.031 | 0.51 |
| Self-concept in science (Year 9) | 0.128 | 0.027 | 0.19 |
| Participation in science-related activities (Year 9) | 0.117 | 0.027 | 0.15 |

speculate as to how these variables may mediate structural factors in the formation of children's science aspirations.

The role of school science. Our analyses suggest a complex relationship between students' experience of school science and the formation and maintenance of aspirations. The models of students' aspirations in science portrayed in [Tables 3](#) and [4](#) highlight the key role that attitudes to school science play in aspirations. However, despite students' positive attitudes to school science, the gap between their attitudes and aspirations in science also remains. The standardised mean of the attitudes to school science composite variable is 18.73 at Year 6 and 18.29 at Year 9, in contrast with means of 13.67 and 14.30 for aspirations in science at Years 6 and 9 (range for both variables: 5–25).

Additionally, even though attitudes to science remain quite positive at both time points, students' enjoyment of lessons seems to decrease over time. While 58% of Year 6 students agree that their science lessons are exciting, only 43% of Year 9 students think so. There are comparable drops in the percentage agreeing that they look forward to science lessons (52% at Year 6 and 43% at Year 9) and that they learn interesting things in science lessons (74% in Year 6 and 66% in Year 9). In the discussion we reflect on possible reasons for this change. Moreover, the mean score on the Year 9 attitudes to school science composite variable is significantly lower for girls ($M = 24.95$) than for boys ($M = 26.43$), as reflected by a one-way ANOVA, $F(1, 4586) = 87.54$, $p < .001$. The mean score on this variable was also lower for students with lower levels of cultural capital ($M = 24.75$) than those with high ($M = 26.47$) or very high ($M = 26.84$) levels, $F(4, 4595) = 60.51$, $p < .001$.

The role of parental attitudes. As with attitudes to school science, the translation from parental attitudes to aspirations is not straightforward. That is, although children tended to report positive parental attitudes to science in both the Year 6 and Year 9 surveys (e.g. over 70% of students at each time point agreed that their parents felt it was important for them to learn science), these attitudes are not translating into science aspirations for all children. It seems that whether or not parents work in science-related jobs may be an important factor here. The mean score on the aspirations in science composite variable is significantly higher for those reporting a family member working in science ($M = 16.29$) than for those who do not ($M = 13.62$), as reflected by a one-way ANOVA, $F(1, 4422) = 242.60$, $p < .001$ and the multilevel logistic analyses indicated that these children were also twice as likely to express strong aspirations in science.

Discussion

The present research formed part of a larger mixed methods study exploring the development of children's aspirations over time and factors related to these aspirations. We focus on aspirations not because they guarantee participation in post-compulsory science (via study or pursuit of a science-related career) but rather because they serve as indicative phenomena that highlight the realm of possibilities that students consider 'thinkable' (Archer et al., 2010), in addition to being linked to later choices and participation (e.g. Atherton et al., 2009; Boe et al., 2011; Maltese &

Tai, 2011; Tai et al., 2006). Put simply, without science aspirations, it is quite unlikely that students will make choices that will lead them to science-related careers. In studying these issues, we do not intend to claim that careers in or from science are more valuable than other careers, but rather are motivated by a concern for equitable access to routes that can potentially lead to outcomes valued by many in Western societies (e.g. a reasonably interesting, reasonably stable, reasonably well-paid job).

The findings presented in this paper paint a picture of aspirations and related factors that seems to be quite stable over time. Moreover, our analyses show that aspirations from Y6 to Y9 are indeed patterned by structure (c.f. our findings related to gender, ethnicity and cultural capital) while at the same time not being deterministic (as exemplified by the reported odds multipliers, which reflect an increased likelihood—but not certainty—of particular patterns occurring). Indeed, the picture presented by our analyses is of a degree of consistency (but not fixity) within young people's aspirations from age 10 to age 14, with these aspirations being reliably patterned by social identities and inequalities, whilst also shaped by parental/family factors and young people's experiences of school science.

For instance, in response to our first research question, students in our Year 6 and Year 9 samples with strong aspirations in science were more likely to be male, from ethnic minority backgrounds and have high levels of cultural capital. They were also more likely than those without such strong aspirations to do well in science (not surprisingly) and to have exposure to a science-related career through family. With the exception of ethnicity, this is a picture that is remarkably similar to that of participation in post-compulsory science, and particularly those working (or studying) in physical science. However, the discrepancy between the current profile of STEM graduates and the high proportion of minority ethnic students aged 10–14 aspiring to a career in science also alerts us to some potential inequalities. Our analyses suggest that a 'lack of aspirations' is not the main barrier to minority ethnic participation in post-compulsory STEM education, despite the assumptions of many policy texts and initiatives (e.g. Department for Education and Skills, 2005). Moreover, we suggest that it may be useful to examine gaps between A-level participation and degree participation, as many qualified minority ethnic students (particularly South Asian) may be choosing medical degree routes rather than physical sciences (Stevenson, 2012).

Despite the resonance of our analyses with an image of the male, middle class scientist (e.g. Buck, Leslie-Pelecky, & Kirby, 2002; Losh, Wilke, & Pop, 2008; Scantlebury, Tal, & Rahm, 2007), our analyses addressing our second research question also reflected that these structural factors are not the ones most directly related to aspirations. Rather, it was parental attitudes to science and attitudes to school science that were the strongest predictors of aspirations in science. However, these attitudes were positive in Year 6 as well as in Year 9, while aspirations in science remained low at both time points. The doing/being divide (Archer et al., 2010), or the discrepancy between attitudes related to aspirations and the aspirations themselves, would seem to remain doggedly persistent—it is certainly not diminishing in older age groups. It would seem that a complex mechanism is likely to underpin the formation and maintenance of occupational aspirations, which rely on and indicate an ability to

imagine oneself in a particular type of career (Markus & Nurius, 1986; Oyserman & Fryberg, 2006)—rather than just being determined directly by broadly positive experiences in school or parental attitudes. In alignment with findings from other research, it may be that students' aspirations are stymied by narrow images of who can 'be' a scientist (Buck, et al., 2002; Rahm, 2007) or even who counts as a 'good science student' (Brickhouse, Lowery, & Schultz, 2000; Calabrese Barton & Tan, 2010; Calabrese Barton et al., 2013; Carlone et al., 2011).

The persistent doing/being divide, in the face of enduringly strong relationships between attitudes to school science, parental attitudes to science and aspirations in science, led us to examine the data more closely to begin to unpick these mechanisms that may be operating to facilitate or hinder the translation of attitudes into aspirations. With regard to school science, survey data highlighted that students in Year 6 and in Year 9 value school science and feel they can do well in it. However, while they are still generally positive about their lessons, Year 9 students do report enjoying them less than Year 6 students, which may be due at least in part to the increased emphasis on test preparation as students move through secondary school in the UK—an activity that can decrease motivation and enjoyment (Black, Harrison, Lee, Marshall, & Wiliam, 2002). This decrease in enjoyment could also potentially be linked to a reduction in practical work as schools face increasing pressure around testing (Ofsted, 2013). Moreover, in Year 9 students are beginning to make choices about their subject options, including whether or not to pursue 'triple science' (the science option involving the three sciences separately, considered the most academically challenging and rigorous) the following year. We hypothesise that this situation might potentially heighten students' awareness of the link between attainment and progression—or to contribute to perceptions that further pursuit of science is for the 'clever'. Such awareness, combined with a decrease in preferred activities, such as practical work (cf. Nuffield Foundation, n.d.), may act as a barrier to the translation from many students' broad enjoyment of science into science aspirations.

Our analyses also reflected structural patterning around attitudes to school science. In particular, girls and students with lower levels of cultural capital had lower mean scores on the attitudes to school science variable. Such a pattern suggests the possibility that something happening in the science lessons themselves is operating not only to reduce enjoyment but also to produce unequal patterns of aspirations and, later, post-16 participation. That this might be the case is congruent with findings from other research about the ways in which the practices of science classrooms operate to privilege some students whilst marginalising others, particularly those from non-dominant groups (e.g. Calabrese Barton & Tan, 2010; Calabrese Barton et al., 2013; Carlone et al., 2011), although there are alternative explanations (e.g. changes due to identity development) that could account for these unequal patterns of aspirations.

As with attitudes to school science, reported parental attitudes to science remained positive across the surveys, suggesting that these positive attitudes do not invariably or directly translate into student aspirations in science. One potential explanation for these patterns may be the effect of science capital. As other findings from the [project name] research suggest (Archer et al., 2012, 2014), a family's possession of

science capital (e.g. science qualifications and resources) may be more influential in promoting and maintaining children's science aspirations over time than positive attitudes towards science. Those qualitative analyses (see Archer et al., 2012, 2013, 2014) of interview data from 83 students and 65 parents from the sample who were tracked from age 10 to age 14 suggest that families who possess high levels of science capital (e.g. parents with post-compulsory science qualifications who work in STEM-related jobs) tend to promote to their children the value and transferability of science qualifications. These families also tend to foster a family context and ethos in which science is highly valued and is a daily feature of family life (e.g. watching science-related TV, reading science newspaper articles, discussing science-related issues around the dinner table, participating in science-related leisure activities and so on). These practices may provide children with both a valuing of, and interest in, science and a perception that science is a part of 'who we are and what we do'. It is also possible that the provision of science-related resources (e.g. science toys, kits and microscopes) and expertise (e.g. help with homework, regularly conveying science knowledge) may further support and promote these children's attainment in school science. In other words, the relationship between children's science aspirations and parental attitudes to science may be mediated by the possession of science capital.

Conclusions and Implications

Overall and in response to our third research question, our data seem to reflect that the picture of aspirations in science does not seem to change much—either in terms of who aspires to science careers or the factors related to these aspirations—between Year 6 students and Year 9 students, despite this time span representing a major transition in students' lives. Thus, the problem of the doing/being divide would seem to be quite an intractable one, and one that is not amenable to straightforward solutions. Nevertheless, our findings do have some implications for practice, as well as policy.

For example, one idea for addressing the disconnect between being and doing would be to help students to develop a sense of science as being 'for me'. One potential way that this might be approached would be to highlight the relevance of science for a greater diversity of students—for instance by flagging how science 'keeps options open' rather than just leading to jobs in science (e.g. see Archer et al., 2013). Explicit emphasis on the link between lessons and students' future lives and work may foster a greater appreciation of the way in which science skills, for instance, could help students attain their future (career) goals. Rather than the vague message 'science is useful in many jobs', a more effective approach may be to provide illustrations of specific jobs that utilise science skills or that connect to areas of study in science. The provision of specific careers-related information may help make careers in science more 'thinkable' or imaginable. Such information may then help school science become a more effective vehicle for fostering aspirations—or translating positive attitudes to science into science-related aspirations. The potential for such an approach is reflected by programmes such as Career Start, which involved incorporating career-relevant instruction into lessons in core subjects (mathematics, English/language arts, science and

social studies) during the middle school years. A randomised control trial of this programme indicated that these career-relevant lessons led to higher levels of school engagement and valuing (Orthner, Jones-Sanpei, Akos, & Rose, 2013) and mathematics attainment (Woolley, Rose, Orthner, Akos, & Jones-Sanpei, 2013).

Although the profile of who aspires to science careers is consistent in some ways (e.g. by gender and cultural capital) with post-compulsory participation in science study and even careers (Smith, 2010, 2011; Smith & Gorard, 2011; Strand, 2007, 2011), our research highlights that these gendered and classed patterns emerge at a very early stage—when students are still in primary school. While demographic variables are not the primary factors determining aspirations, we would argue that interventions, such as those described above, do need to take such factors into consideration, as our data suggest that there would be value in all students receiving messages about who can ‘do science’. Relatedly, another idea for addressing the doing/being divide and making school science relevant for a more diverse range of students would be to make school science more inclusive to different ways of being. In particular, we would challenge policymakers and curriculum developers to help teachers broaden the ways in which students can engage with and participate in science. Other studies have indicated that more inclusive practices in (and outside of) the science classroom have the potential to broaden the extent to which diverse students find science relevant (e.g. Calabrese Barton et al., 2013; Calabrese Barton & Tan, 2009, 2010; Carlone et al., 2011).

Additionally, interventions around careers need to be embedded into classrooms from an earlier age—while children are still in primary school. We are not calling for ‘careers information for 7 year olds’, but rather want to encourage schools to attempt to provide students with a broad perspective on careers and where school subjects might ultimately lead them, and to support teachers in reflecting on the kinds of messages they are already providing to their students about the world of work and the relevance of school for work.

As noted previously, messaging around who can ‘be’ a scientist—or even a ‘good science student’—can also create a barrier to the formation and maintenance of science aspirations. While images of science as being for the exceptionally clever are widespread, we hypothesise that they are exacerbated in England by policies at school level and more widely that dictate who is and is not permitted to continue in science once it is no longer compulsory. For instance, in many English schools, it is only the highest attaining students who are allowed to pursue more rigorous science courses (or any science) as they proceed through the school system. Moreover, routes outside of this ‘gold standard’ of promotion in science are very limited indeed. Such systems and policies may not only send strong messages about who can ‘do science’ (the very clever/high attaining) but also strongly act against a broader range of students continuing to pursue science. Put differently, if a child is interested—even strongly interested—in science, unless they are high attaining, there are almost no means by which they can pursue this interest within the school system. Participation is thus closed off to a wide range of individuals.

While considerations about messaging around careers and images of science itself might seem quite distant from students who may be years away from leaving school, we would argue that students begin to form ideas about ‘who does science’ from a very young age and that these ideas are strongly influenced by their families and experiences of school science. The ideas and images that students encounter at school and home are likely to connect to aspirations—by influencing students’ ability to imagine themselves in a science-related career. Moreover, these aspirations and images likely influence the choices they make, which, in turn, leads to the differential patterns of participation in post-compulsory science. Thus, in order to begin to level the playing field to one in which opportunities brought by participation in science are open to—and taken up by—a more diverse group of individuals, it would seem key to target factors that influence students’ ability to imagine a future for themselves in science, and begin to do so early.

Disclosure statement

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Notes

1. The weights assigned to the items comprising our measure of cultural capital and the borders between the groups are identical to those used in previous studies to facilitate comparison.
2. While all categories related to, for instance, cultural capital (very low, low, etc.) were entered into the analyses, only those significantly related to the outcome were retained in the model and are displayed in the table. Additionally, although interactions (e.g. gender \times ethnicity) were entered, these variables were not statistically significant and thus were not retained in the model.

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Appendix. Cronbach's alphas and sample items for survey components

| Component | Y6 Cronbach's alpha | Y9 Cronbach's alpha |
|---|---------------------|---------------------|
| Aspirations in science (5 items) (I would like to: study more science in the future, become a scientist, have a job that uses science, work in science; I think I could be a good scientist one day) | .899 | .919 |
| Engineering-related aspirations (2 items) (I would like to: work in engineering, be an inventor) | .663 | .665 |
| Attitudes towards school science (7 items) (Sample items: We learn interesting things in science lessons; Science lessons are exciting; Studying science is useful for getting a good job in the future) | .863 | .872 |
| Self-concept in science (7 items) (Sample items: I do well in science; I find science difficult; I learn things quickly in my science lessons) | .837 | .873 |
| Parental attitudes to science (3 items) (My parents: think science is interesting; would be happy if I became a scientist when I grow up; think it is important for me to learn science) | .691 | .782 |

(Continued)

Continued

| Component | Y6 Cronbach's alpha | Y9 Cronbach's alpha |
|---|------------------------|------------------------|
| Participation in science-related activities (5 items) (Sample items: Outside of school, how often do you: Read a book or magazine about science? Visit web sites about science? Watch a TV programme about science or nature?) | .704 | .776 |
| Parental ambition/expectations (4 items) ^a | .646 | .732 |
| Parental involvement (3 items) ^a | .566 | .694 |
| Peer orientation to school (4 items) ^a | .684 | .771 |
| Peer attitudes to science (2 items) ^a | .804 | .813 |
| Positive images of scientists (5 items) ^a | .717 | .738 |
| Stereotypical images of scientists (3 items) ^a | .618 | .735 |

^aA complete copy of the survey is available with the authors.