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Young Children's Aspirations in Science: The Unequivocal, the Uncertain and the Unthinkable

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**Young Children's Aspirations in Science:
The Unequivocal, the Uncertain and the Unthinkable**

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Running head: Children’s aspirations in science

For Peer Review Only

Young Children’s Aspirations in Science:
The Unequivocal, the Uncertain and the Unthinkable

Abstract

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8 Students' lack of interest in studying science and in science-related careers is a concern in the
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10 UK and worldwide. Yet there is limited data, particularly longitudinal, on the sources and
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12 development of science-related aspirations. In response, the ASPIRES (Science Aspirations
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14 and Career Choice: Age 10-14) longitudinal study is investigating the development of
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16 students' educational and occupational aspirations over time. In the first phase of the project,
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18 a questionnaire exploring science-related aspirations and interests was completed by over
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20 9000 primary school students across England. This survey allowed us to explore possible
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22 associations between attitudes and aspirations, links which have not been investigated in
23
24 previous attitudinal studies of this scope. Overall, students expressed positive attitudes to
25
26 science, reported positive parental attitudes to science and held very positive images of
27
28 scientists. Multilevel modelling analyses revealed that aspirations in science were most
29
30 strongly related to parental attitudes to science, attitudes to school science and self-concept in
31
32 science, and are also associated with students' gender, ethnicity and cultural capital.
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34 However, the images students held of scientists were not as closely related to aspirations.
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36 These factors are discussed in more detail within the paper, alongside a consideration of
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38 possible school-related effects.
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Young Children's Aspirations in Science:

The Unequivocal, the Uncertain and the Unthinkable

Students' lack of engagement with school science and the low numbers of individuals choosing to pursue the study of science in post-compulsory education are areas of substantial concern in many countries, particularly in Western, developed nations (European Commission, 2004; HM Treasury, 2006; National Academy of Sciences, 2005). A considerable body of evidence highlights how science fails to engage many young people (Jenkins & Nelson, 2005; Lyons, 2006; Lyons & Quinn, 2010). Moreover, although the majority of children seem to have positive attitudes to science around age 10 (Andre et al., 1999; Murphy & Beggs, 2005; Sturman et al., 2008), interest decreases considerably in the years that follow, particularly as students transition to secondary school (Hutchinson, Stagg, & Bentley, 2009; Osborne, Simon, & Collins, 2003), and ever-diminishing numbers of students choose to study science subjects as they progress through the educational system (Lyons & Quinn, 2010).

Evidence indicates that life-world experiences prior to 14 are the major determinant of any decision to pursue the study of science (Lindahl, 2007; Omerod & Duckworth, 1975; Royal Society, 2006). In particular, there seems to be a link between positive experiences of science and engagement with science later in life (Lindahl, 2007). Other research highlights an important link between the early aspirations or expectations and later educational and career choices and attainment (Beal & Crockett, 2010; Eccles et al., 2004), a relationship that extends to science subjects and careers. For instance, Tai et al. (2006) point to how early science aspirations are a better predictor of studying science at university than levels of achievement in school.

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Despite the links between early experiences and aspirations and later pursuit of science, relatively little work has explored the development of science-related aspirations, particularly among children younger than 14. Hence, the Science Aspirations and Career Choice: Age 10-14 (ASPIRES) project has begun a longitudinal study of how student educational and occupational aspirations, particularly in science, are formed over time. More specifically, the work examines how such aspirations may be related to factors such as gender, ethnicity and social class, as well as to students' peers, parents and experiences of school science. As well as the longitudinal survey, the ASPIRES study draws on data from interviews with students and their parents, to explore the development of aspirations in science – understood as students' desire to pursue science further in their schooling and as a potential career path. This paper reports the findings from the first survey, exploring primary school students' aspirations in science and identifying factors connected to those aspirations.

Formation of aspirations

Previous research has highlighted a number of factors that are potentially related to the formation of educational and occupational aspirations, including structural factors such as gender, ethnicity and social class. However, such relationships are not straightforward. For instance, UK research has shown that both boys and girls express high aspirations at ages 14-16, but these aspirations also reflect a gender dichotomy, with girls tending to express an interest in more 'traditionally female' occupations (Francis, 2002; Francis et al., 2003). In terms of ethnicity, students from some minority ethnic backgrounds (Indian, Pakistani, Bangladeshi and Black African) were more likely to have high educational aspirations and positive academic self-concepts than White British students (Strand 2007, 2011; Strand & Winston, 2008). In contrast, other research has found that 'race'/ethnicity were not connected to aspirations themselves, but that minority ethnic students perceived greater barriers to the

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2
3 attainment of their aspirations than did White students (Fouad & Byars-Winston, 2005;
4
5
6 McWhirter, 1997).

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8 The relationship between social class and aspirations is possibly even more complex.
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10 While research suggests that students from lower socioeconomic groups are as likely to want
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12 to continue into higher education and to pursue high status occupations as those from
13
14 wealthier backgrounds (Atherton et al., 2009; Bandura et al., 2001), they may be less likely to
15
16 be able to achieve them due to the structural inequalities they experience (Author 3 et al,
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18
19
20 2010a).

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22 A relationship between social class and aspirations also emerged in a recent
23
24 comprehensive study exploring the relationships between structural factors (gender, ethnicity,
25
26 social class) and aspirations (St Clair & Benjamin, 2011). When asked about their 'ideal
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28 job', aspirations were high among all 12-13 year-old-students, regardless of gender, ethnicity
29
30 or social class, and students were confident that they could achieve their aspirations.
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32 However, students from more deprived areas (from lower socioeconomic classes) were
33
34 marginally less likely than other students to expect to attain their ideal job (St Clair &
35
36 Benjamin, 2011), an expectation which would seem to be quite realistic in light of
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42 inequalities they are likely to face.

43 44 *Other influences on aspirations*

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46 Although the relationships identified above between aspirations and the structural
47
48 factors of gender, ethnicity and social class are important, research has identified other,
49
50 potentially more powerful, influences on aspirations ([including aspirations in science](#)). These
51
52 are parental or familial attitudes, student attitudes towards school science, self-concept in
53
54 science and perceptions of science and scientists. Because of the links between early
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56 aspirations and later educational and career decisions, it is therefore important to have a
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60 broad picture of these other possible influences on aspirations and choices as well.

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Parental influences on aspirations and choices, though myriad and complex, are certainly important. For example, parental support seems to play a strong role in academic and career development (Ferry, Fouad, & Smith, 2000; Keller & Whitson, 2008). In addition, parental support of math and science and related careers seemed to encourage career interests in math and science and related career aspirations and choices (Baker & Leary, 1995; Gilmartin, Li, & Aschbacher, 2006; Turner, Steward, & Lapan, 2004; Wang & Staver, 2001).

Another potentially key influence on aspirations in science could be students' experience of school science, although the relationship between attitudes towards school science and aspirations is not necessarily straightforward. Negative experiences of school science seem to deter students from decisions to pursue science further and to act as a barrier to science career aspirations (Aschbacher, Li, & Roth, 2010; Cleaves, 2005; Lyons, 2006; Osborne, Simon, & Collins, 2003). Conversely, teachers can inspire interest in science (Aschbacher, Li, & Roth, 2010; Stake, 2006). Additionally, positive experiences can contribute to enjoyment of science, which in turn encourages further pursuit of science (Asbacher, Li, & Roth, 2010; Bennett & Hogarth, 2009; Vidal Rodiero, 2007). However, other research has found experiences of school science to be unrelated to science career aspirations (Gilmartin, Li, & Aschbacher, 2006).

It seems likely, then, that experiences of school science are themselves insufficient to determine choice but rather that they act in conjunction with and through other factors, such as self-concept in science. For instance, Carlone and Johnson (2007) found that positive experiences of school science helped build competence and self-confidence, which contributed to persistence in science and to later science career aspirations. Recognition by others, such as teachers and parents, of one's competence can also bolster self-concept in science (Aschbacher, Li, & Roth, 2010; Hazari et al., 2010; Stake, 2006; Zeldin & Pajares, 2000). Positive self-concept or self-efficacy in science, in turn, can influence aspirations

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3 (Bandura et al., 2001; Ferry, Fouad, & Smith, 2000) as well as the educational or subject
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5 choices that are important steps on the path to attaining those aspirations (Cleaves, 2005;
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8 Murphy & Whitelegg, 2006; Simpkins, Davis-Kean, & Eccles, 2006; Vidal Rodiero, 2007).
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11 Another factor that has been posited to shape aspirations is the extent to which
12
13 individuals can imagine themselves in a particular occupation or field (Gilmartin, Li, &
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15 Aschbacher, 2006; Lyons & Quinn, 2010; Taconis & Kessels, 2009). As a corollary,
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17 aspirations in science would seem likely to be influenced by images or perceptions that
18
19 students have of scientists and those who work in science. Indeed, previous research suggests
20
21 that this is the case (e.g. Koren & Bar, 2009; Springate et al., 2008; Weisgram & Bigler,
22
23 2006). More specifically, the unappealing images held by some females of scientists'
24
25 lifestyles acted as a deterrent from the pursuit of a science-related career (Miller, Blessing, &
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27 Schwartz, 2006).
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32 Simply holding a positive image of scientists, however, may not be sufficient to
33
34 encourage an individual to pursue a career in science, as there often seems to be little overlap
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36 between students' self-perceptions and their perceptions of scientists (Bennett & Hogarth,
37
38 2009). That is, students may hold a positive view of those who work in science but still
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40 perceive them as 'not like me' and previous research has found that students hold a
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42 perception of science as important and valued but nonetheless 'not for them (Jenkins &
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44 Nelson, 2005). Such perceptions are likely to be exacerbated by students' lack of
45
46 understanding about what science careers actually involve (Cleaves, 2005).
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51 In discussing the potential influences of family, school science experiences, self-
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53 concept and images of scientists, we are not claiming that they are unrelated to structural
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55 factors such as gender, ethnicity and social class. Indeed, such influences are likely to play
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57 out differently within different structural groupings. For instance, considerable evidence
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59 reflects that boys and girls have differing attitudes towards or engagement with school
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3 science (c.f., Caleon & Subramaniam, 2008; Miller, Blessing, & Schwartz, 2006; Osborne,
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5 Simon, & Collins, 2003; Schmidt, 2010), though not necessarily at younger ages (Andre et al,
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7 1999; Greenfield, 1997). Boys and girls also seem to differ in their academic self-concepts,
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9 with boys tending to express more positive self-concepts (perceiving themselves as more
10
11 able) in science and maths than girls (Andre et al., 1999; Murphy & Whitelegg, 2006; Lyons
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13 & Quinn, 2010; Simpkins, Davis-Kean, & Eccles, 2006; Stake, 2006). Likewise, school
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15 science is also likely to be experienced differently by students of different ethnic, cultural and
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17 class backgrounds.
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22 In summary, previous research has identified the following factors as potentially
23
24 important influences on students' educational and occupational aspirations: parental attitudes
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26 toward science, attitudes toward school science, self-concept in science and perceptions of
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28 scientists. Other work highlights that gender, ethnicity and social class are also likely to be
29
30 related to aspirations. The relationships between such structural factors (gender, ethnicity and
31
32 social class) and aspirations, as well as those between attitudes and aspirations are necessarily
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34 complex, and may operate in different ways at different ages. Nevertheless, the importance of
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36 these relationships led us to incorporate such factors into our survey instrument, which we
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38 describe beneath.
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43 *Previous survey research on student attitudes and science aspirations*

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45 Despite the important links between aspirations and later educational and career
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47 choices, much of the work exploring the formation of aspirations and factors underpinning
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49 them has been qualitative in nature and/or on a relatively small scale. One important
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51 exception is the Programme for International Student Assessment (PISA) research, which
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53 includes measures of aspirations in science, as well as attitudinal measures (e.g. enjoyment,
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55 self-concept in science). Although it is a very rigorous instrument, PISA focuses on 15 year
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57 old students, whose aspirations are likely to be more solidified and who may have already
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3 begun to make subject and career choices. Thus, the PISA data cannot provide insight into
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5 earlier influences on student aspirations. There has also been some large-scale work on
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7 student attitudes to science and maths during primary school, such as the Trends in
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9 International Mathematics and Science Study (TIMSS), but this was relatively limited in the
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11 breadth and number of attitudinal questions asked and, critically, did not investigate
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13 aspirations. Although the TIMSS work is impressive in the size, scope and representativeness
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15 of its sample and provides an important overview of attitudes to science in primary schools,
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17 our work fills a key gap with its focus on aspirations at younger ages. The survey data
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19 reported in this paper seeks to answer the question of what factors may contribute to the
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21 formation of aspirations in science, as well as exploring the relationship between attitudes
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23 and aspirations in primary school children.
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29 Methods

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32 In order to gain a broad perspective on student aspirations and the factors related to
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34 them, a quantitative online survey has been administered to a sample of over 9000 students in
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36 their last year of primary school (Year 6 in English schools), who will be tracked and
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38 surveyed again at ages 12 and 14. As previous research (e.g. Osborne, Simon, & Collins,
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40 2003) has highlighted that is between the ages 10 to 14 that interest in science is diminished,
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42 the final year of primary school and second and third years of secondary school were selected
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44 as data collection points, in order to track this decline, identify possible contributory factors
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46 and explore how they interact and change over time. The current paper focuses on data from
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48 the first survey.
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52 *Survey Instrument*

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55 The development of the questionnaire instrument was an iterative process, initially
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57 drawing on existing instruments, an extensive body of qualitative literature (particularly
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59 concerning cultural capital and identity), and data gathered from six discussion groups with
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3 Year 6 pupils (Author 3 et al., 2010a). All of the constructs used in the initial version of the
4 questionnaire had a well-established empirical or theoretical base, contributing to the validity
5 of the instrument. For instance, previous research reflects the role that children's attitudes
6 toward school science might play in the development of science aspirations. Consequently, a
7 construct corresponding to attitudes toward school science was incorporated into the
8 questionnaire. Likewise, a measure of parental attitudes to science was also included, in line
9 with research described in the previous section. (As it was not possible to measure parental
10 attitudes to science directly in this survey, we included items about children's perceptions of
11 their parents' attitudes to science as a proxy.) To further support validity, existing instruments
12 – such as the Simpson-Troost Attitude Questionnaire – Revised (Owen et al., 2008) and the
13 'Is Science Me?' survey (Gilmartin et al., 2006) – were also drawn upon in creating items for
14 our questionnaire. (See Appendix 1 for sample items from our final questionnaire.)

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The initial version of our survey instrument was pilot-tested with 298 students ages 10-11, and principal components analyses and measures of internal consistency (such as Cronbach's alpha) were conducted on the pilot data to establish psychometric validity and refine the items and scales. Details of these analyses and how the questionnaire was developed, along with a thorough discussion of instrument validity, are published elsewhere (Author 1 et al., 2011).

The final version of the questionnaire was administered online in autumn 2009, with the majority of the items formatted as Likert scale items on a 5 point scale from 'strongly agree' to 'strongly disagree'. It also included a free-response question about aspirations, questions about school subject preferences and a measure of 'cultural capital' (as conceptualised by Bordieu, 1984, comprising for example credentials/qualifications and cultural knowledge and resources). A complete copy of the questionnaire is available from

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3 the authors, but sample items (comprising approximately half of the total number) can be
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5 found in Appendix 1.
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8 Reliability and validity analyses were carried out, using principal components
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10 analysis and Cronbach's alpha to determine the unidimensionality and internal consistency of
11
12 our scales. Missing data in this analysis was handled by using the modal value (for the
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14 sample) of any item left blank by an individual student. (The percentage of data missing was
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16 less than 1.5% per item, for all but 4 items.) The principal components analysis revealed 15
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18 resolvable components, including: aspirations in science, engineering-related career
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20 aspirations, participation in science-related activities outside of school, parental attitudes to
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22 science, parental aspiration/ambition for their children, parental involvement with (their
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24 children's) schooling, peer orientation to school, peer attitudes to science, attitudes to science
25
26 lessons, self-concept in science, images of scientists (positive and stereotypical) and
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28 occupational values (three components). Cronbach's alpha for all but two of these dimensions
29
30 were within an acceptable range for attitudinal instruments used with children (above .6). See
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32 Appendix 1 for the Cronbach's alphas and sample items for these components. These
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34 components are also the same as those identified in the analyses of the pilot questionnaire
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36 (Author 1 et al, 2011).
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43 *Sample*

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45 9319 students from 279 schools completed the survey. Of these schools 248 were
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47 state (public) schools and 31 were independent (private) schools. This sample represented all
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49 regions of England and was approximately comparable to the overall national distribution of
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51 schools in England by attainment and proportion of students eligible for free school meals.¹
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55 Of the 9319 students, 50.6% were boys and 49.3% were girls. 846 (9.1%) attended
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57 private schools and 8473 (90.9%) attended state schools. Because the study focuses in part on
58
59 the impact of ethnicity on students' aspirations, schools with higher populations of ethnic
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3 minority students were deliberately over-recruited to ensure sufficient numbers for analysis.
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6 Consequently, there are fewer white students (74.9%) in the sample than in all primary
7
8 schools in England (78.5%). Otherwise, the sample is comparable to proportions of students
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10 from various racial and ethnic groups in English primary schools, with 8.9% of South Asian
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12 heritage (Indian, Pakistani, Bangladeshi), 7.5% Black (primarily Black African and Black
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14 Caribbean heritage), 1.4% Far Eastern (Chinese, Japanese, Korean heritage), and 7.8% of
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16 students from a mixed or other ethnic background. Due to the contested and problematic
17
18 nature of constructions of 'race'/ethnicity (as well as a pragmatic need to reduce the burden
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20 of information requested from schools), ethnic categories were supplied by students
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22 themselves. Consequently, they may not be as 'accurate' as those from official sources, but
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24 discussion groups with students suggested that most were able to provide a description of
25
26 their ethnic heritage.
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32 Measures of social class were more challenging to obtain and parental occupation was
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34 used as an indicator of social class. However, many children at this age have difficulty
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36 providing sufficient information about what their parents do in order to clearly determine
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38 occupation. Thus, although questions about parental occupation were pilot tested extensively,
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40 findings about social class/parental occupation should be treated with caution. In attempting
41
42 to gain some picture of the social class of participants, students were assigned to categories
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44 based on whichever parent's occupation indicated a higher social class. For instance, if one
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46 parent was a doctor and the other worked in a shop, the child was assigned to the
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48 'professional' category of social class. Overall, of the nine categories used 35.2% of our
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50 sample had a parent in a professional or managerial occupation (two categories combined),
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52 21.1% in a skilled occupation, 21.3% in semi-skilled or unskilled occupation (two categories
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54 combined), and 8.8% in 'some other job' (at least one parent worked, but occupation was
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3 impossible to determine). Of the remainder, 1.3% were classified as students, 6.2% as
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5 unemployed and 6.3% as unknown.
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8 As noted above, the survey also included questions pertaining to 'cultural capital'
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10 (e.g. parental university attendance, leaving school before age 16, approximate number of
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12 books in the home, frequency of museum visitation). These questions were used to gain an
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14 overall measure of a student's cultural capital which could be used in analysis. For simplicity,
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16 students were grouped into five cultural capital categories: very low (2%), low (23.3%),
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18 medium (34.1%), high (20.3%) and very high (20.3%).
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22 *Analyses*

23
24 Following the reliability and validity analyses described previously, the latent
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26 variables (components) that emerged from the principal components analysis (e.g. aspirations
27
28 in science, attitudes toward school science and others found in Appendix 1) were utilized to
29
30 explore patterns in children's responses, including by gender, ethnicity, social class and
31
32 cultural capital. More specifically, descriptive analyses and comparison of standardized
33
34 means (including t-tests) were used to gain an overview of the data. Next, multi-level
35
36 modelling (MLM) analyses were conducted using MLWin software to further investigate
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38 factors that may contribute to students' aspirations in science and to explore the relations
39
40 among them. Similar to regression, MLM analyses allow identification of variables that
41
42 explain or account for significant amounts of variance in an outcome variable of interest. For
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44 instance, they can identify which combination of independent variables (e.g. gender, attitudes
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46 to school science) best explains the variation in students' aspirations in science. The key
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48 advantage of multilevel models is that they recognise that students' responses are contained
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50 in a set that comes from a common source (each of their schools). Due to this recognition,
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52 MLM analyses provide a more accurate measure of standard error compared with standard
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54 regression analysis. Consequently, it is less likely that independent variables will be included
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3 in the final model that are not significantly related to the outcome variable (Type 1 errors are
4 less likely), increasing the accuracy of the model (or the accuracy our picture of variables
5 associated with an outcome).
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10 Carrying out the multilevel analyses involved a two stage process. In the first stage,
11 an unconditional or base model, which included no independent variables, was constructed
12 for the outcome variable. This model gave a measure of the variance at the pupil and school
13 level for the outcome variable (i.e. aspirations in science). Second, all of the categorical
14 variables (gender, ethnicity, school type, parental occupation and cultural capital²) were
15 entered into the analysis, along with latent variables most strongly correlated with the
16 outcome measure. Variables that did not contribute significantly to a reduction in the pupil-
17 level variance from the base model on the outcome variable (i.e. aspirations in science) were
18 successively removed from the model.
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31 At the end of this process, the only independent (predictor) variables remaining in the
32 model were those whose relationship with the outcome measure was statistically significant.
33 Finally, effect sizes were calculated for these variables according to the principles outlined in
34 Schagen and Elliot (2004), to determine the relative strength of the relationships between the
35 independent variables and the outcome variable.
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43 *Limitations*

44 One of the strengths of multilevel modelling is its ability to provide a more accurate
45 account of nested data and to incorporate, for example, both pupil-level and classroom-level
46 variables. However, resource limitations made the collection of classroom-level data (such as
47 years of experience of the students' teacher) unfeasible. Moreover, our decision to include
48 private schools in the sample meant we were not able to include school-level data available
49 from the UK National Pupil Database such as attainment (as it was not available for the
50 private schools in our sample).
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Findings

Overview

In the first stages of analysis, student responses to the items in each of the 15 components identified by the principal component analyses were scored (e.g., strongly disagree = 1, disagree = 2, strongly agree = 5, and so forth) and summed across items to create 15 latent variables. Of course, scores on latent variables such as 'parental attitudes to science' or 'peer orientation to school' do not reflect parental and peer attitudes directly, but rather children's perceptions of those attitudes.

Because latent variables were comprised of different numbers of items, their means were standardised on the most common range of 5 to 25. Table 1 reflects the standardized means for the six latent variables most relevant to aspirations in science, which were the ones used in the multilevel modelling analyses. (The remaining latent variables, [along with sample items for each](#), are listed in Appendix 1.)

--- Insert Table 1 about here ---

Overall, students expressed quite positive attitudes to science, both in school and out, held positive self-concepts in science, reported positive parental attitudes to science and seemed to hold very positive images of scientists. Looking in more detail at the items comprising the attitudes toward school science latent variable, 73.8% of students agreed or strongly agreed that they learn interesting things in science lessons and 58.1% even agreed or strongly agreed with the item 'science lessons are exciting'. This would seem to be comparable, or perhaps slightly higher, than the 59% of Year 5 students (in England) in the high group for 'positive affect towards science' in the 2007 TIMSS survey (Sturman et al., 2008).

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4 Drawing on the parental attitudes to science latent variable, 72.4% of students in our
5 sample believed that their parents think it is important to learn science and nearly 60%
6 asserted that their parents think science is interesting. Such measures were not included in
7 TIMSS and show that parental support for the study of science at this age was positive.
8
9 Turning to the items in the positive views of scientists latent variable, results reflect that over
10 60% of students agreed or strongly agreed with statements that scientists and people who
11 work in science can make a difference in the world (76.7%), make a lot of money (66.2%)
12 and are respected (60.3%). However, these positive experiences and images do not
13 necessarily translate directly into strong aspirations in science, with 28.5% of students
14 claiming they would like to have a job using science, 23.4% agreeing they would like to work
15 in science and only 16.6% agreeing that they wanted to 'become a scientist'. (See Appendix 1
16 for the five items comprising aspirations in science latent variable.) These differences are also
17 reflected by t-tests comparing the standardized means of the latent variables in Table 1,
18 which show that the mean of the aspirations in science variable (13.67) was significantly
19 lower than the mean for parental attitudes to science ($t(9318)=104.18, p < .001$), attitudes
20 toward school science ($t(9318)=122.29, p < .001$), and positive images of scientists
21 ($t(9318)=108.7, p < .001$).

22 *Aspirations in science*

23
24 Outcomes from the MLM analyses, summarised in Table 2, revealed that the
25 following variables were most strongly related to students' aspirations in science: Gender,
26 ethnicity, cultural capital, parental attitudes to science, attitudes towards school science and
27 self-concept in science. More specifically, girls, students of mixed Black and White ethnicity,
28 and those with lower levels of cultural capital had lower aspirations in science relative to
29 other students (e.g. boys, White students, those with medium levels of cultural capital),
30 whereas students of South Asian heritage (Indian, Pakistani, Bangladeshi and 'other' South
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3 Asian) expressed higher aspirations in science. In addition, students reporting more positive
4
5 parental attitudes to science tended to have higher aspirations in science, and those whose
6
7 self-concept in science and attitudes to school science were more positive also tended to have
8
9 higher aspirations in science.
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15 --- Insert Table 2 about here ---
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19

20 In the base model, 6% of the variance in the outcome variable (aspirations in science)
21
22 is attributable to the school level and 94% to the student level. The final model, presented in
23
24 Table 2, explains 50.5% of that 94%. That is, the combination of independent variables
25
26 summarised in Table 2 can account for nearly half of the variation in student scores on the
27
28 aspirations in science dependent variable. For the sake of clarity, only those variables that
29
30 remained in the model (those that accounted for a significant amount of the variance in
31
32 aspirations in science) are included in the table.
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35

36 Although the relationship between each of these variables and the aspirations in
37
38 science variable was strong enough to be included in the model, in that each independent
39
40 variable accounted for a statistically significant amount of variance in the aspirations in
41
42 science outcome variable, an analysis of effect sizes revealed that some of these relationships
43
44 were considerably stronger than others. Parental attitudes to science and attitudes to school
45
46 science had the strongest relationships with aspirations in science (with effect sizes of 0.44
47
48 and 0.53, respectively³), followed by membership in one or the other of two small ethnic
49
50 groups ('other' South Asian and Chinese, which comprised 40 and 70 students, respectively),
51
52 and self-concept in science (effect size of 0.20). All of the other relationships, including that
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54 between gender and aspirations, were very small, especially the relationship between cultural
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56 capital and aspirations. This pattern suggests that although the relationship between, for
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3 example, gender and aspirations is statistically significant, gender does not have nearly as
4
5 much influence on students' aspirations as parental attitudes toward science or attitudes
6
7 towards school science. That gender should be related to aspirations in science but less
8
9 strongly than other variables should not be surprising, in light of previous research indicating
10
11 that gender differences in attitudes toward science at this age are relatively small (e.g. Ceci,
12
13 Williams & Barnett, 2009; Murphy & Beggs, 2005).
14
15

16 17 *Influence of schools on aspirations*

18
19 Analyses identified that school variance (put simply, the schools that children attend)
20
21 does account for a significant proportion of the variance in the aspirations in science outcome
22
23 variable. This effect is reflected in the intra-school correlation of 0.031 for the aspirations in
24
25 science latent variable, which is not unusual for an attitudinal questionnaire (S. Rutt, pers
26
27 comm., 2010).
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31
32 Although the size of the effect of the school variance on aspirations in science was not
33
34 exceptionally large (indeed, the proportion of explained variance in the outcome measure at
35
36 school level is only 8.7%, compared with 91.3% at pupil level), one feature is worth noting.
37
38 In Table 2 above, the latent variable 'parental attitudes to science' is listed under 'random
39
40 effects'. This means that the slope and intercept of the relationship between these two
41
42 variables (aspirations in science and parental attitudes to science) were allowed to vary
43
44 among schools. (Doing so increased the amount of variance in the outcome the model was
45
46 able to explain.) As Table 2 sets out, the covariance between the slope and intercept is
47
48 positive, reflecting that the slopes of the lines depicting this relationship for each of the
49
50 schools in the sample diverge. In other words, there is a greater variation in aspirations in
51
52 science among schools when parental attitudes to science are more positive than when they
53
54 are less positive. This relationship is portrayed in Figure 1 and represented schematically by
55
56 Figure 2, below.⁴ In some schools, the relationship between parental attitudes to science and
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3 aspirations in science is similar to that of 'School A' and for others, this relationship is
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5 similar to that of 'School B'.
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10 --- Insert Figures 1 and 2 about here ---
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15 As Figure 2 indicates, in some schools (such as School A), positive parental attitudes to
16 science are related to higher aspirations in science than in other schools (such as School B).
17 This divergence suggests that some schools are doing more to 'capitalise' on these positive
18 parental attitudes than others. The analysis shows that there were no significant differences
19 between state and private schools on the aspirations outcome variable, and resource
20 limitations prohibited exploration of other possible school differences (e.g., time devoted to
21 practical work, teacher enthusiasm for science, differences in curriculum implementation).
22 Identifying possible causal factors remains a question of interest for further research.
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34 *Factors underpinning aspirations in science*

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36 In order to gain a clearer picture of students' aspirations in science, it is helpful to
37 examine the factors related to those aspirations in greater depth. Consequently, further MLM
38 analyses were conducted on the three latent variables that accounted for a significant
39 proportion of the variance in students' aspirations in science: attitudes toward school science
40 self-concept in science and parental attitudes to science. Details of the models constructed for
41 each of these latent variables and associated effect sizes are available from the authors but the
42 salient findings are summarised here.
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53 The attitudes towards school science latent variable was most closely related to
54 aspirations in science. MLM analyses revealed that the following variables accounted for a
55 significant proportion of the variance in students' attitudes towards school science: parental
56 occupation (proxy for social class), ethnicity, aspirations in science, parental attitudes to
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3 science, self-concept in science, peer attitudes to science and positive images of scientists.
4
5 More specifically, South Asian, Black African and 'Other' Far Eastern students tended to
6
7 have more positive attitudes to school science relative to White British students. Additionally,
8
9 students from ostensibly lower social classes also expressed more positive attitudes towards
10
11 school science, while those whose parents were in managerial and professional occupations
12
13 seemed to have less positive attitudes. Finally, those students with higher aspirations in
14
15 science, those who reported more positive parental and peer attitudes to science, those
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17 holding more strongly positive images of scientists and those with more positive self-
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19 concepts in science tended to have more positive attitudes to school science.
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25 This combination of variables accounted for a considerable proportion of the variance
26
27 in student scores on the attitudes to school science latent variable (62%). However, analyses
28
29 of effect sizes revealed that parental occupation and ethnicity (effect sizes ranging from 0.06
30
31 to 0.17) were not as strongly correlated with attitudes to school science as the five latent
32
33 variables included in the model: aspirations in science, self-concept in science, positive
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35 images of scientists, peer and parental attitudes to science (effect sizes ranging from 0.23 to
36
37 0.42).
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41 The MLM analyses of student aspirations in science (Table 2) also found self-concept
42
43 in science to be closely related to aspirations. The self-concept in science latent variable was
44
45 comprised of seven items, four of which were very similar to the items forming the index of
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47 students' self-confidence in science in the 2007 TIMSS. Similar to the TIMSS outcomes, our
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49 survey respondents also expressed positive self-concepts in science, with 67% agreeing (or
50
51 strongly agreeing) they do well in science, 56.5% agreeing they learn things quickly in
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53 science lessons and 58.5% disagreeing that they are 'just not good at science'. This pattern of
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55 responses would seem to be broadly comparable to the TIMSS 2007 finding that 55% of
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57 English students expressed high self-confidence in learning science (Sturman et al., 2008).
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3 MLM analyses revealed that students' self-concepts in science seem to be related to
4
5 ethnicity, gender, social class (as reflected in parental occupation) and cultural capital, as well
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7 as to aspirations in science and attitudes to school science. In line with previous multilevel
8
9 models, students with stronger aspirations in science and more positive attitudes to school
10
11 science were more likely also to express more positive self-concepts in science. Additionally,
12
13 similar to the TIMSS 2007 findings for Year 5 students on their index of self-confidence in
14
15 learning science (Sturman et al., 2008), our MLM analyses revealed less positive self-
16
17 concepts among girls relative to boys (although there were no gender differences on the
18
19 measure of attitudes towards school science). Such a finding is also in alignment with other
20
21 research that has found similar differences between girls and boys (c.f. Andre et al., 1999;
22
23 Lyons & Quinn, 2010; Osborne, Simon, & Collins, 2003). Nevertheless this relationship is
24
25 very small (effect size = -0.06) and, indeed, the relationships between the ethnicity, class and
26
27 cultural capital variables and self-concept were considerably weaker than those between
28
29 attitudes to school science and self-concept (effect size = 0.67) and between aspirations in
30
31 science and self-concept in science (effect size = 0.24).
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39 Finally, looking at the parental attitudes to science latent variable, MLM analyses
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41 reflected that ethnicity, social class, cultural capital, aspirations in science and attitudes
42
43 toward school science are the variables most closely related to parental attitudes. More
44
45 specifically, girls, Pakistani students, students whose parents are involved in professional
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47 occupations and those with higher levels of cultural capital are likely to report more positive
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49 parental attitudes to science, whereas those with lower levels of cultural capital are likely to
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51 report less positive parental attitudes to science. That only Asian students of Pakistani
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53 heritage report more positive parental attitudes to science relative to White British students is
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55 also intriguing because there is no evidence that Pakistani parents should be different from
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3 other South Asian parents in this respect. The effect may be spurious, but it will be interesting
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5
6 to note if it continues as students progress through school.
7

8 As with the other three multilevel models constructed in these analyses, the latent
9
10 variables have stronger relationships with the outcome variable (parental attitudes to science)
11
12 than do the categorical variables. That is, the effect sizes for aspirations in science (0.52) and
13
14 attitudes toward school science (0.45) are higher than those for the categorical variables
15
16 (ranging from 0.08 to 0.16).
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20 The MLM analyses summarised in this section highlight a group of factors which are
21
22 related to each other and to student aspirations in science. An emergent picture appears where
23
24 scores on the aspirations in science variable seem to be influenced particularly by attitudes
25
26 toward school science and self-concept in science, which, in turn, are closely related to each
27
28 other. Scores on the aspirations variable are also strongly associated with parental attitudes to
29
30 science, which are themselves linked to attitudes to school science. Although MLM analyses
31
32 show correlational relationships, rather than causation, logic suggests that a student's
33
34 aspirations in science may be influenced by, for example, their attitudes toward school
35
36 science rather than the other way around. We acknowledge, though, the likelihood that the
37
38 links between all of these factors – aspirations, self-concept, attitudes toward school science
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40 and parental attitudes to science – are more complex and nuanced than a unidirectional
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42 relationship would imply.
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48 *The enthusiastic and the disinterested* 49

50 Previous analyses reflect that some students have stronger science-related aspirations
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52 than others. Indeed, despite the generally positive attitudes students hold towards school
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54 science, their positive self-concepts in science, positive parental attitudes towards science,
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56 and very positive images of scientists and their work, there seems to be a group of students
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3 for whom pursuit of science (particularly as a career) may already be 'unthinkable', as
4 suggested by the histogram of student scores on the aspirations in science latent variable.
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10 --- Insert Figure 3 about here ---
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15 Examination of the students whose responses formed both spikes (at the low and high ends of
16 the distribution) revealed no response biases. For example, although the 648 students in the
17 low group responded 'strongly disagree' to all five items comprising this latent variable ('I
18 would like to study more science in the future', 'I would like to have a job that uses science'
19 and so forth), their responses to other items on the survey were varied and without patterns
20 that would give rise to concern. Moreover, it appears that the groups forming the high and
21 low spikes are essentially 'amplifications' of trends seen in the MLM analyses for the
22 aspirations in science latent variable. That is, in terms of composition of the groups, the low
23 group, who seem to be disinterested even at this age in pursuing science any further than
24 absolutely necessary, contains proportionally fewer South Asian students (5.1%) than the
25 overall sample (8.9%). Conversely, the high group, albeit smaller with 251 students, contains
26 proportionally more students of South Asian heritage (12.7%) than the sample as a whole.
27
28 Although the gender differences on the aspirations in science latent variable were very small,
29 the high group contained proportionally more boys (63.3%) than in the complete sample
30 (50.6%). Analysis of subject preferences also reflects that 67.2% of the high group selected
31 science as their favourite school subject, in comparison with 13.3% of the complete sample.
32
33 Additionally, the means for the three latent variables most closely associated with aspirations
34 in science (attitudes towards school science, parental attitudes to science, self-concept in
35 science) were also in alignment with these trends, with means for the disinterested group
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3 lower than the sample mean and those for the enthusiastic higher than the sample mean for
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5 each of those three variables.
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8 These findings suggest, then, that there is already a group of students for whom
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10 science may be an 'unthinkable' identity. Conversely, there is also a smaller group who are
11
12 exceptionally eager to pursue science.
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15 Discussion

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17 With the survey described in this paper, we set out to investigate the aspirations in
18
19 science held by students in their last year of primary school and to identify and explore
20
21 factors that may be linked to these aspirations. Taken together, our analyses point to an
22
23 emergent picture where aspirations in science are closely related to attitudes toward school
24
25 science lessons, self concept in science and parental attitudes to science. Our analyses also
26
27 investigated the relationship between structural factors, embodied in the categorical variables
28
29 of gender, ethnicity, social class and cultural capital, and aspirations. The data suggest that
30
31 there are differences among groups of students along lines of gender, ethnicity, social class
32
33 and cultural capital, generally in alignment with what might be expected from previous
34
35 research. For instance, as in other work (e.g. Andre et al., 1999; Jovanovic & King, 1998;
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37 Kessels & Hannover, 2008; Schmidt, 2010 and in maths, see Correll, 2001; Simpkins et al,
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39 2006) girls in our study expressed weaker aspirations in science and less positive self-
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41 concepts in science than boys. However, there were no gender differences in attitudes toward
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43 school science nor in reports of parental attitudes to science.
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50 Our analyses also revealed that South Asian students (i.e. students of Indian,
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52 Pakistani, Bangladeshi or other South Asian heritage) had stronger aspirations in science
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54 compared with White students. They also tended to express more positive attitudes toward
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56 school science. Other research, although not focused specifically on science, has found more
57
58 positive attitudes towards school and higher educational aspirations among at least some
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3 Asian subgroups, relative to White students (e.g. Elias et al, 2006; Strand, 2007, 2011; Strand
4 & Winston, 2008), which is in alignment with our findings. However, the multilevel
5
6 modelling analyses in the present study show that these structural factors (e.g. gender,
7
8 ethnicity) seem to play a very small part in the formation of students' aspirations, at least at
9
10 Year 6, and that other factors such as parental attitudes to science and attitudes towards
11
12 school science have a stronger role.
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17 Our survey findings are also consistent with previous work, much of which was
18
19 qualitative in nature, around other factors that may impact career aspirations in science and
20
21 decisions about whether or not to pursue science at higher levels. For instance, other studies
22
23 have found that subject choice and career aspirations can be impacted by parents, although
24
25 this influence operates in a very complex and nuanced way (e.g. Atherton et al., 2009; Baker
26
27 & Leary, 1995; Bleeker & Jacobs, 2004; Diemer, 2007; Jacobs et al., 1998; Turner, Steward,
28
29 & Lapan, 2004), by self-perceptions or self-concept (e.g. Andre et al., 1999; Bandura et al.,
30
31 2001; Haussler & Hoffmann, 2002; Simpkins et al. 2006; Vidal Rodiero, 2007), which can in
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33 turn be influenced by recognition of ability by others and encouragement (e.g. Aschbacher,
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35 Li, & Roth, 2010; Carlone & Johnson, 2007; Stake, 2006; Zeldin & Pajares, 2000), and by
36
37 experiences of school science (e.g. Aschbacher, Li, & Roth, 2010; Carlone & Johnson, 2007;
38
39 Fraser & Kahle, 2007; Lyons, 2006; Osborne, Simon, & Collins, 2003; Vidal Rodiero, 2007).
40
41 When such factors are negative (e.g. if they have negative self-concepts in science), students
42
43 are less likely to make choices that would lead to science-related careers. Similarly, our
44
45 survey has found that more positive parental attitudes to science, self-concept in science and
46
47 experience of school science were associated with higher aspirations in science (and vice
48
49 versa). That our survey findings were similar to previous qualitative research (and
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51 quantitative research involving smaller samples) serves to bolster confidence in the emerging
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53 picture of the influences on student aspirations.
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3 Further analyses of the factors most closely related to aspirations in science (attitudes
4 towards school science, parental attitudes to science, self-concept in science) reflected that
5
6 these factors are also related to each other. That is, there seems to be a cluster of inter-related
7
8 factors that may reinforce each other and support the development of aspirations in science.
9
10 Indeed, it is possible that such a group may contribute to an environment in which aspirations
11
12 in science can flourish. Our results reflected that the schools children attend also play a role
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14 in their scores on the aspirations in science latent variable, but the analyses were not able to
15
16 identify any particular characteristic of the schools (such as state vs private) that could
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18 explain this influence. Perhaps it is some other characteristic of certain schools – such as the
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20 presence of an enthusiastic teacher – that is adding to an environment supportive of science-
21
22 related aspirations.
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29 Looking more closely at those factors most related to aspirations in science also
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31 revealed that students' attitudes toward school science are generally positive overall, as are
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33 their self-concepts in science, findings similar to TIMSS 2007. Additionally, we found that
34
35 students generally reported positive parental attitudes toward science. It is possible that it is
36
37 parental valuing of efforts in schooling or encouragement of high aspirations generally, rather
38
39 than parental attitudes to science *per se*, that is supporting aspirations in science. However, as
40
41 seen in Appendix 1, there were components in our survey to measure parental involvement in
42
43 their children's education and parental ambitions for their children, but neither of these
44
45 factors were related to aspirations in science. Thus, it would seem that there is something
46
47 specific about parental attitudes to science as such that may be encouraging science-related
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49 aspirations, a possibility that is supported by previous research (e.g. Gilmartin, Li, &
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51 Aschbacher, 2006).
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57 As for the impact that peer attitudes may have on choices and aspirations in science,
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59 the findings of previous research are more ambiguous. While research suggests that peers
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3 may have some influence on attitudes, choices and aspirations, this relationship does not
4
5 seem to be direct, individuals may not be aware of its influence on them, and it may also vary
6
7 with age (e.g. Aschbacher, Li, & Roth, 2010; George, 2006; Jacobs et al., 1998; Panizzon &
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9 Levins, 1997; Springate et al., 2008; Stake & Nickens, 2005). It is perhaps not surprising,
10
11 then, that our analyses did not find peer attitudes to science (or to school) to be closely related
12
13 to student aspirations in science, although they were correlated with attitudes to school
14
15 science.
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20 Likewise, despite previous research indicating the influence of images of science and
21
22 scientists on students' educational choices and aspirations (e.g. Bennett & Hogarth, 2009;
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24 Koren & Bar, 2009; Miller, Blessing, & Schwartz, 2006; Weisgram & Bigler, 2006; Wyer,
25
26 2003), the current study did not reveal an association between images of scientists (either
27
28 positive or stereotypical) and aspirations in science. This may be partly due to the generally
29
30 positive images students in our study have of scientists and lack of variation in their scores on
31
32 this latent variable (see Table 1). It is also possible that influences of peer attitudes and/or of
33
34 images of scientists on aspirations may be operating in too subtle a manner to be picked up
35
36 by a survey instrument. Alternatively, it could be that such influences will become stronger as
37
38 children progress through school and thus may appear in subsequent survey data.
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43 Although the findings from the current study are generally in alignment with previous
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45 research – and serve to broaden and enrich the picture of what is known about aspirations
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47 among students of this age, some issues remain unresolved about these aspirations and future
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49 choices. That is, even though 40% of students agreed that they would like to study more
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51 science in the future, 29% would 'like to have a job that uses science' and 31% even think
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53 they would be capable of being good scientists, only 17% agreed that they would like to
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55 'become a scientist'. This pattern suggests that future engagement with science – even as part
56
57 of a career – is imaginable and desirable for many pupils, but that 'being' a scientist is
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3 already undesirable or even unthinkable for the majority, even at age ten. Thus, it seems that
4
5 although students' positive attitudes about science could be contributing to an interest in
6
7 pursuing science further, there is nevertheless a reluctance to take up an identity as a scientist
8
9 or to embrace a scientist identity as a possible future self (Markus & Nurius, 1986; Stevenson
10
11 & Clegg, 2011). Even at this relatively young age, then, it seems that for some students –
12
13 particularly those in the group of 648 with the lowest possible score on the aspirations in
14
15 science latent variable – scientist is already an 'unthinkable identity'. This finding also
16
17 suggests that careers education or classroom interventions intended to engage students with
18
19 careers in and from science need to begin much earlier than ages 14 or 15, and possibly as
20
21 early as primary school.
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26 27 Conclusions and implications

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29 Although the data presented here provide some insights into 10-11 year olds'
30
31 aspirations in science, survey data can only provide an overview of the landscape. Thus, the
32
33 broader ASPIRES study has used data from interviews with students and parents to provide a
34
35 richer picture of these aspirations and to explore in more depth the patterns underlying them.
36
37 These data will be used moving forward in the project to provide insight and an explanatory
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39 analysis in terms of the distinction students draw even at this age between 'doing science'
40
41 (which they enjoy) and 'being a scientist' (which is considered with reluctance and is not
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43 something to which the majority aspire).
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49 The discrepancy between the positive experiences and attitudes toward science in
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51 school and out, including impressions of scientists, and the significantly less positive
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53 aspirations in science expressed by these students who are still in primary school (as reflected
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55 by their scores on the aspirations in science latent variable) is striking and contributes to an
56
57 understanding of how aspirations in science emerge and develop over time. Put differently, it
58
59 has the potential to shed light on the early formation of attitudes and aspirations later
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3 measured by studies with older children, such as PISA. Importantly, although much of the
4 value of our survey will be the baseline it offers for comparison as students mature, its size
5
6 enables us to observe influences that social class, gender, and ethnicity may be exerting on
7
8 aspirations, even at this relatively young age. Despite the statistical power of the survey to
9
10 detect such group differences, the findings indicate that they are minor among Year 6
11
12 students. While aspirations can shift considerably, previous research would suggest that as
13
14 children progress through school, interest in pursuing science tends to decrease (Jenkins &
15
16 Nelson, 2005; Lyons & Quinn, 2010; Osborne, Simon, & Collins, 2003). Thus, the
17
18 emergence of a tension between positive regard for 'doing' science and lack of interest in
19
20 'being' a scientist in the attitudes of students still in primary school highlights that educators,
21
22 researchers and policymakers need to do more to address issues around science aspirations,
23
24 including by supporting a wider, more inclusive image of science and scientists among young
25
26 students before they finish primary school. Moreover, it is not simply a matter of providing
27
28 'positive images' of scientists, as students already hold such views, but rather there is a need
29
30 to broaden students' perceptions of scientists and science-related careers. Doing so could, in
31
32 turn, increase opportunities for more students to adopt a vision of a career in science as
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34 something that might be 'for me'.
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44 Additionally, the relatively minor influence of structural variables (gender, ethnicity,
45
46 social class) overall suggests that targeting specific groups in an attempt to raise aspirations
47
48 in science may not be as fruitful an approach as a more sophisticated tailoring that takes a
49
50 wider range of attitudes and characteristics into account. A series of interviews with 92
51
52 primary school children and 76 of their parents also conducted as part of our wider study
53
54 highlighted a number of different types of relationships that families have with science. That
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56 these relationships intersect with, but do not fall neatly along, ethnic or class lines reinforces
57
58 the case for utilising a range of approaches, including working with families, and avoiding a
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3 narrow focus on specific structural groups, in efforts to broaden students' career horizons
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5
6 (Author 3 et al, 2010b).
7

8 While positive attitudes towards science are not translating directly into aspirations in
9
10 science, there do seem to be some positive foundations which could also be nurtured to
11
12 encourage ongoing engagement with science. At the same time, the findings of the current
13
14 study raise questions that are still unresolved in education and policy discourses around
15
16 aspirations in science. Firstly, what are the implications for policy and educational practice of
17
18 groups of students who appear to be quite set in their views at this age? Put differently, what
19
20 educational interventions or structures should be implemented to best engage those students
21
22 for whom work involving science is already 'unthinkable', as well as for those students who
23
24 are particularly eager to pursue a science-related path? Responses to these questions, though,
25
26 are at least partly contingent on the goals for science education.
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31 Related to the issue of goals for science education is the second question arising from
32
33 our findings about aspirations in science. More specifically, 17% of our respondents agreed
34
35 that they would like to 'become a scientist', while 29% were interested in a 'job that uses
36
37 science'. But what proportion of students 'should' have aspirations in science at this age? Not
38
39 only is there no clear and definitive answer to this question (Tytler et al., 2008), the answer
40
41 itself is closely tied to goals for science education. Do societies want to encourage the
42
43 intrinsic value of a knowledge of science and the development of a scientifically literate
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45 population? Or are they really more concerned with sustaining the supply of scientists and
46
47 engineers (leaving aside the question of what constitutes a 'sufficient' supply)? Is the primary
48
49 function of school science a training or an education? These questions form part of an
50
51 ongoing policy debate. Moreover, the answers will not only help frame how to respond to the
52
53 question of what proportion of students 'should' have aspirations in science, but will also
54
55 help define what is meant by aspirations – to 'be a scientist'? To 'have a job that uses
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3 science'? To 'study more science in the future'? Additionally, despite previous research
4
5 highlighting the influence of early aspirations in science on later educational decisions (Tai et
6
7 al., 2006), it remains unclear what proportion of students should express aspirations in
8
9 science (and what kind of science-related aspirations) in late primary school in order to
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11 increase the likelihood of a particular 'desired' proportion of students pursuing science post-
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16 16.

17
18 Although the current work probably raises more questions than it answers, it does
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20 provide some interesting insights into student aspirations at this age and the kinds of factors
21
22 that are associated with these aspirations. In this way, it complements and builds on previous
23
24 work, providing a clearer picture of the students' attitudes towards science in their last year of
25
26 primary school, as well as information about the relationship between attitudes and
27
28 aspirations. Moreover, this research is an initial step towards tracing how aspirations develop
29
30 as students progress through some key years of their schooling.
31
32

33 34 Acknowledgements

35
36 We wish to acknowledge [NAME] from [ORGANISATION] for his role in
37
38 conducting the statistical analyses reported in this paper. This research was funded by a grant
39
40 from [FUNDING AGENCY], grant RES-179-25-0008.
41
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43 44 Notes

45
46 ¹ Due to practical considerations, the sample was drawn from schools in England, rather than
47
48 the whole of the UK (Wales, Scotland and Northern Ireland).
49

50
51 ² Dummy variables were created for the specific groups within the categorical variables,
52
53 using males, White British, the skilled category of parental occupation and the medium level
54
55 of cultural capital as bases for comparison. Missing values on these variables were assigned
56
57 to an 'unknown' category, which was entered into the analysis. Consequently, all students
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59 (cases) were able to be included in creating the multi-level models.
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³ Effect sizes of .3 to .5 are generally considered medium.

⁴ This relationship is reflected schematically because the graph of the data itself in Figure 1 contains 249 lines, making the difference demonstrated by the positive covariance more difficult to discern visually.

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For Peer Review Only

Appendix 1

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For Peer Review Only

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Table 1

Standardized means for latent variables

| Latent variable | Mean | SD |
|----------------------------------|-------|------|
| Aspirations in science | 13.67 | 5.12 |
| Peer attitudes to science | 14.11 | 4.74 |
| Parental attitudes to science | 17.98 | 4.00 |
| Self-concept in science | 18.00 | 3.85 |
| Attitudes towards school science | 18.73 | 4.00 |
| Positive views of scientists | 19.47 | 3.42 |

N.B., all (standardized) latent variables had a possible range of 5 to 25.

Table 2

Effects of structural and latent variables on student aspirations in science

| Type of Effect | Coefficient | SE | Effect Size |
|---|-------------|-------|-------------|
| <i>Fixed effects</i> | | | |
| Intercept | 13.944 | 0.072 | |
| Gender (female) | -0.651 | 0.074 | -0.13 |
| Ethnicity – Black Caribbean | -0.665 | 0.284 | -0.13 |
| Ethnicity – Indian | 0.602 | 0.197 | 0.12 |
| Ethnicity – Pakistani | 0.663 | 0.254 | 0.13 |
| Ethnicity – Bangladeshi | 0.833 | 0.283 | 0.16 |
| Ethnicity – ‘Other’ South Asian | 1.253 | 0.424 | 0.24 |
| Ethnicity - Chinese | 1.271 | 0.424 | 0.25 |
| Ethnicity – Mixed, Black & White | -0.447 | 0.203 | -0.09 |
| Ethnicity – Mixed, Asian & White | 0.779 | 0.340 | 0.15 |
| Cultural capital – low | -0.317 | 0.092 | -0.06 |
| Cultural capital – very high | 0.298 | 0.098 | 0.06 |
| Attitudes towards school science | 0.343 | 0.009 | 0.53 |
| Self-concept in science | 0.134 | 0.009 | 0.20 |
| <i>Random effect</i> | | | |
| Parental attitudes towards science ¹ | 0.668 | 0.021 | 0.44 |
| Variance around intercept | 0.269 | 0.056 | |
| Variance around slope | 0.020 | 0.007 | |
| Covariance (between slope & intercept) | 0.046 | 0.014 | |

¹ Other variables were set as fixed effects because including them as random did not significantly reduce the amount of variance in the outcome variable explained by the model. Consequently, and for ease of interpretation, they are left as fixed effects.

Table 3

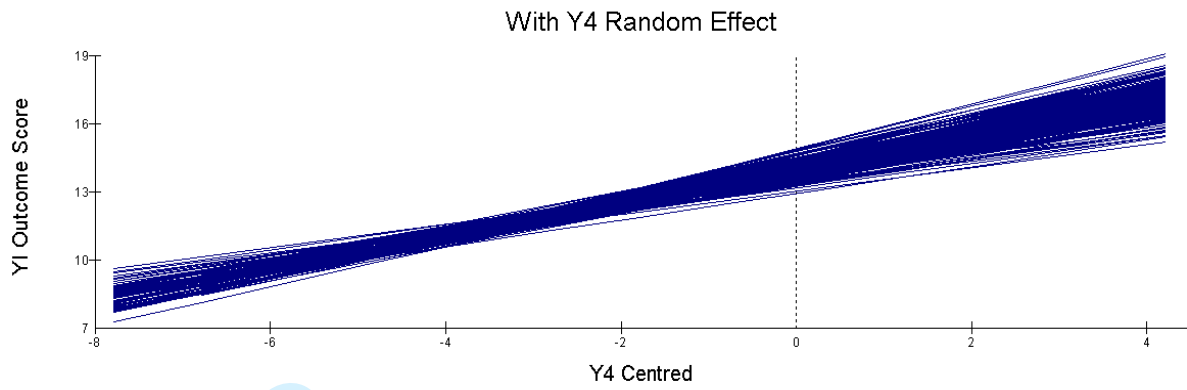
Cronbach's alphas and sample items for survey components

| Component | Cronbach's alpha |
|---|------------------|
| Aspirations in science (5 items) | .899 |
| (Items: I would like to study more science in the future; I would like to become a scientist; I would like to have a job that uses science; I would like to work in science ; I think I could be a good scientist one day) | |
| Engineering-related aspirations (2 items) | .663 |
| (Items: I would like to work in engineering; I would like to be an inventor) | |
| Attitudes towards school science (7 items) | .863 |
| (Sample items: We learn interesting things in science lessons; I look forward to my science lessons; Science lessons are exciting; Studying science is useful for getting a good job in the future) | |
| Self-concept in science (7 items) | .837 |
| (Sample items: I do well in science; I find science difficult; I am just not good at science ; I learn things quickly in my science lessons) | |
| Parental attitudes to science (3 items) | .691 |
| (Items: My parents think science is interesting; My parents would be happy if I became a scientist when I grow up; My parents think it is important for me to learn science) | |
| Parental aspiration/ambition (4 items) | .646 |
| (Sample items: My parents want me to go to university; My parents want me to make a lot of money when I grow up) | |
| Parental involvement (4 items) | .566 |
| (Sample items: They know how well I'm doing in school; They always attend parents' evenings at school) | |
| Participation in science-related activities (5 items) | .704 |
| (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?) | |

Children's aspirations in science 4

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|----|---|------|
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| 2 | | |
| 3 | Peer orientation to school (4 items) | .684 |
| 4 | | |
| 5 | (Sample items: How many of your classmates care about their marks in school? Encourage | |
| 6 | you to do well in school?) | |
| 7 | | |
| 8 | | |
| 9 | Peer attitudes to science (2 items) | .803 |
| 10 | | |
| 11 | (Items: How many of your classmates like science? Think science is cool?) | |
| 12 | | |
| 13 | Positive images of scientists (5 items) | .717 |
| 14 | | |
| 15 | (Sample items: Scientists and people who work in science can make a difference in the world; | |
| 16 | Have exciting jobs; Make a lot of money) | |
| 17 | | |
| 18 | | |
| 19 | Stereotypical images of scientists (3 items) | .618 |
| 20 | | |
| 21 | (Sample items: Scientists and people who work in science are odd; Don't have other interests) | |
| 22 | | |
| 23 | Future job – making/creating (4 items) | .612 |
| 24 | | |
| 25 | (Sample items: For my future job it is important to me to make, design or invent things; To | |
| 26 | build or repair things using my hands) | |
| 27 | | |
| 28 | | |
| 29 | Future job – social (4 items) | .584 |
| 30 | | |
| 31 | (Sample items: For my future job it is important to me work with others instead of by myself; | |
| 32 | To have time for a family) | |
| 33 | | |
| 34 | | |
| 35 | Future job – raw ambition (3 items) | .641 |
| 36 | | |
| 37 | (Sample items: For my future job it is important to me to earn a lot of money; To become | |
| 38 | famous) | |
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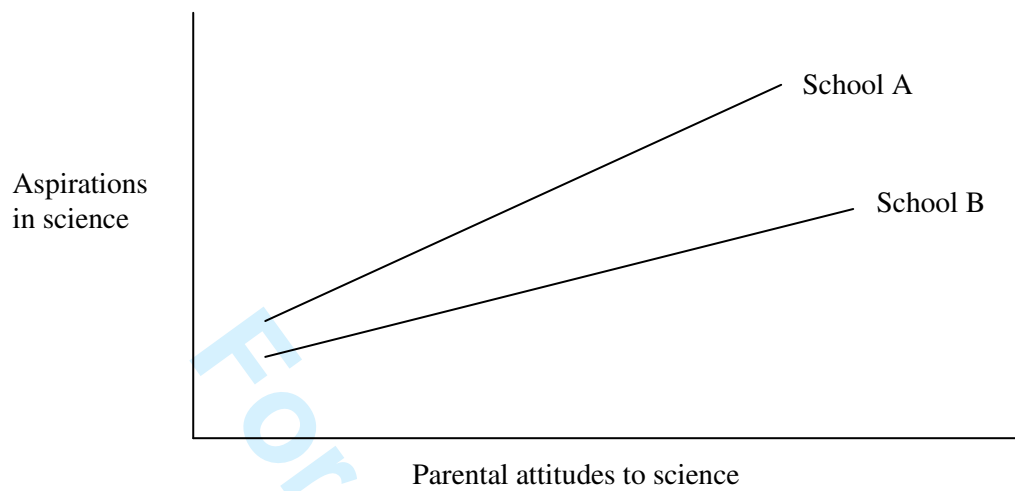
Figure 1



Relationship between aspirations in science (Y1) and parental attitudes to science (Y4, mean centred around 0).

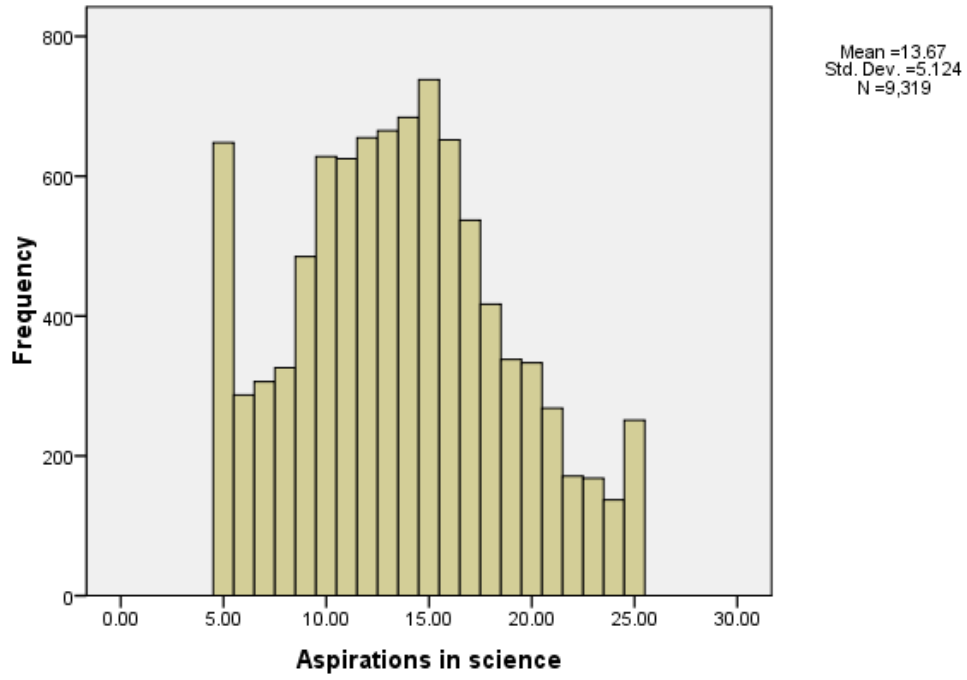
Children's aspirations in science 2

Figure 2



Relationship between aspirations in science and parental attitudes to science, schematic.

Figure 3



Distribution of the aspirations in science latent variable.

Review Only