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

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Abstract

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

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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.

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

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

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

Other influences on aspirations

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

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

(Bandura et al., 2001; Ferry, Fouad, & Smith, 2000) as well as the educational or subject choices that are important steps on the path to attaining those aspirations (Cleaves, 2005; Murphy & Whitelegg, 2006; Simpkins, Davis-Kean, & Eccles, 2006; Vidal Rodiero, 2007).

Another factor that has been posited to shape aspirations is the extent to which individuals can imagine themselves in a particular occupation or field (Gilmartin, Li, & Aschbacher, 2006; Lyons & Quinn, 2010; Taconis & Kessels, 2009). As a corollary, aspirations in science would seem likely to be influenced by images or perceptions that students have of scientists and those who work in science. Indeed, previous research suggests that this is the case (e.g. Koren & Bar, 2009; Springate et al., 2008; Weisgram & Bigler, 2006). More specifically, the unappealing images held by some females of scientists' lifestyles acted as a deterrent from the pursuit of a science-related career (Miller, Blessing, & Schwartz, 2006).

Simply holding a positive image of scientists, however, may not be sufficient to encourage an individual to pursue a career in science, as there often seems to be little overlap between students' self-perceptions and their perceptions of scientists (Bennett & Hogarth, 2009). That is, students may hold a positive view of those who work in science but still perceive them as 'not like me' and previous research has found that students hold a perception of science as important and valued but nonetheless 'not for them (Jenkins & Nelson, 2005). Such perceptions are likely to be exacerbated by students' lack of understanding about what science careers actually involve (Cleaves, 2005).

In discussing the potential influences of family, school science experiences, self-concept and images of scientists, we are not claiming that they are unrelated to structural factors such as gender, ethnicity and social class. Indeed, such influences are likely to play out differently within different structural groupings. For instance, considerable evidence reflects that boys and girls have differing attitudes towards or engagement with school science (c.f., Caleon & Subramaniam, 2008; Miller, Blessing, & Schwartz, 2006; Osborne, Simon, & Collins, 2003; Schmidt, 2010), though not necessarily at younger ages (Andre et al, 1999; Greenfield, 1997). Boys and girls also seem to differ in their academic self-concepts, with boys tending to express more positive self-concepts (perceiving themselves as more able) in science and maths than girls (Andre et al., 1999; Murphy & Whitelegg, 2006; Lyons & Quinn, 2010; Simpkins, Davis-Kean, & Eccles, 2006; Stake, 2006). Likewise, school science is also likely to be experienced differently by students of different ethnic, cultural and class backgrounds.

In summary, previous research has identified the following factors as potentially important influences on students' educational and occupational aspirations: parental attitudes toward science, attitudes toward school science, self-concept in science and perceptions of scientists. Other work highlights that gender, ethnicity and social class are also likely to be related to aspirations. The relationships between such structural factors (gender, ethnicity and social class) and aspirations, as well as those between attitudes and aspirations are necessarily complex, and may operate in different ways at different ages. Nevertheless, the importance of these relationships led us to incorporate such factors into our survey instrument, which we describe beneath.

Previous survey research on student attitudes and science aspirations

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

Methods

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

Survey Instrument

The development of the questionnaire instrument was an iterative process, initially drawing on existing instruments, an extensive body of qualitative literature (particularly concerning cultural capital and identity), and data gathered from six discussion groups with

Year 6 pupils (Author 3 et al., 2010a). All of the constructs used in the initial version of the questionnaire had a well-established empirical or theoretical base, contributing to the validity of the instrument. For instance, previous research reflects the role that children's attitudes toward school science might play in the development of science aspirations. Consequently, a construct corresponding to attitudes toward school science was incorporated into the questionnaire. Likewise, a measure of parental attitudes to science was also included, in line with research described in the previous section. (As it was not possible to measure parental attitudes to science directly in this survey, we included items about children's perceptions of their parents' attitudes to science as a proxy.) To further support validity, existing instruments – such as the Simpson-Troost Attitude Questionnaire – Revised (Owen et al., 2008) and the 'Is Science Me?' survey (Gilmartin et al., 2006) – were also drawn upon in creating items for our questionnaire. (See Appendix 1 for sample items from our final questionnaire.)

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 the authors, but sample items (comprising approximately half of the total number) can be found in Appendix 1.

Reliability and validity analyses were carried out, using principal components analysis and Cronbach's alpha to determine the unidimensionality and internal consistency of our scales. Missing data in this analysis was handled by using the modal value (for the sample) of any item left blank by an individual student. (The percentage of data missing was less than 1.5% per item, for all but 4 items.) The principal components analysis revealed 15 resolvable components, including: aspirations in science, engineering-related career aspirations, participation in science-related activities outside of school, parental attitudes to science, parental aspiration/ambition for their children, parental involvement with (their children's) schooling, peer orientation to school, peer attitudes to science, attitudes to science lessons, self-concept in science, images of scientists (positive and stereotypical) and occupational values (three components). Cronbach's alpha for all but two of these dimensions were within an acceptable range for attitudinal instruments used with children (above .6). See Appendix 1 for the Cronbach's alphas and sample items for these components. These components are also the same as those identified in the analyses of the pilot questionnaire (Author 1 et al, 2011).

Sample

9319 students from 279 schools completed the survey. Of these schools 248 were state (public) schools and 31 were independent (private) schools. This sample represented all regions of England and was approximately comparable to the overall national distribution of schools in England by attainment and proportion of students eligible for free school meals.[1]

Of the 9319 students, 50.6% were boys and 49.3% were girls. 846 (9.1%) attended private schools and 8473 (90.9%) attended state schools. Because the study focuses in part on the impact of ethnicity on students' aspirations, schools with higher populations of ethnic minority students were deliberately over-recruited to ensure sufficient numbers for analysis. Consequently, there are fewer white students (74.9%) in the sample than in all primary schools in England (78.5%). Otherwise, the sample is comparable to proportions of students from various racial and ethnic groups in English primary schools, with 8.9% of South Asian heritage (Indian, Pakistani, Bangladeshi), 7.5% Black (primarily Black African and Black Caribbean heritage), 1.4% Far Eastern (Chinese, Japanese, Korean heritage), and 7.8% of students from a mixed or other ethnic background. Due to the contested and problematic nature of constructions of 'race'/ethnicity (as well as a pragmatic need to reduce the burden of information requested from schools), ethnic categories were supplied by students themselves. Consequently, they may not be as 'accurate' as those from official sources, but discussion groups with students suggested that most were able to provide a description of their ethnic heritage.

Measures of social class were more challenging to obtain and parental occupation was used as an indicator of social class. However, many children at this age have difficulty providing sufficient information about what their parents do in order to clearly determine occupation. Thus, although questions about parental occupation were pilot tested extensively, findings about social class/parental occupation should be treated with caution. In attempting to gain some picture of the social class of participants, students were assigned to categories based on whichever parent's occupation indicated a higher social class. For instance, if one parent was a doctor and the other worked in a shop, the child was assigned to the 'professional' category of social class. Overall, of the nine categories used 35.2% of our sample had a parent in a professional or managerial occupation (two categories combined), 21.1% in a skilled occupation, 21.3% in semi-skilled or unskilled occupation (two categories combined), and 8.8% in 'some other job' (at least one parent worked, but occupation was impossible to determine). Of the remainder, 1.3% were classified as students, 6.2% as unemployed and 6.3% as unknown.

As noted above, the survey also included questions pertaining to 'cultural capital' (e.g. parental university attendance, leaving school before age 16, approximate number of books in the home, frequency of museum visitation). These questions were used to gain an overall measure of a student's cultural capital which could be used in analysis. For simplicity, students were grouped into five cultural capital categories: very low (2%), low (23.3%), medium (34.1%), high (20.3%) and very high (20.3%).

Analyses

Following the reliability and validity analyses described previously, the latent variables (components) that emerged from the principal components analysis (e.g. aspirations in science, attitudes toward school science and others found in Appendix 1) were utilized to explore patterns in children's responses, including by gender, ethnicity, social class and cultural capital. More specifically, descriptive analyses and comparison of standardized means (including t-tests) were used to gain an overview of the data. Next, multi-level modelling (MLM) analyses were conducted using MLWin software to further investigate factors that may contribute to students' aspirations in science and to explore the relations among them. Similar to regression, MLM analyses allow identification of variables that explain or account for significant amounts of variance in an outcome variable of interest. For instance, they can identify which combination of independent variables (e.g. gender, attitudes to school science) best explains the variation in students' aspirations in science. The key advantage of multilevel models is that they recognise that students' responses are contained in a set that comes from a common source (each of their schools). Due to this recognition, MLM analyses provide a more accurate measure of standard error compared with standard regression analysis. Consequently, it is less likely that independent variables will be included in the final model that are not significantly related to the outcome variable (Type 1 errors are less likely), increasing the accuracy of the model (or the accuracy our picture of variables associated with an outcome).

Carrying out the multilevel analyses involved a two stage process. In the first stage, an unconditional or base model, which included no independent variables, was constructed for the outcome variable. This model gave a measure of the variance at the pupil and school level for the outcome variable (i.e. aspirations in science). Second, all of the categorical variables (gender, ethnicity, school type, parental occupation and cultural capital[2]) were entered into the analysis, along with latent variables most strongly correlated with the outcome measure. Variables that did not contribute significantly to a reduction in the pupil-level variance from the base model on the outcome variable (i.e. aspirations in science) were successively removed from the model.

At the end of this process, the only independent (predictor) variables remaining in the model were those whose relationship with the outcome measure was statistically significant. Finally, effect sizes were calculated for these variables according to the principles outlined in Schagen and Elliot (2004), to determine the relative strength of the relationships between the independent variables and the outcome variable.

Limitations

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

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).

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

Aspirations in science

Outcomes from the MLM analyses, summarised in Table 2, revealed that the following variables were most strongly related to students' aspirations in science: Gender, ethnicity, cultural capital, parental attitudes to science, attitudes towards school science and self-concept in science. More specifically, girls, students of mixed Black and White ethnicity, and those with lower levels of cultural capital had lower aspirations in science relative to other students (e.g. boys, White students, those with medium levels of cultural capital), whereas students of South Asian heritage (Indian, Pakistani, Bangladeshi and 'other' South

Asian) expressed higher aspirations in science. In addition, 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.

--- Insert Table 2 about here ---

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

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

Influence of schools on aspirations

Analyses identified that school variance (put simply, the schools that children attend) does account for a significant proportion of the variance in the aspirations in science outcome variable. This effect is reflected in the intra-school correlation of 0.031 for the aspirations in science latent variable, which is not unusual for an attitudinal questionnaire (S. Rutt, pers comm., 2010).

Although the size of the effect of the school variance on aspirations in science was not exceptionally large (indeed, the proportion of explained variance in the outcome measure at school level is only 8.7%, compared with 91.3% at pupil level), one feature is worth noting. In Table 2 above, the latent variable 'parental attitudes to science' is listed under 'random effects'. This means that the slope and intercept of the relationship between these two variables (aspirations in science and parental attitudes to science) were allowed to vary among schools. (Doing so increased the amount of variance in the outcome the model was able to explain.) As Table 2 sets out, the covariance between the slope and intercept is positive, reflecting that the slopes of the lines depicting this relationship for each of the schools in the sample diverge. In other words, there is a greater variation in aspirations in science among schools when parental attitudes to science are more positive than when they are less positive. This relationship is portrayed in Figure 1 and represented schematically by Figure 2, below.[4] In some schools, the relationship between parental attitudes to science and aspirations in science is similar to that of 'School A' and for others, this relationship is similar to that of 'School B'.

--- Insert Figures 1 and 2 about here ---

As Figure 2 indicates, in some schools (such as School A), positive parental attitudes to science are related to higher aspirations in science than in other schools (such as School B). This divergence suggests that some schools are doing more to 'capitalise' on these positive parental attitudes than others. The analysis shows that there were no significant differences between state and private schools on the aspirations outcome variable, and resource limitations prohibited exploration of other possible school differences (e.g., time devoted to practical work, teacher enthusiasm for science, differences in curriculum implementation). Identifying possible causal factors remains a question of interest for further research.

Factors underpinning aspirations in science

In order to gain a clearer picture of students' aspirations in science, it is helpful to examine the factors related to those aspirations in greater depth. Consequently, further MLM analyses were conducted on the three latent variables that accounted for a significant proportion of the variance in students' aspirations in science: attitudes toward school science self-concept in science and parental attitudes to science. Details of the models constructed for each of these latent variables and associated effect sizes are available from the authors but the salient findings are summarised here.

The attitudes towards school science latent variable was most closely related to aspirations in science. MLM analyses revealed that the following variables accounted for a significant proportion of the variance in students' attitudes towards school science: parental occupation (proxy for social class), ethnicity, aspirations in science, parental attitudes to science, self-concept in science, peer attitudes to science and positive images of scientists. More specifically, South Asian, Black African and 'Other' Far Eastern students tended to have more positive attitudes to school science relative to White British students. Additionally, students from ostensibly lower social classes also expressed more positive attitudes towards school science, while those whose parents were in managerial and professional occupations seemed to have less positive attitudes. Finally, those students with higher aspirations in science, those who reported more positive parental and peer attitudes to science, those holding more strongly positive images of scientists and those with more positive self-concepts in science tended to have more positive attitudes to school science.

This combination of variables accounted for a considerable proportion of the variance in student scores on the attitudes to school science latent variable (62%). However, analyses of effect sizes revealed that parental occupation and ethnicity (effect sizes ranging from 0.06 to 0.17) were not as strongly correlated with attitudes to school science as the five latent variables included in the model: aspirations in science, self-concept in science, positive images of scientists, peer and parental attitudes to science (effect sizes ranging from 0.23 to 0.42).

The MLM analyses of student aspirations in science (Table 2) also found self-concept in science to be closely related to aspirations. The self-concept in science latent variable was comprised of seven items, four of which were very similar to the items forming the index of students' self-confidence in science in the 2007 TIMSS. Similar to the TIMSS outcomes, our survey respondents also expressed positive self-concepts in science, with 67% agreeing (or strongly agreeing) they do well in science, 56.5% agreeing they learn things quickly in science lessons and 58.5% disagreeing that they are 'just not good at science'. This pattern of responses would seem to be broadly comparable to the TIMSS 2007 finding that 55% of English students expressed high self-confidence in learning science (Sturman et al., 2008).

MLM analyses revealed that students' self-concepts in science seem to be related to ethnicity, gender, social class (as reflected in parental occupation) and cultural capital, as well as to aspirations in science and attitudes to school science. In line with previous multilevel models, students with stronger aspirations in science and more positive attitudes to school science were more likely also to express more positive self-concepts in science. Additionally, similar to the TIMSS 2007 findings for Year 5 students on their index of self-confidence in learning science (Sturman et al., 2008), our MLM analyses revealed less positive self-concepts among girls relative to boys (although there were no gender differences on the measure of attitudes towards school science). Such a finding is also in alignment with other research that has found similar differences between girls and boys (c.f. Andre et al., 1999; Lyons & Quinn, 2010; Osborne, Simon, & Collins, 2003). Nevertheless this relationship is very small (effect size = -0.06) and, indeed, the relationships between the ethnicity, class and cultural capital variables and self-concept were considerably weaker than those between attitudes to school science and self-concept (effect size = 0.67) and between aspirations in science and self-concept in science (effect size = 0.24).

Finally, looking at the parental attitudes to science latent variable, MLM analyses reflected that ethnicity, social class, cultural capital, aspirations in science and attitudes toward school science are the variables most closely related to parental attitudes. More specifically, girls, Pakistani students, students whose parents are involved in professional occupations and those with higher levels of cultural capital are likely to report more positive parental attitudes to science, whereas those with lower levels of cultural capital are likely to report less positive parental attitudes to science. That only Asian students of Pakistani heritage report more positive parental attitudes to science relative to White British students is also intriguing because there is no evidence that Pakistani parents should be different from other South Asian parents in this respect. The effect may be spurious, but it will be interesting to note if it continues as students progress through school.

As with the other three multilevel models constructed in these analyses, the latent variables have stronger relationships with the outcome variable (parental attitudes to science) than do the categorical variables. That is, the effect sizes for aspirations in science (0.52) and attitudes toward school science (0.45) are higher than those for the categorical variables (ranging from 0.08 to 0.16).

The MLM analyses summarised in this section highlight a group of factors which are related to each other and to student aspirations in science. An emergent picture appears where scores on the aspirations in science variable seem to be influenced particularly by attitudes toward school science and self-concept in science, which, in turn, are closely related to each other. Scores on the aspirations variable are also strongly associated with parental attitudes to science, which are themselves linked to attitudes to school science. Although MLM analyses show correlational relationships, rather than causation, logic suggests that a student's aspirations in science may be influenced by, for example, their attitudes toward school science rather than the other way around. We acknowledge, though, the likelihood that the links between all of these factors – aspirations, self-concept, attitudes toward school science and parental attitudes to science – are more complex and nuanced than a unidirectional relationship would imply.

The enthusiastic and the disinterested

Previous analyses reflect that some students have stronger science-related aspirations than others. Indeed, despite the generally positive attitudes students hold towards school science, their positive self-concepts in science, positive parental attitudes towards science, and very positive images of scientists and their work, there seems to be a group of students for whom pursuit of science (particularly as a career) may already be 'unthinkable', as suggested by the histogram of student scores on the aspirations in science latent variable.

--- Insert Figure 3 about here ---

Examination of the students whose responses formed both spikes (at the low and high ends of the distribution) revealed no response biases. For example, although the 648 students in the low group responded 'strongly disagree' to all five items comprising this latent variable ('I would like to study more science in the future', 'I would like to have a job that uses science' and so forth), their responses to other items on the survey were varied and without patterns that would give rise to concern. Moreover, it appears that the groups forming the high and low spikes are essentially 'amplifications' of trends seen in the MLM analyses for the aspirations in science latent variable. That is, in terms of composition of the groups, the low group, who seem to be disinterested even at this age in pursuing science any further than absolutely necessary, contains proportionally fewer South Asian students (5.1%) than the overall sample (8.9%). Conversely, the high group, albeit smaller with 251 students, contains proportionally more students of South Asian heritage (12.7%) than the sample as a whole. Although the gender differences on the aspirations in science latent variable were very small, the high group contained proportionally more boys (63.3%) than in the complete sample (50.6%). Analysis of subject preferences also reflects that 67.2% of the high group selected science as their favourite school subject, in comparison with 13.3% of the complete sample. Additionally, the means for the three latent variables most closely associated with aspirations in science (attitudes towards school science, parental attitudes to science, self-concept in science) were also in alignment with these trends, with means for the disinterested group lower than the sample mean and those for the enthusiastic higher than the sample mean for each of those three variables.

These findings suggest, then, that there is already a group of students for whom science may be an 'unthinkable' identity. Conversely, there is also a smaller group who are exceptionally eager to pursue science.

Discussion

With the survey described in this paper, we set out to investigate the aspirations in science held by students in their last year of primary school and to identify and explore factors that may be linked to these aspirations. Taken together, our analyses point to an emergent picture where aspirations in science are closely related to attitudes toward school science lessons, self concept in science and parental attitudes to science. Our analyses also investigated the relationship between structural factors, embodied in the categorical variables of gender, ethnicity, social class and cultural capital, and aspirations. The data suggest that there are differences among groups of students along lines of gender, ethnicity, social class and cultural capital, generally in alignment with what might be expected from previous research. For instance, as in other work (e.g. Andre et al., 1999; Jovanovic & King, 1998; Kessels & Hannover, 2008; Schmidt, 2010 and in maths, see Correll, 2001; Simpkins et al, 2006) girls in our study expressed weaker aspirations in science and less positive self-concepts in science than boys. However, there were no gender differences in attitudes toward school science nor in reports of parental attitudes to science.

Our analyses also revealed that South Asian students (i.e. students of Indian, Pakistani, Bangladeshi or other South Asian heritage) had stronger aspirations in science compared with White students. They also tended to express more positive attitudes toward school science. Other research, although not focused specifically on science, has found more positive attitudes towards school and higher educational aspirations among at least some

Asian subgroups, relative to White students (e.g. Elias et al, 2006; Strand, 2007, 2011; Strand & Winston, 2008), which is in alignment with our findings. However, the multilevel modelling analyses in the present study show that these structural factors (e.g. gender, ethnicity) seem to play a very small part in the formation of students' aspirations, at least at Year 6, and that other factors such as parental attitudes to science and attitudes towards school science have a stronger role.

Our survey findings are also consistent with previous work, much of which was qualitative in nature, around other factors that may impact career aspirations in science and decisions about whether or not to pursue science at higher levels. For instance, other studies have found that subject choice and career aspirations can be impacted by parents, although this influence operates in a very complex and nuanced way (e.g. Atherton et al., 2009; Baker & Leary, 1995; Bleeker & Jacobs, 2004; Diemer, 2007; Jacobs et al., 1998; Turner, Steward, & Lapan, 2004), by self-perceptions or self-concept (e.g. Andre et al., 1999; Bandura et al., 2001; Haussler & Hoffmann, 2002; Simpkins et al. 2006; Vidal Rodiero, 2007), which can in turn be influenced by recognition of ability by others and encouragement (e.g. Aschbacher, Li, & Roth, 2010; Carlone & Johnson, 2007; Stake, 2006; Zeldin & Pajares, 2000), and by experiences of school science (e.g. Aschbacher, Li, & Roth, 2010; Carlone & Johnson, 2007; Fraser & Kahle, 2007; Lyons, 2006; Osborne, Simon, & Collins, 2003; Vidal Rodiero, 2007). When such factors are negative (e.g. if they have negative self-concepts in science), students are less likely to make choices that would lead to science-related careers. Similarly, our survey has found that more positive parental attitudes to science, self-concept in science and experience of school science were associated with higher aspirations in science (and vice versa). That our survey findings were similar to previous qualitative research (and quantitative research involving smaller samples) serves to bolster confidence in the emerging picture of the influences on student aspirations.

Further analyses of the factors most closely related to aspirations in science (attitudes towards school science, parental attitudes to science, self-concept in science) reflected that these factors are also related to each other. That is, there seems to be a cluster of inter-related factors that may reinforce each other and support the development of aspirations in science. Indeed, it is possible that such a group may contribute to an environment in which aspirations in science can flourish. Our results reflected that the schools children attend also play a role in their scores on the aspirations in science latent variable, but the analyses were not able to identify any particular characteristic of the schools (such as state vs private) that could explain this influence. Perhaps it is some other characteristic of certain schools – such as the presence of an enthusiastic teacher – that is adding to an environment supportive of science-related aspirations.

Looking more closely at those factors most related to aspirations in science also revealed that students' attitudes toward school science are generally positive overall, as are their self-concepts in science, findings similar to TIMSS 2007. Additionally, we found that students generally reported positive parental attitudes toward science. It is possible that it is parental valuing of efforts in schooling or encouragement of high aspirations generally, rather than parental attitudes to science *per se*, that is supporting aspirations in science. However, as seen in Appendix 1, there were components in our survey to measure parental involvement in their children's education and parental ambitions for their children, but neither of these factors were related to aspirations in science. Thus, it would seem that there is something specific about parental attitudes to science as such that may be encouraging science-related aspirations, a possibility that is supported by previous research (e.g. Gilmartin, Li, & Aschbacher, 2006).

As for the impact that peer attitudes may have on choices and aspirations in science, the findings of previous research are more ambiguous. While research suggests that peers may have some influence on attitudes, choices and aspirations, this relationship does not seem to be direct, individuals may not be aware of its influence on them, and it may also vary with age (e.g. Aschbacher, Li, & Roth, 2010; George, 2006; Jacobs et al., 1998; Panizzon & Levins, 1997; Springate et al., 2008; Stake & Nickens, 2005). It is perhaps not surprising, then, that our analyses did not find peer attitudes to science (or to school) to be closely related to student aspirations in science, although they were correlated with attitudes to school science.

Likewise, despite previous research indicating the influence of images of science and scientists on students' educational choices and aspirations (e.g. Bennett & Hogarth, 2009; Koren & Bar, 2009; Miller, Blessing, & Schwartz, 2006; Weisgram & Bigler, 2006; Wyer, 2003), the current study did not reveal an association between images of scientists (either positive or stereotypical) and aspirations in science. This may be partly due to the generally positive images students in our study have of scientists and lack of variation in their scores on this latent variable (see Table 1). It is also possible that influences of peer attitudes and/or of images of scientists on aspirations may be operating in too subtle a manner to be picked up by a survey instrument. Alternatively, it could be that such influences will become stronger as children progress through school and thus may appear in subsequent survey data.

Although the findings from the current study are generally in alignment with previous research – and serve to broaden and enrich the picture of what is known about aspirations among students of this age, some issues remain unresolved about these aspirations and future choices. That is, even though 40% of students agreed that they would like to study more science in the future, 29% would 'like to have a job that uses science' and 31% even think they would be capable of being good scientists, only 17% agreed that they would like to 'become a scientist'. This pattern suggests that future engagement with science – even as part of a career – is imaginable and desirable for many pupils, but that 'being' a scientist is already undesirable or even unthinkable for the majority, even at age ten. Thus, it seems that although students' positive attitudes about science could be contributing to an interest in pursuing science further, there is nevertheless a reluctance to take up an identity as a scientist or to embrace a scientist identity as a possible future self (Markus & Nurius, 1986; Stevenson & Clegg, 2011). Even at this relatively young age, then, it seems that for some students – particularly those in the group of 648 with the lowest possible score on the aspirations in science latent variable – scientist is already an 'unthinkable identity'. This finding also suggests that careers education or classroom interventions intended to engage students with careers in and from science need to begin much earlier than ages 14 or 15, and possibly as early as primary school.

Conclusions and implications

Although the data presented here provide some insights into 10-11 year olds' aspirations in science, survey data can only provide an overview of the landscape. Thus, the broader ASPIRES study has used data from interviews with students and parents to provide a richer picture of these aspirations and to explore in more depth the patterns underlying them. These data will be used moving forward in the project to provide insight and an explanatory analysis in terms of the distinction students draw even at this age between 'doing science' (which they enjoy) and 'being a scientist' (which is considered with reluctance and is not something to which the majority aspire).

The discrepancy between the positive experiences and attitudes toward science in school and out, including impressions of scientists, and the significantly less positive aspirations in science expressed by these students who are still in primary school (as reflected by their scores on the aspirations in science latent variable) is striking and contributes to an understanding of how aspirations in science emerge and develop over time. Put differently, it has the potential to shed light on the early formation of attitudes and aspirations later measured by studies with older children, such as PISA. Importantly, although much of the value of our survey will be the baseline it offers for comparison as students mature, its size enables us to observe influences that social class, gender, and ethnicity may be exerting on aspirations, even at this relatively young age. Despite the statistical power of the survey to detect such group differences, the findings indicate that they are minor among Year 6 students. While aspirations can shift considerably, previous research would suggest that as children progress through school, interest in pursuing science tends to decrease (Jenkins & Nelson, 2005; Lyons & Quinn, 2010; Osborne, Simon, & Collins, 2003). Thus, the emergence of a tension between positive regard for 'doing' science and lack of interest in 'being' a scientist in the attitudes of students still in primary school highlights that educators, researchers and policymakers need to do more to address issues around science aspirations, including by supporting a wider, more inclusive image of science and scientists among young students before they finish primary school. Moreover, it is not simply a matter of providing 'positive images' of scientists, as students already hold such views, but rather there is a need to broaden students' perceptions of scientists and science-related careers. Doing so could, in turn, increase opportunities for more students to adopt a vision of a career in science as something that might be 'for me'.

Additionally, the relatively minor influence of structural variables (gender, ethnicity, social class) overall suggests that targeting specific groups in an attempt to raise aspirations in science may not be as fruitful an approach as a more sophisticated tailoring that takes a wider range of attitudes and characteristics into account. A series of interviews with 92 primary school children and 76 of their parents also conducted as part of our wider study highlighted a number of different types of relationships that families have with science. That these relationships intersect with, but do not fall neatly along, ethnic or class lines reinforces the case for utilising a range of approaches, including working with families, and avoiding a narrow focus on specific structural groups, in efforts to broaden students' career horizons (Author 3 et al, 2010b).

While positive attitudes towards science are not translating directly into aspirations in science, there do seem to be some positive foundations which could also be nurtured to encourage ongoing engagement with science. At the same time, the findings of the current study raise questions that are still unresolved in education and policy discourses around aspirations in science. Firstly, what are the implications for policy and educational practice of groups of students who appear to be quite set in their views at this age? Put differently, what educational interventions or structures should be implemented to best engage those students for whom work involving science is already 'unthinkable', as well as for those students who are particularly eager to pursue a science-related path? Responses to these questions, though, are at least partly contingent on the goals for science education.

Related to the issue of goals for science education is the second question arising from our findings about aspirations in science. More specifically, 17% of our respondents agreed that they would like to 'become a scientist', while 29% were interested in a 'job that uses science'. But what proportion of students 'should' have aspirations in science at this age? Not only is there no clear and definitive answer to this question (Tytler et al., 2008), the answer itself is closely tied to goals for science education. Do societies want to encourage the intrinsic value of a knowledge of science and the development of a scientifically literate population? Or are they really more concerned with sustaining the supply of scientists and engineers (leaving aside the question of what constitutes a 'sufficient' supply)? Is the primary function of school science a training or an education? These questions form part of an ongoing policy debate. Moreover, the answers will not only help frame how to respond to the question of what proportion of students 'should' have aspirations in science, but will also help define what is meant by aspirations – to 'be a scientist'? To 'have a job that uses science'? To 'study more science in the future'? Additionally, despite previous research highlighting the influence of early aspirations in science on later educational decisions (Tai et al., 2006), it remains unclear what proportion of students should express aspirations in science (and what kind of science-related aspirations) in late primary school in order to increase the likelihood of a particular 'desired' proportion of students pursuing science post-16.

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

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Notes

[1] Due to practical considerations, the sample was drawn from schools in England, rather than the whole of the UK (Wales, Scotland and Northern Ireland).

[2] Dummy variables were created for the specific groups within the categorical variables, using males, White British, the skilled category of parental occupation and the medium level of cultural capital as bases for comparison. Missing values on these variables were assigned to an 'unknown' category, which was entered into the analysis. Consequently, all students (cases) were able to be included in creating the multi-level models.

[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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Appendix 1

--- Insert Table 3 about here ---

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
Fixed effects			
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
Random effect			
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.

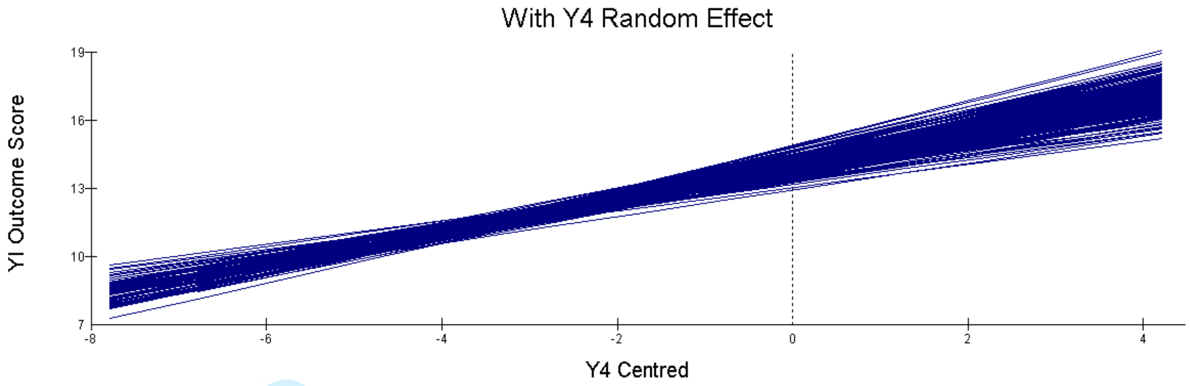
Table 3

Cronbach's alphas and sample items for survey components

Component	Cronbach's alpha
Aspirations in science (5 items) (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)	.899
Engineering-related aspirations (2 items) (Items: I would like to work in engineering; I would like to be an inventor)	.663
Attitudes towards school science (7 items) (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)	.863
Self-concept in science (7 items) (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)	.837
Parental attitudes to science (3 items) (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)	.691
Parental aspiration/ambition (4 items) (Sample items: My parents want me to go to university; My parents want me to make a lot of money when I grow up)	.646
Parental involvement (4 items) (Sample items: They know how well I'm doing in school; They always attend parents' evenings at school)	.566
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

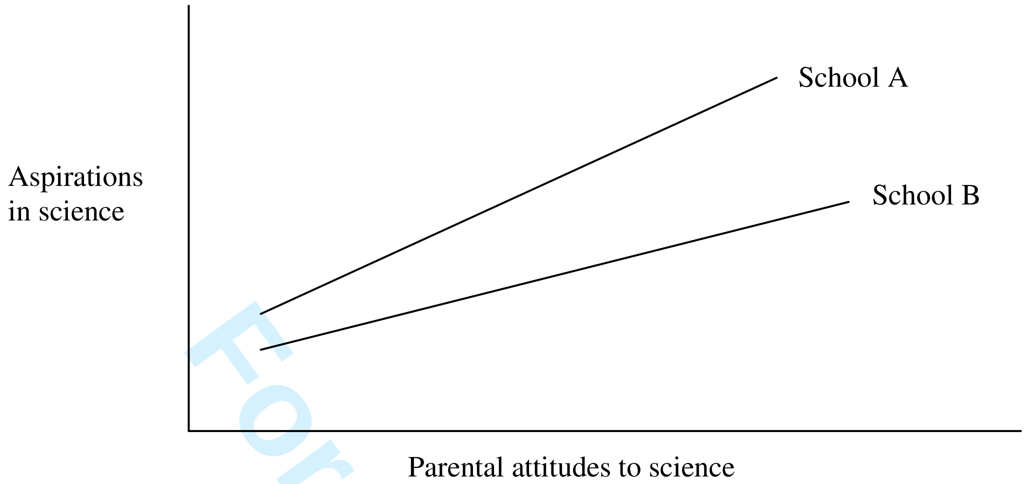
Peer orientation to school (4 items)	.684
(Sample items: How many of your classmates care about their marks in school? Encourage you to do well in school?)	
Peer attitudes to science (2 items)	.803
(Items: How many of your classmates like science? Think science is cool?)	
Positive images of scientists (5 items)	.717
(Sample items: Scientists and people who work in science can make a difference in the world; Have exciting jobs; Make a lot of money)	
Stereotypical images of scientists (3 items)	.618
(Sample items: Scientists and people who work in science are odd; Don't have other interests)	
Future job – making/creating (4 items)	.612
(Sample items: For my future job it is important to me to make, design or invent things; To build or repair things using my hands)	
Future job – social (4 items)	.584
(Sample items: For my future job it is important to me work with others instead of by myself; To have time for a family)	
Future job – raw ambition (3 items)	.641
(Sample items: For my future job it is important to me to earn a lot of money; To become famous)	

Figure 1



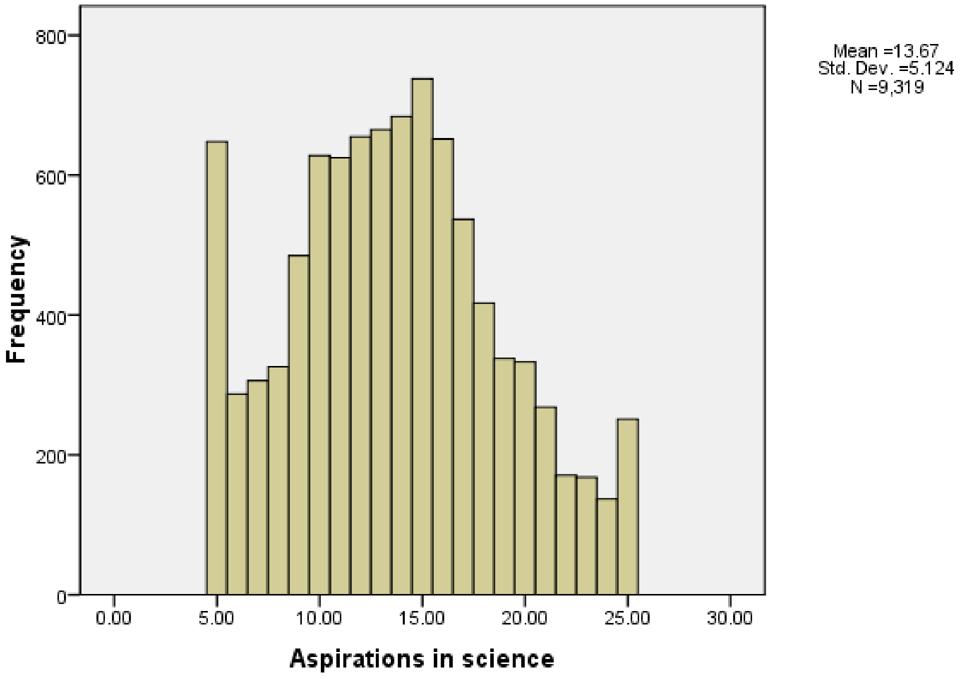
Relationship between aspirations in science (Y1) and parental attitudes to science (Y4, mean centred around 0).

Figure 2



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

Figure 3



Distribution of the aspirations in science latent variable.