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Children's Aspirations Towards Science-related Careers

Richard Sheldrake · Tamjid Mujtaba

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Abstract Science-related careers are often considered to be less accessible by many children. More research is needed to distinguish any influences from different aspects of life so that support and/or interventions can be focused to help mitigate any disadvantage and inaccessibility. In order to gain greater understanding of constraints or influences on children's aspirations towards science-related careers, a nationally-representative cohort of 7820 children in England was considered at age 11 and at age 14. At age 11, children's science-related career aspirations were predictively associated with their ethnicity, gender, and science self-confidence, and also (at lower magnitudes) with the children's motivation towards school and indicators of family advantage. At age 14, children's aspirations were predictively associated with their prior aspirations (as of age 11), science self-confidence (as of age 14), and again with ethnicity and gender. Notably, these gender and ethnicity associations varied when considering specific aspirations towards science/engineering and towards medicine/health: boys were more likely to express science/engineering aspirations and less likely to express medicine/health aspirations; concurrently, children from some minority ethnic backgrounds were less likely to express science/engineering aspirations and more likely to express medicine/health aspirations. Overall, the findings suggest that support after age 11 still needs to promote the feasibility of different science careers for all children.

Résumé Des recherches plus approfondies sont nécessaires pour distinguer toutes les influences liées à différents aspects de la vie quotidienne, de façon à mieux cibler le soutien ou les interventions nécessaires pour atténuer les désavantages et réduire l'inaccessibilité. Afin de mieux comprendre les contraintes ou les influences qui affectent les aspirations des enfants à poursuivre des carrières scientifiques, nous avons analysé une cohorte, représentative au niveau national, de 7 820 enfants en Angleterre, à l'âge de 11 ans et à l'âge de 14 ans. À 11 ans, les aspirations professionnelles des enfants étaient associées de manière prédictive à leur appartenance ethnique, à leur sexe et à leur assurance en matière de connaissances scientifiques, mais aussi (à un degré moindre) à la motivation scolaire des enfants et aux indicateurs d'avantages familiaux. À 14 ans, les aspirations des enfants étaient associées de manière prédictive à leurs aspirations antérieures (celles des 11 ans), à leur assurance en matière de connaissances scientifiques (à 14 ans), et encore une fois à leur appartenance ethnique et à leur sexe. En particulier, ces associations liées aux sexe et à

R. Sheldrake (✉) · T. Mujtaba
UCL Institute of Education, University College London, 20 Bedford Way, London WC1H 0AL, UK
e-mail: rsheldrake@ioe.ac.uk

l'appartenance ethnique varient en fonction des aspirations spécifiques centrées sur les sciences et génie d'une part, et sur la médecine et les sciences de la santé d'autre part : les garçons étaient plus susceptibles d'exprimer des aspirations liées aux sciences et aux technologies plutôt qu'à la médecine et aux sciences de la santé. D'un autre côté, on a également remarqué que les enfants appartenant à des minorités ethniques étaient moins susceptibles d'exprimer des aspirations de type scientifique/technologique, et plus susceptibles d'exprimer des aspirations liées aux domaines de la médecine et de la santé. Dans l'ensemble, les résultats suggèrent que le soutien offert aux enfants de plus de 11 ans doit continuer de promouvoir la possibilité de différentes carrières scientifiques ouvertes à tous les enfants.

Keywords Engineering · Health · Longitudinal · Medicine · Science · STEM

Introduction

Science-related fields are often valued within society, where technological, industrial, medical, and other innovations help improve general prosperity and people's quality of life (EngineeringUK, 2018; Institute of Physics, 2012; National Academy of Sciences, 2005). Science-related careers are often promoted in order to maintain or increase the supply of science-related professionals, and also so that these careers might become more accessible (EACEA, 2011; Royal Society, 2014). In England, however, relatively few children have aspired towards science-related careers and/or studied non-compulsory science subjects, including few girls, few children from some ethnic backgrounds, and few children from disadvantaged families (Elias et al., 2006; EngineeringUK, 2018; Gatsby, 2017; Homer et al., 2014; Institute of Physics, 2013, 2014; Royal Society, 2006, 2008a, 2008b; WISE, 2014). Some differences across science-related areas have become apparent, however, for example where girls have been less likely to study engineering, computer sciences, mathematical sciences, and other physical sciences at university, but more likely to study biological sciences, medicine, veterinary science, and other subjects related to medicine (EngineeringUK, 2018; Gatsby, 2017).

Children's aspirations may be influenced by numerous factors, including their family circumstances, their educational experiences, and their own views (Bøe & Henriksen, 2015; Regan & DeWitt, 2015); these may intersect or link with other aspects of life such as gender and ethnicity (Archer, DeWitt, & Osborne, 2015b; Archer et al., 2017). Nevertheless, it remains less clear how specific aspirations, such as towards medicine/health careers, might be facilitated or constrained by these various aspects of life and develop over time. In order to gain new insights, the research presented here considered a nationally-representative cohort of children in England surveyed at age 11 (the start of secondary school) and age 14. The analysis aimed to reveal independent associations between the children's science-related career aspirations and aspects of their family circumstances, their personal characteristics, and the children's own views; the analysis also considered specific aspirations towards physical science/engineering and medicine/health fields in order to gain detailed insights. The findings offer insights for educators and wider stakeholders, within England and other countries, who may be concerned with students' progressions into science-related fields, mitigating disadvantage and increasing equity, and considering where support might plausibly be focused.

Background

Career aspirations during secondary school are especially important, as early studying choices may facilitate or constrain future career options. In England, science-related careers generally require someone to have studied science-related subjects at university, which generally requires someone to have studied science-related subjects at upper-secondary school (Royal Society, 2006, 2008a). Aspirations towards science-related careers, expressed during secondary school, have indeed predicted whether people then studied science at university and worked within science-related fields (Cannady et al., 2014; Morgan et al., 2013; Tai et al., 2006).

Children's aspirations towards science-related careers may follow from various antecedents or be influenced in various ways. Often, children's career aspirations and/or studying choices have associated with their own views, including their self-confidence in science, their interest in science, and how useful studying or working within science is considered to be (Regan & DeWitt, 2015; Tripney et al., 2010). For example, recent studies of children in secondary school in England have found associations between science-related aspirations and children perceiving that science is useful and interesting, having self-confidence in their abilities in science (thinking that they 'do well' and/or 'are good' at science), engaging in extra-curricular science activities, and having support and encouragement from their parents and other people (DeWitt & Archer, 2015b; Mujtaba & Reiss, 2014; Sheldrake et al., 2017). Children's aspirations, views, and/or their wider identification with science may nevertheless be constrained in various ways, which may ultimately reduce equitable access to science. For example, some children have considered science subjects such as physics to be 'masculine' and to require 'cleverness', which can entail that science is perceived to be less accessible to girls and for those with lower self-confidence in their abilities (Archer, DeWitt, & Osborne, 2015b; Archer et al., 2017).

Children's science-related aspirations may also be influenced by their family circumstances, which may limit equitable access to science. Considered in general terms, levels of family advantage or disadvantage, usually considered as socio-economic status, has often associated with children's aspirations and/or their subsequent occupations (Ashby & Schoon, 2010; Berrington et al., 2016; Bukodi et al., 2015). Children have also been more likely to subsequently work within science when their parents have had higher levels of education (Eccles & Wang, 2016; Wang et al., 2013). Additionally, science-specific aspects of family circumstances appear to be relevant: children's science-related aspirations have associated with having parents who work in science (and/or other family members acting as science-specific role models), parents who find science interesting, and family members giving support and encouragement towards science (Archer, Dawson, DeWitt, Seakins, & Wong, 2015a; Buschor et al., 2014; DeWitt & Archer, 2015; Sheldrake et al., 2017). Aspects of children's characteristics and family circumstances may also intersect: in England, parents from Chinese, Indian, and some other minority ethnic backgrounds have often held positive views about science, and conveyed these to their children; nevertheless, many of their children have still considered science to be linked with 'being male' and 'being White', and hence as still being less accessible (Archer, DeWitt, & Osborne, 2015b; Aschbacher et al., 2010; Wong, 2015). As an exception, medicine and health have often been considered to be more accessible by those from minority ethnic backgrounds, given the greater visible diversity of the workforce within these areas (Wong, 2015).

Considered from a wider perspective, medicine and health are usually classified as science-related areas, especially when considering student numbers at university (e.g. EngineeringUK, 2018; Gatsby, 2017; Royal Society, 2006). However, less research has focused on children's aspirations towards these areas. For example, aspirations towards medicine have sometimes been encompassed within children's science-related career aspirations, where 'I would like to be a doctor or work in medicine' has been aggregated with other aspirations including 'I would like to become a scientist' and 'I would like to have a job that uses science' (e.g. DeWitt et al., 2014). Other studies have considered science in general terms, relying on children to interpret and answer questions such as whether they would 'like to study a science subject at university', where children may or may not consider medicine to be a science subject (e.g. Archer, Dawson, DeWitt, Seakins, & Wong, 2015a). Clearer insights may be revealed through specifically considering children's aspirations towards different fields.

Additionally, and again from a wider perspective, it still remains less clear which aspects of life have more or less influence on children's aspirations. For example, concerns over social mobility/immobility in England may suggest the importance of family socio-economic status (e.g. Bukodi et al., 2015; Shaw et al., 2016), while other research highlights the importance of children's own views such as their self-confidence (e.g. DeWitt & Archer, 2015; Mujtaba & Reiss, 2014). Fundamentally, mitigating disadvantage and increasing equitable access to science requires an increased understanding of the independent influences of someone's family background, personal circumstances, and also their own views.

Research Aims

In summary, children's science aspirations may be facilitated or constrained by their family circumstances and level of advantage (e.g. Ashby & Schoon, 2010; Berrington et al., 2016), by science-specific family circumstances (e.g. Archer, Dawson, DeWitt, Seakins, & Wong, 2015a; DeWitt & Archer, 2015), and by their own views including their self-confidence in their abilities in science (e.g. Bøe & Henriksen, 2015; Regan & DeWitt, 2015). More research needs to distinguish the independent influences of these different aspects of life so that support, encouragement, and/or interventions can be focused, essentially to help mitigate any disadvantage/inaccessibility so that children's aspirations are not unnecessarily constrained. Additionally, less research has considered specific aspirations towards medicine/health careers.

As part of a wider programme of work, the research presented here explored these areas through considering the Millennium Cohort Study. The Millennium Cohort Study surveyed children/families in England when the children were aged 9 months in 2001, aged 3 in 2004, aged 5 in 2006, aged 7 in 2008, aged 11 in 2012, and (most recently) aged 14 in 2015 (Fitzsimons et al., 2017; Ipsos MORI, 2017). The research presented here considered the age 11 and age 14 surveys in order to explore changes occurring during the initial years of secondary school (which starts at age 11 in England). The research aimed to reveal and quantify how the children's science-related career aspirations independently associated with various indicators of their family background, personal characteristics, and personal views. In order to gain new and greater insights, specific aspirations towards physical science/engineering careers and medicine/health careers were also considered.

Methods

Sample

The Millennium Cohort Study follows a nationally-representative cohort of children in England who were born between the start of September 2000 and the end of August 2001 (Fitzsimons et al., 2017). While the cohort initially consisted of 11695 children in England, the latest survey covered 7820 of these children when they were aged 14 in 2015; applying the latest sample-weighting during analysis ensured that the results still generalise to the national population, accounting for attrition and the original complex sampling approaches (Fitzsimons et al., 2017).

Measurement

When the children were aged 11 and aged 14, the children and their parents/guardians completed separate questionnaires (Fitzsimons et al., 2017; Ipsos MORI, 2017). The analysis focused on areas that were consistently measured at both times in order to explicitly explore changes over time, while including indicators of the children's personal characteristics and their family background.

Science-related Aspirations and Occupations

At age 11 and age 14, the children reported their aspirations via writing free-text responses to 'When you grow up what would you like to be?' as part of the children's questionnaire. The survey organisers then converted the children's responses into 'Standard Occupational Classification 2010' (SOC2010) codes

(Fitzsimons et al., 2017; Office for National Statistics, 2010a). Concurrently, the parents' and/or guardians' occupations were collected (via the parental/guardian questionnaires for these two time points) and similarly converted to SOC2010 codes.

The research presented here classified the SOC2010 aspiration/career codes as being 'science-related' (or not) using the criteria from the Organisation for Economic Co-operation and Development (OECD), in order to maximise comparability with international research (OECD, 2016). Accordingly, 'science-related' aspirations and occupations encompassed science/engineering, medicine/health, and information/technology professionals, and also technicians (OECD, 2016, pp. 282-283). Within science/engineering, the definition encompassed natural/physical scientists (across biology, chemistry, and physics, including astronomers and geologists/geophysicists), engineers (including civil, mechanical, electrical, and electronics engineers), and also conservation/environmental and architectural professionals; within medicine/health, the definition encompassed doctors, dentists, veterinarians, nurses, and various specialists, but excluded psychologists and therapists (OECD, 2016, pp. 282-283). The definition excluded social scientists, sociologists, social workers, production/functional managers, and teaching professionals (OECD, 2016, pp. 282-283).

Children's Family Background

The highest level of parental/guardian education was measured via 'National Vocational Qualification' levels: the highest level was determined across the parents/guardians who responded when their child was aged 11, and again for the highest level across the two parents/guardians who responded when their child was aged 14. The levels reflected (0) 'no relevant qualifications', (1) 'secondary school qualifications (e.g. GCSE [General Certificates of Secondary Education]) or equivalents below grade C', (2) 'secondary school qualifications or equivalents at grades A-C', (3) 'upper-secondary school qualifications (e.g. A-Level [Advanced Level General Certificates of Education]) or equivalents', (4) 'first university degrees or equivalent diplomas', and (5) 'higher (post-graduate) degrees or equivalent diplomas'. For contextualisation, levels 3, 4, and 5 on this scale reflect not-compulsory education. Secondary school qualifications such as GCSEs are taken around age 15/16 (Year 11) in England, after which education is not compulsory; non-compulsory upper-secondary qualifications such as A-Levels are usually taken around age 17/18 (Year 13). Higher levels of parental education may reflect an aspect of 'cultural capital', where qualifications may have symbolic and/or exchange value within society (Archer, Dawson, DeWitt, Seakins, & Wong, 2015a).

The highest level of parental/guardian socio-economic status was similarly considered (across the parents/guardians who responded when their child was aged 11 and again when their child was aged 14) via the 'National Statistics Socio-economic Classification' (NS-SEC) scheme (which considers someone's occupation and employment status, managerial responsibilities, and workplace size; Rose et al., 2005). The levels reflected (1) 'routine occupations', (2) 'semi-routine occupations', (3) 'lower supervisory and technical occupations', (4) 'small employers and own account workers', (5) 'intermediate occupations', (6) 'lower managerial, administrative, and professional occupations', and (7) 'higher managerial, administrative, and professional occupations' (Rose et al., 2005; Office for National Statistics, 2010b). These labels are only illustrative because two people with the same occupation could be classified with different statuses, depending on having less/more managerial responsibilities and/or working in smaller/larger organisations (Office for National Statistics, 2010b). Higher socio-economic status may reflect generalised 'advantage' within society (Rose et al., 2005).

Children's Characteristics

The children's gender, ethnicity, and age (in months as of the start of 2015) were considered. Preliminary analysis revealed no differences in gender from age 11 to 14, and few differences in ethnicity (56 out of 7820 children reported differently). Given the small number of differences, and for brevity/efficiency, the children's ethnicity as of age 14 was considered (exploring the implications of any changes in ethnicity over time remained outside of the research scope).

Children's Views

The children's wider views were measured via questionnaires at age 11 and age 14. However, only a limited selection of aspects/areas was consistently measured at both times; other aspects/areas were only measured at age 11 or age 14 but not both, and/or remained outside of the research scope.

Children's self-confidence was measured through their disagreement/agreement with 'I am good at English', 'I am good at Maths', and 'I am good at Science', via response categories of (1) 'strongly disagree', (2) 'disagree', (3) 'agree', and (4) 'strongly agree'. These indicators reflect subject-specific or domain-specific self-confidence, sometimes referred to as academic 'self-concept beliefs' (Bong and Skaalvik, 2003; Eccles, 2009).

Children's experiences and motivations concerning their education were measured across multiple questions ('How often do you try your best at school?', 'How often do you find school interesting?', 'How often do you feel unhappy at school?', 'How often do you get tired at school?', 'How often do you feel school is a waste of time?') via response categories of (1) 'never', (2) 'some of the time', (3) 'most of the time', and (4) 'all of the time'. Confirmatory factor analysis via maximum-likelihood estimation affirmed that these items could be aggregated into a single indicator of the children's school motivation. The Kaiser-Meyer-Olkin measure of sampling adequacy was 0.763 at age 11 and 0.743 at age 14; the Kaiser-Meyer-Olkin measure affirms that the items are likely to form one factor (shown via values being above 0.500). Bartlett's test of sphericity was significant at age 11 (χ^2 (10) = 5898.156, $p < 0.001$) and age 14 (χ^2 (10) = 6265.789, $p < 0.001$); Bartlett's test affirms that the items are not independent (via considering their correlation matrix). One single factor was observed across the items (rather than multiple factors emerging) at age 11 (the single factor reflected 2.312 Eigenvalues and 46.2% of the variance across the items, where factors above 1 Eigenvalue are commonly considered to be meaningful) and age 14 (the single factor reflected 2.284 Eigenvalues and 45.7% of the variance across the items). Additionally, acceptable reliability across the items was seen at age 11 (Cronbach's alpha = 0.707) and age 14 (Cronbach's alpha = 0.699); Cronbach's alpha reflects the internal consistency of the items when they are considered together, and values above 0.700 are commonly considered to be acceptable (in this situation, 0.699 is sufficiently close to 0.700 to be pragmatically acceptable). The responses/categories were re-coded as necessary so that higher response values consistently reflected positive views/experiences (e.g. for 'How often do you feel unhappy at school?' the response categories were re-coded as (1) 'all of the time' to (4) 'never'), and the average across the items was calculated to produce a single indicator of school motivation.

Children's self-esteem was measured through disagreeing or agreeing with multiple statements ('On the whole, I am satisfied with myself', 'I feel that I have a number of good qualities', 'I am able to do things as well as most other people', 'I am a person of value', and 'I feel good about myself'), via response categories of (1) 'strongly disagree', (2) 'disagree', (3) 'agree', and (4) 'strongly agree'. These statements reflect an established measure of self-esteem (Rosenberg, 1965). Factor analysis highlighted that these items could be aggregated: the Kaiser-Meyer-Olkin measure of sampling adequacy was 0.798 at age 11 and 0.873 at age 14 (both above the threshold of 0.500); Bartlett's test of sphericity was significant at age 11 (χ^2 (10) = 6692.476, $p < 0.001$) and age 14 (χ^2 (10) = 23325.566, $p < 0.001$); one single factor was observed across the items at age 11 (reflecting 2.480 Eigenvalues and 49.6% of the variance across the items) and age 14 (reflecting 3.636 Eigenvalues and 72.7% of the variance across the items). Additionally, acceptable reliability was seen at age 11 (Cronbach's alpha = 0.741) and age 14 (Cronbach's alpha = 0.905). The responses/categories were coded so that higher values consistently reflected positive self-esteem, and the average across the items was calculated to provide a single indicator of self-esteem.

Analytical Approaches

Across the analysis, the standard criterion ($p < 0.05$) was used as an indicator of 'statistical significance'.

Sample-weighting

The Millennium Cohort Study used stratified and clustered sampling, and attrition has also occurred over time (Fitzsimons et al., 2017). Accordingly, the latest sample-weighting was applied across the analysis, via 'complex samples' software functionality (which mitigates the slight risk of 'false positive' results that might otherwise occur from the stratified/clustered sampling design; Jones & Ketende, 2010).

Missing responses/values

Statistical approaches such as predictive modelling usually only consider cases (children) when there is information (responses) for every single indicator (predictor), which often entails that cases are excluded from analysis; even if information is missing for only one predictor (but information is available for all other predictors) then the case would still be excluded. In order to consistently consider all 7820 children, estimates of any missing responses/values were produced using expectation-maximisation, which is considered one of the best contemporary approaches to handling missing information (IBM, 2014; Peugh & Enders, 2004). Preliminary analysis highlighted that the same results/conclusions emerged regardless of whether missing responses/values were estimated or not (i.e. affirming that the findings were not dependent on these methodological/analytical aspects). The presented results therefore included estimates of missing responses/values, which allowed all 7820 children to be consistently analysed.

Predictive Modelling

The predictive models used logistic regression, given that the children's aspirations were coded as either science-related or not, and the predictive odds ratio (the exponential of the predictive coefficients) are reported. For one unit increase in the predictor, odds ratios above 1 reflect increasing likelihood of the outcome being observed (i.e. the child having science-related aspirations rather than not) while odds ratios below 1 reflect decreasing likelihood. Odds ratios can be easily converted into the percentage change in odds (percentage change in odds = (odds ratio – 1) × 100). For example, an odds ratio of 1.433 reflects that one unit increase in the predictor increases the odds of someone expressing science-related aspirations by 1.433 (or (1.433 – 1) × 100 = 43.3%).

For the categorical predictors, the odds ratios reflect comparisons. For gender, the odds ratios show decreasing or increasing likelihood of the outcome being observed for boys compared to girls. For ethnicity, the odds ratios reflect comparisons against those reporting White backgrounds. For example, an odds ratio shows decreasing or increasing likelihood of the outcome being observed for those reporting Indian backgrounds compared to those reporting White backgrounds, another odds ratio shows decreasing or increasing likelihood of the outcome being observed for those reporting Pakistani backgrounds compared to those reporting White backgrounds, and so on. This approach was unavoidable, because considering categorical indicators within predictive modelling has to involve one category being set as the 'reference' category to be compared against (Cohen et al., 2003). In this context, reporting a White background was set as the reference category because this was reported by the majority of children, so that the results could then reveal whether those reporting other backgrounds were more or less likely to report science aspirations (i.e. to help reveal any potential disadvantage/inequity linking with minority ethnicities/backgrounds and therefore consider whether and where support might plausibly need to be focused). Considering any disadvantage/inequity linking with minority ethnicities/backgrounds remains a concern for science-related fields (Institute of Physics, 2013, 2014; Royal Society, 2006, 2008a, 2008b; WISE, 2014).

The predictive models considered children's science-related aspirations (encompassing science/engineering, medicine/health, information/technology, and technicians). For additional insight, science/engineering aspirations and medicine/health aspirations were also predicted separately. Preliminary analysis highlighted that there were too few children reporting information/technology or technician aspirations for reliable modelling to be undertaken for those separate areas.

The models predicted the children's age 11 aspirations using indicators measured at age 11 in order to provide an initial cross-sectional view. Further models then predicted the children's age 14 aspirations using their earlier age 11 aspirations and the indicators measured at age 11 and age 14, to reveal what might plausibly associate with children's subsequent aspirations while accounting for their earlier aspirations and views (i.e. whether/how change might be possible).

Results

Sample Summary

On average (Table 1), 20.8% of the cohort expressed science-related career aspirations at age 11; more specifically, 6.9% expressed science/engineering aspirations, 13.2% medicine/health aspirations, 0.8% information/technology aspirations, and 0.7% technician aspirations. At age 14, 24.3% expressed science-related career aspirations; more specifically, 9.5% expressed science/engineering aspirations, 12.1% medicine/health aspirations, 3.3% information/technology aspirations, and 0.3% technician aspirations. Children could express multiple aspirations, so the overall science-related percentages are not necessarily the sum of the more specific percentages. On average (Table 1), more children expressed science-related aspirations at age 14 than at age 11, although their self-confidence, school motivation, and self-esteem were slightly lower at age 14.

Predictive Models

Aspirations at Age 11

The initial models predicted the children's science-related aspirations at age 11 (Table 2, Table 3, and Table 4). For ease of interpretation, the tabulated odds ratios are described as percentage changes in odds (i.e. (tabulated odds ratio – 1) × 100).

At age 11, children's science-related aspirations (Table 2) were more likely: for Bangladeshi children (124.9% more likely, compared to White backgrounds), Pakistani children (111.4%), Black African children (77.6%), children from 'other' ethnicities (74.8%), and Indian children (45.7%); with higher science self-confidence (43.3% more likely, per 1 unit increase on the 1-4 scale); with higher school motivation (26.7%, per 1 unit increase on the 1-4 scale); and when parents/guardians had higher levels of education (7.2%, per 1 unit increase on the 0-5 scale) and higher socio-economic status (6.6%, per 1 unit increase on the 1-7 scale). Children's science-related aspirations were less likely: when ethnicity was unknown (52.6% less likely, compared to White backgrounds); for boys (43.9% less likely than girls); and with higher self-esteem (17.1% less likely, per 1 unit increase on the 1-4 scale).

At age 11, children's specific aspirations towards science/engineering (Table 3) were more likely: with higher science self-confidence (109.1% more likely per unit increase); for boys (102.6% more likely than girls); with higher school motivation (42.2% per unit increase); and when parents/guardians had higher levels of education (21.6% per unit increase). Science/engineering aspirations were less likely: for children with unknown ethnicities (70.8% less likely, compared to White backgrounds); for Pakistani children (51.7% less likely); and with higher self-esteem (31.0% less likely per unit increase).

Table 1 Sample summary

Indicator (scale units)	Age 11		Age 14		Change	
	M	SD	M	SD	D	Sig.
Children's science-related career aspirations: all (1=Yes)	.208	.406	.243	.429	.085	**<.001**
– Science/engineering (1=Yes)	.069	.254	.095	.294	.095	**<.001**
– Medicine/health (1=Yes)	.132	.338	.121	.326	.031	.081
– Information/technology (1=Yes)	.008	.090	.033	.180	.177	**<.001**
– Technicians (1=Yes)	.007	.083	.003	.059	.048	**.013**
Either parent working in science-related fields: all (1=Yes)	.091	.288	.104	.305	.043	**<.001**
– Science/engineering (1=Yes)	.017	.129	.025	.156	.055	**<.001**
– Medicine/health (1=Yes)	.039	.195	.047	.212	.038	**<.001**
– Information/technology (1=Yes)	.025	.156	.022	.146	.022	.095
– Technicians (1=Yes)	.014	.118	.015	.123	.010	.519
Highest parental SES (1-7)	4.451	1.798	4.497	1.837	.025	**.010**
Highest parental education (0-5)	2.913	1.467	2.955	1.483	.029	**<.001**
Age (months, as of 1/1/2015)	166.478	3.505	166.478	3.505	NA	NA
Gender (1=boy)	.525	.499	.525	.499	NA	NA
Ethnicity (1=White)	.742	.438	.742	.438	NA	NA
Ethnicity (1=Mixed)	.058	.234	.058	.234	NA	NA
Ethnicity (1=Indian)	.025	.155	.025	.155	NA	NA
Ethnicity (1=Pakistani)	.039	.193	.039	.193	NA	NA
Ethnicity (1=Bangladeshi)	.015	.123	.015	.123	NA	NA
Ethnicity (1=Black Caribbean)	.015	.122	.015	.122	NA	NA
Ethnicity (1=Black African)	.026	.159	.026	.159	NA	NA
Ethnicity (1=Other)	.030	.171	.030	.171	NA	NA
Ethnicity (1=Unknown)	.050	.217	.050	.217	NA	NA
Self-confidence, English (1-4)	3.061	.680	2.979	.704	.119	**<.001**
Self-confidence, mathematics (1-4)	3.276	.722	2.993	.784	.375	**<.001**
Self-confidence, science (1-4)	3.000	.730	2.966	.768	.045	**.006**
School motivation (1-4)	3.180	.468	2.910	.493	.561	**<.001**
Self-esteem (1-4)	3.360	.428	3.089	.566	.541	**<.001**

Notes: Sample-weighted means (M), standard deviations (SD), and the magnitude ('D'; Cohen's D) and statistical significance ('Sig.'; p-value) of the difference over time are reported. Significant p-values ($p < 0.05$) are highlighted in bold for clarity. Missing responses were estimated by expectation-maximisation.

At age 11, children's specific aspirations towards medicine/health (Table 4) were more likely: for Pakistani children (231.5% more likely, compared to White children), Black African children (169.4%), Bangladeshi children (153.5%), children from 'other' ethnicities (106.9%), and Indian children (94.6%); when either parents/guardians worked within medicine/health (77.4%); for mixed ethnicity children (39.3%); with higher school motivation (38.0% per unit increase); and with higher science self-confidence (20.0% per unit increase). Children's medicine/health aspirations were less likely for boys (78.4% less likely, compared to girls).

Particular differences across science/engineering aspirations (Table 3) and medicine/health aspirations (Table 4) were that: parents/guardians working within medicine/health predicted increased likelihood of children expressing medicine/health aspirations, but an equivalent association was not observed for science/engineering; boys were predicted to be more likely to express science/engineering aspirations and less likely

Table 2 Predicting children's age 11 career aspirations: all science-related aspirations

Predictor	Odds ratio	Sig.
Constant	.102	.159
Either parent working in any science-related field (1=Yes)	1.086	.377
Highest parental SES	**1.066**	**.013**
Highest parental education	**1.072**	**.030**
Age in months	.995	.571
Gender (1=boy)	**.561**	**<.001**
Ethnicity (1=Mixed)	1.249	.111
Ethnicity (1=Indian)	**1.457**	**.041**
Ethnicity (1=Pakistani)	**2.114**	**<.001**
Ethnicity (1=Bangladeshi)	**2.249**	**<.001**
Ethnicity (1=Black Caribbean)	.740	.254
Ethnicity (1=Black African)	**1.776**	**.028**
Ethnicity (1=Other)	**1.748**	**.008**
Ethnicity (1=Unknown)	**.474**	**.001**
Self-confidence, English	.993	.893
Self-confidence, mathematics	1.114	.051
Self-confidence, science	**1.433**	**<.001**
School motivation	**1.267**	**.004**
Self-esteem	**.829**	**.040**
Explained variance (Nagelkerke R^2)	6.9%	

Notes: Sample-weighted logistic regression odds ratios (exp. B) and significance (p-values) are reported. The ethnicity categories reflect comparisons against children from White backgrounds. Significant p-values ($p < 0.05$) are highlighted in bold for clarity. Missing responses were estimated by expectation-maximisation.

to express medicine/health aspirations; children from Pakistani backgrounds were predicted to be less likely to express science/engineering aspirations and more likely to express medicine/health aspirations.

Aspirations at Age 14

Further models predicted the children's science-related aspirations at age 14 (Table 5, Table 6, and Table 7). At age 14, children's science-related aspirations (Table 5) were more likely: when children held earlier science-related aspirations at age 11 (146.8% more likely); with higher science self-confidence at age 14 (83.3% per unit increase); for Bangladeshi children (59.3%); for Pakistani children (49.6%); with higher school motivation at age 14 (36.0% per unit increase); and when either parent/guardian worked within science-related fields at age 14 (28.9%). Children's science-related aspirations were less likely: when children had an unknown ethnic background (90.4% less likely); and when children had higher English self-confidence at age 14 (9.9% less likely per unit increase).

At age 14, children's specific aspirations towards science/engineering (Table 6) were more likely: when children held science/engineering aspirations at age 11 (244.9% more likely); for boys (123.5% more likely than girls); with higher science self-confidence at age 14 (106.0% per unit increase); and with higher school motivation at age 14 (49.4% per unit increase). Science/engineering aspirations were less likely: when children had an unknown ethnic background (86.8% less likely); and with higher English self-confidence at age 14 (16.5% less likely per unit increase).

At age 14, children's specific aspirations towards medicine/health (Table 7) were more likely: when children held medicine/health aspirations at age 11 (254.3% more likely); for Pakistani children (138.1%);

Table 3 Predicting children's age 11 career aspirations: science/engineering aspirations only

Predictor	Odds ratio	Sig.
Constant	**.001**	**.005**
Either parent working in science/engineering (1=Yes)	1.590	.096
Highest parental SES	1.074	.090
Highest parental education	**1.216**	**.003**
Age in months	1.002	.862
Gender (1=boy)	**2.026**	**<.001**
Ethnicity (1=Mixed)	1.036	.879
Ethnicity (1=Indian)	1.118	.678
Ethnicity (1=Pakistani)	**.483**	**.012**
Ethnicity (1=Bangladeshi)	1.429	.285
Ethnicity (1=Black Caribbean)	.438	.086
Ethnicity (1=Black African)	1.660	.359
Ethnicity (1=Other)	1.282	.259
Ethnicity (1=Unknown)	**.292**	**.001**
Self-confidence, English	.990	.916
Self-confidence, mathematics	1.104	.276
Self-confidence, science	**2.091**	**<.001**
School motivation	**1.422**	**.006**
Self-esteem	**.690**	**.016**
Explained variance (Nagelkerke R^2)	10.0%	

Notes: Sample-weighted logistic regression odds ratios (exp. B) and significance (p-values) are reported. The ethnicity categories reflect comparisons against children from White backgrounds. Significant p-values ($p < 0.05$) are highlighted in bold for clarity. Missing responses were estimated by expectation-maximisation.

for Bangladeshi children (70.2%); with higher science self-confidence at age 14 (69.3% per unit increase); for children with an 'other' ethnic background (68.8%); and for Black African children (64.0%). Medicine/health aspirations were less likely: for children with an unknown ethnic background (94.6% less likely); for boys (74.2% less likely than girls); and with higher mathematics self-confidence (12.9% less likely per unit increase).

Particular differences across science/engineering aspirations (Table 6) and medicine/health aspirations (Table 7) were that: boys were again predicted to be more likely to express science/engineering aspirations and less likely to express medicine/health aspirations; most ethnicity associations were only apparent for medicine/health aspirations; higher English self-confidence at age 14 associated with lower likelihood of science/engineering aspirations (but was not relevant to medicine/health aspirations); higher mathematics self-confidence at age 14 associated with lower likelihood of medicine/health aspirations (but was not relevant to science/engineering aspirations); and higher school motivation associated with higher likelihood of science/engineering aspirations (but was not relevant to medicine/health aspirations).

Discussion

The presented results provided important insights through considering and quantifying how children's science-related aspirations associated with their family backgrounds, personal characteristics, and personal views from age 11 to age 14. Overall, children's personal views and personal characteristics appeared most relevant to their aspirations, including children's science self-confidence and children's gender and

Table 4 Predicting children's age 11 career aspirations: medicine/health aspirations only

Predictor	Odds ratio	Sig.
Constant	.227	.435
Either parent working in medicine/health (1=Yes)	**1.774**	**<.001**
Highest parental SES	1.034	.225
Highest parental education	.982	.623
Age in months	.991	.424
Gender (1=boy)	**.216**	**<.001**
Ethnicity (1=Mixed)	**1.393**	**.040**
Ethnicity (1=Indian)	**1.946**	**.001**
Ethnicity (1=Pakistani)	**3.315**	**<.001**
Ethnicity (1=Bangladeshi)	**2.535**	**<.001**
Ethnicity (1=Black Caribbean)	1.160	.638
Ethnicity (1=Black African)	**2.694**	**.001**
Ethnicity (1=Other)	**2.069**	**.003**
Ethnicity (1=Unknown)	.796	.338
Self-confidence, English	.988	.870
Self-confidence, mathematics	1.091	.187
Self-confidence, science	**1.200**	**.007**
School motivation	**1.380**	**.002**
Self-esteem	.876	.217
Explained variance (Nagelkerke R^2)	14.0%	

Notes: Sample-weighted logistic regression odds ratios (exp. B) and significance (p-values) are reported. The ethnicity categories reflect comparisons against children from White backgrounds. Significant p-values ($p < 0.05$) are highlighted in bold for clarity. Missing responses were estimated by expectation-maximisation.

ethnicity, while some aspects of family backgrounds also remained relevant. The longitudinal methodology also allowed an important insight to emerge: many factors associated with aspirations as of age 14, over and above aspirations as of age 11, highlighting that changes are indeed possible. Nevertheless, the influence of gender and ethnicity at both time points highlighted that inequalities may increase over time, so that increasing accessibility and mitigating inequality needs to remain a priority for science education and for the wider fields of science.

The associations between children's aspirations and family backgrounds (the level of parental/guardian socio-economic status, the level of parental/guardian education, and whether parents/guardians work within a science-related field) were variable across age 11 and age 14 and across the fields within science. This provides another important insight: any influences from family backgrounds may be more complex than previously considered or assumed (Archer, Dawson, DeWitt, Seakins, & Wong, 2015a; Ashby & Schoon, 2010; Bukodi et al., 2015; DeWitt & Archer, 2015; Macmillan et al., 2015). New insights also arose through considering the children's specific aspirations towards science/engineering and medicine/health. For example, at age 11, children's specific aspirations for science/engineering careers were independently more likely when parents/guardians had higher levels of education (while the other aspects of family background were not relevant), together with other predictors; conversely, at age 11, children's specific aspirations for medicine/health careers were independently more likely when parents/guardians worked within medicine/health (while the other aspects of family background were not relevant), together with other predictors. Further support from schools and society may be beneficial to help make some careers more accessible, for example when parents/guardians might not be available as role models and to

Table 5 Predicting children's age 14 career aspirations: all science-related aspirations

Predictor	Odds ratio	Sig.
Constant	**.046**	**.048**
Age 11: Child's aspirations for any science-related field (1=Yes)	**2.468**	**<.001**
Age 11: Either parent working in any science-related field (1=Yes)	.833	.117
Age 14: Either parent working in any science-related field (1=Yes)	**1.289**	**.017**
Age 11: Highest parental SES	.989	.732
Age 14: Highest parental SES	.996	.898
Age 11: Highest parental education	.974	.697
Age 14: Highest parental education	1.102	.085
Age in months	.995	.600
Gender (1=boy)	.898	.094
Ethnicity (1=Mixed)	.859	.301
Ethnicity (1=Indian)	1.080	.661
Ethnicity (1=Pakistani)	**1.496**	**.013**
Ethnicity (1=Bangladeshi)	**1.593**	**.015**
Ethnicity (1=Black Caribbean)	1.074	.828
Ethnicity (1=Black African)	1.710	.051
Ethnicity (1=Other)	1.039	.815
Ethnicity (1=Unknown)	**.096**	**<.001**
Age 11: Self-confidence, English	.967	.545
Age 14: Self-confidence, English	**.901**	**.032**
Age 11: Self-confidence, mathematics	1.067	.215
Age 14: Self-confidence, mathematics	.943	.315
Age 11: Self-confidence, science	1.050	.375
Age 14: Self-confidence, science	**1.833**	**<.001**
Age 11: School motivation	1.025	.781
Age 14: School motivation	**1.360**	**.001**
Age 11: Self-esteem	.965	.712
Age 14: Self-esteem	.976	.733
Explained variance (Nagelkerke R^2)	14.2%	

Notes: Sample-weighted logistic regression odds ratios (exp. B) and significance (p-values) are reported. The ethnicity categories reflect comparisons against children from White backgrounds. Significant p-values ($p < 0.05$) are highlighted in bold for clarity. Missing responses were estimated by expectation-maximisation.

help mitigate against disadvantage entailing more disadvantage (such as lower levels of parental/ guardian education influencing and potentially limiting children's aspirations).

The following sections consider and contextual the results in more detail, and highlight further insights and implications.

Aspirations at Age 11

Across the nationally-representative sample of children in England surveyed by the Millennium Cohort Study, 20.8% expressed science-related aspirations at age 11 (surveyed in 2012); 6.9% expressed specific aspirations towards science/engineering and 13.2% expressed specific aspirations towards medicine/health.

The predictive models revealed that children's science-related aspirations at age 11 were independently more likely for Bangladeshi, Pakistani, Black African, and Indian children (compared to White children),

Table 6 Predicting children's age 14 career aspirations: science/engineering aspirations only

Predictor	Odds ratio	Sig.
Constant	**.001**	**<.001**
Age 11: Child's science/engineering aspirations (1=Yes)	**3.449**	**<.001**
Age 11: Either parent working in science/engineering (1=Yes)	1.591	.161
Age 14: Either parent working in science/engineering (1=Yes)	1.110	.679
Age 11: Highest parental SES	1.010	.825
Age 14: Highest parental SES	.997	.949
Age 11: Highest parental education	1.011	.901
Age 14: Highest parental education	1.072	.422
Age in months	1.004	.741
Gender (1=boy)	**2.235**	**<.001**
Ethnicity (1=Mixed)	.735	.112
Ethnicity (1=Indian)	.610	.111
Ethnicity (1=Pakistani)	.712	.092
Ethnicity (1=Bangladeshi)	1.355	.351
Ethnicity (1=Black Caribbean)	.983	.963
Ethnicity (1=Black African)	1.559	.177
Ethnicity (1=Other)	.866	.616
Ethnicity (1=Unknown)	**.132**	**<.001**
Age 11: Self-confidence, English	.913	.293
Age 14: Self-confidence, English	**.835**	**.011**
Age 11: Self-confidence, mathematics	.965	.620
Age 14: Self-confidence, mathematics	1.079	.305
Age 11: Self-confidence, science	1.112	.238
Age 14: Self-confidence, science	**2.060**	**<.001**
Age 11: School motivation	1.162	.153
Age 14: School motivation	**1.494**	**<.001**
Age 11: Self-esteem	1.047	.681
Age 14: Self-esteem	.981	.841
Explained variance (Nagelkerke R^2)	16.7%	

Notes: Sample-weighted logistic regression odds ratios (exp. B) and significance (p-values) are reported. The ethnicity categories reflect comparisons against children from White backgrounds. Significant p-values ($p < 0.05$) are highlighted in bold for clarity. Missing responses were estimated by expectation-maximisation.

for children with higher science self-confidence, for children with higher school motivation, but less likely for boys than girls. These findings cohere with prior research highlighting ethnicity differences (Archer, DeWitt, & Osborne, 2015b; Wong, 2015), and with prior studies and theoretical perspectives that emphasise the importance of children's self-confidence (Bøe & Henriksen, 2015; Eccles, 2009). However, the presented results contrast with prior research into gender differences, where boys have often appeared more likely to express science aspirations (e.g. Archer et al., 2017; Institute of Physics, 2013). The difference followed from considering children's overall 'science-related' aspirations: the detailed results clarified that boys were predicted to be more likely to express science/engineering aspirations and less likely to express medicine/health aspirations, which indeed coheres with prior research into physical science and engineering gender differences (EngineeringUK, 2018; Institute of Physics, 2013; Royal Society, 2008b). The presented results therefore extend prior research through clarifying the situation regarding medicine/health via a large-scale and nationally-representative cohort.

Table 7 Predicting children's age 14 career aspirations: medicine/health aspirations only

Predictor	Odds ratio	Sig.
Constant	.031	.115
Age 11: Child's medicine/health aspirations (1=Yes)	**3.543**	**<.001**
Age 11: Either parent working in medicine/health (1=Yes)	.961	.891
Age 14: Either parent working in medicine/health (1=Yes)	1.549	.117
Age 11: Highest parental SES	1.002	.960
Age 14: Highest parental SES	1.006	.882
Age 11: Highest parental education	.960	.559
Age 14: Highest parental education	1.070	.267
Age in months	.998	.854
Gender (1=boy)	**.258**	**<.001**
Ethnicity (1=Mixed)	1.201	.299
Ethnicity (1=Indian)	1.503	.064
Ethnicity (1=Pakistani)	**2.381**	**<.001**
Ethnicity (1=Bangladeshi)	**1.702**	**.009**
Ethnicity (1=Black Caribbean)	1.650	.197
Ethnicity (1=Black African)	**1.640**	**.032**
Ethnicity (1=Other)	**1.688**	**.008**
Ethnicity (1=Unknown)	**.054**	**<.001**
Age 11: Self-confidence, English	.951	.517
Age 14: Self-confidence, English	1.023	.751
Age 11: Self-confidence, mathematics	1.047	.492
Age 14: Self-confidence, mathematics	**.871**	**.041**
Age 11: Self-confidence, science	.984	.828
Age 14: Self-confidence, science	**1.693**	**<.001**
Age 11: School motivation	1.039	.763
Age 14: School motivation	1.244	.056
Age 11: Self-esteem	1.029	.823
Age 14: Self-esteem	.958	.644
Explained variance (Nagelkerke R^2)	21.1%	

Notes: Sample-weighted logistic regression odds ratios (exp. B) and significance (p-values) are reported. The ethnicity categories reflect comparisons against children from White backgrounds. Significant p-values ($p < 0.05$) are highlighted in bold for clarity. Missing responses were estimated by expectation-maximisation.

Additionally at age 11, children's science-related aspirations were more likely with higher levels of parental/guardian socio-economic status and education, although these had relatively modest predictive magnitudes. This extends prior research, which has often shown general benefits arising from family advantage but without considering aspirations towards specific fields (Ashby & Schoon, 2010; Bukodi et al., 2015; Macmillan et al., 2015). There was no independent predictive association between parents/guardians working within science-related fields (as of their children being aged 11) and the children's science-related aspirations at age 11; however, parents/guardians specifically working within medicine/health associated with increased independent likelihood of children's medicine/health aspirations at age 11, but there was no equivalent independent association between parents/guardians working in science/engineering and children's aspirations towards science/engineering, when accounting for the various other predictors. These findings therefore reveal a new and important distinction. Prior studies have highlighted the broad relevance of parents/guardians working within science-related fields, which may facilitate parents/guardians to provide direct and/or indirect influences on their children's aspirations such as advice and/or other support (Archer, Dawson, DeWitt, Seakins, & Wong, 2015b; DeWitt & Archer, 2015). Future research may benefit from detailed explorations of these areas in order to clarify how any potentially-indirect influences may occur, and for which specific fields/occupations.

When specifically considering aspirations towards science/engineering and medicine/health at age 11, important differences were also highlighted: boys were more likely to express science/engineering aspirations and less likely to express medicine/health aspirations; concurrently, children from Pakistani backgrounds were less likely to express science/engineering aspirations and more likely to express medicine/health aspirations. This coheres with prior research highlighting that physical sciences may be perceived as more accessible to boys and that medicine/health may be perceived as more accessible to girls (Archer, DeWitt, & Osborne, 2015b; Archer et al., 2017; Royal Society, 2006, 2008b). Prior qualitative research has also highlighted that medicine/health may be perceived as more accessible for children from minority ethnic backgrounds (Aschbacher et al., 2010; Wong, 2015), and the presented results provide important evidence to confirm this from a large-scale quantitative perspective.

Additionally, at age 11, children's self-esteem had a negative predictive association with science-related aspirations: lower self-esteem predicted higher likelihood of science-related career aspirations, when accounting for the other predictors. Considering and supporting children's well-being is increasingly important within education and society (OECD, 2015), but little research appears to have considered any links between aspects of well-being (such as self-esteem) and studying science or aspiring towards science careers. Science can be perceived to be difficult or challenging (e.g. Archer et al., 2017), and it is possible that this may influence children's well-being and decisions to study science. Further research into these areas may be beneficial, and could help clarify whether any children might benefit from particular support in school.

Aspirations at Age 14

Science-related aspirations were expressed by more children at age 14 as of 2015 compared to at age 11 as of 2012: 24.3% of the cohort expressed science-related aspirations at age 14 compared to 20.8% at age 11. Specific aspirations towards science/engineering were also higher (9.5% at age 14 compared to 6.9% at age 11), while specific aspirations towards medicine/health remained similar (12.1% at age 14 compared to 13.2% at age 11, where the difference was not statistically significant). For contextualisation, for children in England aged 15 surveyed in 2015 through the Programme for International Student Assessment, 29.7% expressed science-related aspirations, with 13.0% expressing specific aspirations towards science/engineering and 13.8% towards medicine/health (OECD, 2016, p. 447).

The predictive modelling presented here revealed that, at age 14, children's science-related aspirations were independently more likely when the children held earlier science-related aspirations at age 11, with higher science self-confidence at age 14, for Bangladeshi and Pakistani children (compared to White children), with higher school motivation at age 14, and when either parent/guardian worked within science-related fields at age 14. Children's science-related aspirations were less likely when their ethnicity was unknown and with higher English self-confidence at age 14. When specifically considering aspirations towards science/engineering and medicine/health at age 14, boys were again more likely to express science/engineering aspirations and less likely to express medicine/health aspirations, and most ethnicity associations were only apparent for medicine/health aspirations.

These findings broadly highlight the importance of early science-related aspirations (from age 11), but that changes in aspirations are still possible. For example, higher science self-confidence at age 14 predicted increased likelihood of science-related aspirations at age 14, over and above earlier science-related aspirations, earlier science self-confidence, and all of the other indicators. Nevertheless, this conversely highlighted that lower science self-confidence would entail that children might move away from science-related aspirations. Prior research has indeed linked decreasing science self-confidence with movements away from science during secondary school, together with the children having increasing or competing interests in other areas, less access to extra-curricular activities, and less school and/or family support (Aschbacher et al., 2010). Many other prior studies have associated children's science-related aspirations and/or studying choices with their science self-confidence, their interest in science, and how useful studying or working within science is considered to be, together with various other factors (DeWitt & Archer, 2015; Mujtaba & Reiss, 2014; Regan & DeWitt, 2015; Tripney et al., 2010). Most of these factors were not measured within the Millennium Cohort Study, which highlights the benefit of further research.

Children's gender and ethnicity had independent associations with their aspirations at age 11 and also at age 14, accounting for all of the other predictors. Essentially, differences in aspirations across children with different personal characteristics may increase over time, which suggests the benefit of support and interventions. In the presented results, the children's gender associated with their aspirations even after accounting for their science self-confidence, which has also been seen in prior studies (e.g. DeWitt & Archer, 2015; Mujtaba & Reiss, 2014). Essentially, girls and boys potentially having different levels of science self-confidence may not necessarily or always be an underlying cause of differences in science aspirations. Wider aspects of life may be relevant, such as perceived stereotypes, norms, and beliefs about fields of study and work (e.g. Archer et al., 2017; Wong, 2015), although further research will be necessary in order to (quantitatively) clarify how these may influence aspirations.

Wider Implications and Limitations

The presented results highlighted that science-related aspirations can increase, on average, during the early stages of secondary school in England (from age 11 to age 14), although it remains unclear whether these children would study non-compulsory science subjects in upper-secondary school (after age 16) and/or at university (after age 18/19). Nevertheless, benefit may arise from highlighting that positive changes are possible: dissemination and discussion regarding issues within science education may help prompt stakeholders towards action but may not necessarily help inspire or reassure children. Given the presented results from the various predictive models, which highlighted gender and ethnicity differences, wider support might involve ensuring that children are aware of the benefits of studying and following careers in science, together with addressing assumptions and/or stereotypes regarding who can and/or does work within science and also medicine (e.g. Archer et al., 2013; Archer et al., 2017). This might facilitate more girls to aspire towards science/engineering and more boys to aspire towards medicine/health, so that both fields then become more accessible and diverse.

The presented results highlighted that children from most ethnic backgrounds other than White were more likely to have aspirations towards medicine/health careers (accounting for all of the other considered factors). It is possible that this links with many children perceiving medicine to be visibly diverse and accessible (Wong, 2015), which suggests the benefit of increasing the visible diversity of fields such as the physical sciences and engineering. Children might be able to encounter a diverse workforce in medicine within everyday life (for example when visiting doctors, dentists, and other practitioners, together with seeing media representations), while children might have fewer chances to encounter physical scientists (other than through media representations). Various practical actions may be beneficial, including tangible outreach and engagement with diverse scientists through schools, together with increased attention towards increasing diversity within science-related and general media.

The predictive models highlighted that the considered factors only explained relatively modest amounts of variance in the children's science-related career aspirations. This implicitly provides a wider insight: while family circumstances may associate with (and hence facilitate or constrain) children's career aspirations, children's own agency and any number of (unmeasured) other factors may be more relevant (such as children's beliefs about occupational fields being interesting, useful, and/or otherwise rewarding; e.g. DeWitt & Archer, 2015; Mujtaba & Reiss, 2014). Nevertheless, the modest levels of explained variance may partially reflect that dichotomous indicators are generally harder to predict than rating-scale/linear indicators. Further research may benefit from applying multiple modes of measurement, including free-text responses and also agreement/disagreement scales.

The analysis was unavoidably limited by the available data within the Millennium Cohort Study: most obviously, no measures of science attainment were present within the publicly-available data. Self-confidence reflects someone's interpretations of their attainment and abilities (Bong & Skaalvik, 2003), but may not necessarily correspond to classroom and/or examination attainment. Numerous other aspects of life may also help explain the development of children's aspirations and/or their changing aspirations (e.g. Bøe & Henriksen, 2015).

Science-related career aspirations were defined following an international definition for increased contextualisation and comparability (OECD, 2016, pp. 282-283): essentially, the presented results are directly comparable with any analysis that also uses the OECD definition, which includes (most importantly) the Programme for International Student Assessment (OECD, 2016). Nevertheless, the study originally hoped to also consider specific aspirations towards information/technology careers and technician careers, but preliminary analysis highlighted that there were too few children reporting these aspirations for reliable modelling to be undertaken for those areas. Other analytical approaches and/or categorisation of aspirations may be necessary in order to reveal more insights; ideally, research would also consider children's aspirations towards even more specific careers/occupations.

Finally, and from a wider perspective, promoting the feasibility of science careers for all children may be beneficial, but careful balancing of foci towards supporting children and towards changing education and the fields of science may be necessary. For example, further guidance and training may need to address assumptions and stereotypes held by others, such as those within the fields of education and/or science, otherwise these may remain unchallenged and unchanged.

Compliance with Ethical Standards All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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