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What do you think being a good scientist involves? School students' views about science, scientific research, and being scientists

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ABSTRACT

Students often convey positive perceptions of science and scientists, although fewer express aspirations towards becoming scientists. Students' science identities may link with wider perceptions, including what working as a scientist involves, although less research has explored these perceptions in detail. To gain new insights, questionnaire responses were considered from 289 school students across Year 9 to Year 13 (age 13/14 to 17/18 years old) from England and the island of Guernsey. Many students within the sample felt informed about science and scientific research and developments (67%), but fewer agreed that they saw themselves as scientists now (19%) or in the future (33%). Students' written responses to 'What do you think being a good scientist involves?' were analysed and encompassed themes including: working scientifically; curiosity and discovery; determination, resilience, and perseverance; ability and understanding; interest, passion, and motivation; and openness to new ideas and different views. Some differences in the prevalence of themes were revealed across students with different characteristics, circumstances, and science identities. The findings offer new insight into students' perceptions, to help understand how being a (good) scientist may be more or less feasible for different students.

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Introduction

Students often convey positive views about science and scientific research (Hamlyn et al., 2017; Yeoman et al., 2017), and positive views about scientists, including believing that scientists seek to gain new knowledge, understand the world, and solve problems (Andersen et al., 2014). Nevertheless, students often convey that doing science or being a scientist is less feasible or appealing (Archer et al., 2015; Godec, 2018; Wong, 2015). Ultimately, in many countries, relatively few students aspire to become scientists and

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follow science-related careers (Archer et al., 2010, 2013; Hamlyn et al., 2020; OECD, 2016; Sheldrake, 2020; Sheldrake & Mujtaba, 2020).

Students' science identities involve who someone is and/or who they want to become, within the context of perceptions or expectations around what working as a scientist may involve (Avraamidou, 2020; Eccles, 2009; Holmegaard et al., 2015). Research has often considered whether students aspire towards science careers and being a scientist, although less research has explored students' perceptions around what being a scientist involves. To gain new insights, the research presented here considered students' science identities, including whether they see themselves as scientists now and in the future, and together with their written responses to 'What do you think being a good scientist involves?'.

Students' views about science and scientists

Many students in primary schools across England express enjoyment in doing science, although some consider that science at school can be hard and difficult (Archer et al., 2015; Archer & DeWitt, 2015; DeWitt et al., 2013). Some primary school students believe that possessing a natural interest in science is important in order to be good at science (Archer et al., 2010). At the same time, some believe that the science undertaken in school is distinct from 'real science' in the wider world (Archer et al., 2010). Many students in secondary schools across England hold that science is interesting and important for careers, and recognise that science benefits society, but also consider that careers using science can be difficult to enter (Hamlyn et al., 2017). Secondary school students in England also often feel that research in science is progressive and beneficial, helps the world, and generates new knowledge; many also understand that such research can be challenging, including through needing specific approaches, repetition and replication, and/or because of varying findings (Yeoman et al., 2017). Nevertheless, university science students in England convey having had little to no previous experience with research before starting their courses (Cartrette & Melroe-Lehrman, 2012; John & Creighton, 2011); few students gain experiences and insights from undertaking scientific research through their formal education (Reiss et al., 2023).

Students in primary schools across England often have positive views about scientists, including that they are respected and make a difference in the world (DeWitt et al., 2013). Many secondary school students in Denmark report that scientists seek to gain new knowledge, are curious, aim to understand the world, aim to solve key problems, and are inventive (Andersen et al., 2014). Scientists are also considered to be logical and analytical, hard-working, focused/targeted, knowledgeable and literate, and intrinsically motivated through enjoying and gaining satisfaction from problem-solving (Andersen et al., 2014). From a wider perspective, across studies in many countries, students' narrative or artistic representations of scientists have often conveyed people presented/presenting as male, who undertake experimental laboratory work, sometimes with particular indicators of research (such as scientific equipment), knowledge (such as books), technology, and which highlight a process of discovery (Finson, 2002; Miller et al., 2018). Students' representations of scientists also include that they are eccentric, passionate, happy, curious, hard-working, and clever (Ferguson & Lezotte, 2020). Nevertheless, secondary students across England often feel that the idea of 'being a scientist', considered as traditionally/stereotypically only involving experimental laboratory work, is not especially appealing. Some students from backgrounds that continue to be under-represented within contemporary science fields recognise that science has tended to be dominated by white men (Archer et al., 2015; Godec, 2018; Wong, 2015).

Science identities

Relatively few secondary school students across England aspire to become scientists (Archer et al., 2020; Hamlyn et al., 2020). Students' aspirations towards science and science-related studies and careers associate with their contemporary science identities and many of their other views, including their interest and confidence in doing science, and their views around the value of and benefits from science careers (Bøe et al., 2011; Regan & DeWitt, 2015; Wang & Degol, 2017). Secondary school students' science identities, considered through views such as 'Thinking scientifically is an important part of who I am', have been found to associate with their aspirations towards further science-related studies and careers, together with their confidence, interest, and other views around science (Mujtaba et al., 2020; Sheldrake, 2016). University students' science-related identities, considered through views including 'I see myself as a science person' and 'Other people see me as a science person' (and where identity was measured as also encompassing confidence and interest in science), have been found to associate with a greater likelihood of students studying science-related courses compared to studying courses not related to science (Godec et al., 2024). Many other aspects of life also associate with students' aspirations, including encouragement and support from others (Mujtaba et al., 2020; Mujtaba & Reiss, 2014; Regan & DeWitt, 2015; Wang & Degol, 2013).

Contemporary models of science identity highlight the relevance of someone recognising themselves and also being recognised by others as being a science person; someone may enact or embody a science identity through particular practices, which may require specific knowledge and capabilities, and which also need to be recognised by others (Carlone & Johnson, 2007). Science identities can also involve perceptions of norms and expectations (Avraamidou, 2020; Carlone & Johnson, 2007). However, science identities can be more or less feasible for different students. Some students may consider that science is unfeasible for them through having had limited opportunities to develop interests and skills, gain experiences, receive support, and benefit via other aspects of life that may be relevant within or otherwise valued by the fields of science; some may perceive that doing science and being a scientist would (therefore or also) involve unfeasible norms and expectations (Archer et al., 2015; Avraamidou, 2020; Carlone & Johnson, 2007). Being recognised as a science person can be particularly hard for those with characteristics or backgrounds that continue to be under-represented in contemporary science fields (Aschbacher et al., 2010; Carlone et al., 2015; Carlone et al., 2015; Tan et al., 2013).

Contemporary models of science identity recognise that fields of science can determine what is valued within them, including knowledge, capabilities, and resources (some of which may be considered to be science-specific 'capital' that has benefit within and via fields of science), and also what particular practices (and other ways of doing science and being a scientist) are recognised or not (Archer et al., 2010; Archer et al., 2015; Avraamidou, 2020; Carlone & Johnson, 2007). Contemporary fields of science are increasingly focusing on how good science can be fostered through research cultures, which broadly encompasses what is done, recognised, valued, and rewarded within scientific research (Nuffield Council on Bioethics, 2014; Wellcome Trust, 2020). Many scientific researchers have described high quality research as rigorous, accurate, original, honest, and transparent, and where collaboration, multi-disciplinarity, openness, and creativity are also often considered to be important (Nuffield Council on Bioethics, 2014). Nevertheless, many have also highlighted challenges around competition, limited funding, pressure to publish, career progression, and other aspects that may create risks or otherwise hinder good research; some have also considered research to be particularly demanding, and where high levels of passion and resilience are needed to achieve within contemporary working cultures (Nuffield Council on Bioethics, 2014; Wellcome Trust, 2020).

Methods

Research aims

Research has often considered whether students aspire towards being a scientist, although less research has explored students' perceptions of what being a scientist involves. Understanding students' perceptions could give greater insights, and allow education to affirm and encourage, or help address misunderstandings. Accordingly, the research presented here considered: students' science identities; students' perceptions around 'What do you think being a good scientist involves?'; and whether/how these intersected.

Sample

Schools and students were recruited through a research project exploring students' experiences and views around doing science at school, including extra-curricular research (the focus of later stages of the project). All students were studying science, including those in upper-secondary school/college.

The research was reviewed and approved by the ethics committee of the host university before data collection commenced. Schools and their students were provided with information about the research so that they could make informed decisions around participating. Teachers arranged for their students to complete an online questionnaire towards the start of the 2021–2022 academic year. Students were able to choose whether to complete the questionnaire and whether to answer questions within the questionnaire (any/all questions could be left blank).

Participants

The sample encompassed students from 16 secondary schools across England and offshore (specifically, across the East Midlands, London, South East, South West, West Midlands of England, and also the island of Guernsey). The schools were of varied types: academies (8 schools), local authority maintained (3 schools), independent schools (2 schools), and other classifications (3 schools).

In England, the mandatory period at secondary school covers Year 7 (aged 11/12) to Year 11 (age 15/16), during which time science is compulsory. Upper-secondary school or college covers Year 12 (age 16/17) and Year 13 (age 17/18), where students can study different subjects (often via A-Level or equivalent qualifications) but none are compulsory. University admissions can require students to have studied particular subjects and/or have gained particular grades through A-Level or equivalent qualifications. Education in Guernsey has a similar organisation to England, and students undertake the same examinations.

The sample encompassed 289 students, across Year 9 to Year 13 (63%, 182 of 289 in Years 9–11; 37%, 107 of 289, in Years 12–13). The majority of the students reported they were girls (71%, 204 of 287), with fewer boys (25%, 71 of 287), and even fewer identifying in other ways (4%, 12 of 287), while the remaining students did not answer questions about gender. The majority of the students described their ethnicity as white (72%, 206 of 288), with fewer Asian / Asian British (18%, 52 of 288) and mixed backgrounds (8%, 24 of 288), while fewer than 10 students reported as being Black / Black British or of other backgrounds, and the remaining students did not answer questions about ethnicity. Many of the students reported that one or both of their parents/guardians went to university (76%, 221 of 289), that someone in their family worked as a scientist or in a job using science, medicine, engineering, computing, or mathematics (66%, 190 of 286), and that they knew someone else (outside of their family) who worked as a scientist or in a job using science, medicine, engineering, computing, or mathematics (76%, 217 of 287).

Questionnaire items

The questionnaire facilitated students to convey their personal characteristics and home/family circumstances (as above). It also measured views around science, scientific research, and science identity, informed by existing research and theory (Carlone & Johnson, 2007; Castell et al., 2014; Eccles, 2009; Fitzpatrick et al., 2020). The questionnaire included:

- ‘How well informed do you feel about science, and scientific research and developments?’ (with response categories of ‘Not at all informed’, ‘Not very well informed’, ‘Fairly well informed’, ‘Very well informed’);
- ‘How interested are you in finding out more from scientists about the research they are conducting?’ (‘Not at all interested’, ‘Not very interested’, ‘Fairly interested’, ‘Very interested’).

The questionnaire also measured extents of agreement (‘Strongly disagree’, ‘Disagree’, ‘Neither disagree nor agree’, ‘Agree’, ‘Strongly agree’) for:

- ‘I have a good idea of what working as a scientist would be like’;
- ‘I know what scientific research involves’;
- ‘I am interested in doing my own scientific research’;
- ‘I feel confident that I could do scientific research’;

- 'I think that I'm a science person';
- 'Other people think that I'm a science person';
- 'I see myself as a scientist now';
- 'I see myself as a scientist in the future'.

The questionnaire also asked 'What do you think being a good scientist involves?' where students provided written responses. This question holistically considered being and doing, informed by research and theory (Avraamidou, 2020; Carlone & Johnson, 2007; Eccles, 2009), via an idealised/aspirational framing (being a 'good scientist' rather than a 'scientist') to cover norms/expectations and wider contextualisation (Nuffield Council on Bioethics, 2014; Wellcome Trust, 2020).

Analytical approach

Science identity

Preliminary factor analysis affirmed that questionnaire items considering science identity ('I think that I'm a science person', 'Other people think that I'm a science person', 'I see myself as a scientist now', and 'I see myself as a scientist in the future') could also be aggregated (and where the consistency/reliability was affirmed via Cronbach's Alpha = .897). The average extent of agreement was then calculated across these items, where the responses were scaled via (1) 'Strongly disagree', (2) 'Disagree', (3) 'Neither disagree nor agree', (4) 'Agree', and (5) 'Strongly agree'. The average extent of agreement was then categorised into 'lower science identity' (values from 1 to just below 4, reflecting average disagreement to ambivalence) and 'higher science identity' (values of 4 to 5, reflecting average agreement). The analysis then considered these overall lower/higher identity groups for potential generalisation, and also considered each questionnaire item for potential detailed insight.

What do you think being a good scientist involves?

Students' written responses to 'What do you think being a good scientist involves?' were considered through inductive and iterative content analysis to reveal themes: initial review and categorisation identified commonalities, which were reviewed and refined through subsequent iterations (which also helped achieve and ensure consistency in classification). This produced themes, which could involve particular facets that often followed from the language used and/or other underlying commonalities. For example, some students wrote that being a good scientist involved 'being good' at science while others conveyed that this involved 'understanding' science or 'knowledge' of science content and topics, which formed a theme around 'ability and understanding'. The aggregation into (more general) themes helped consider their prevalence, while (more detailed) facets helped in understanding students' perceptions.

Analysis

Similarities/differences across students' views, including themes around being a good scientist, were considered across those with different characteristics and circumstances (for wider insight) and those with lower/higher science identity (the focus of this research).

When considering characteristics and circumstances, the analysis unavoidably needed to consider some simplified categories for: academic years (Years 9–11 or Years 12–13, reflecting those in secondary school or upper-secondary school); gender (boys compared to girls and others, given few non-binary/other participants to form separate groups); and ethnicity (those with white backgrounds compared to others, given few participants reporting some backgrounds). Larger samples, which help provide more extensive and diverse representation, would be needed for analysis through and across more detailed groups.

Preliminary analysis applied multiple approaches, including: considering the percentages of those strongly agreeing or agreeing or selecting the equivalent positive response categories (through cross-tabulations with chi-squared tests, **Supplementary Material A**); and considering extents of agreement across response scales (from 'Strongly disagree' to 'Strongly agree' or equivalents through independent-samples t-tests, **Supplementary Material B**). Similar results emerged. For ease of interpretation, the presented results follow from cross-tabulations and report 'statistically significant' differences ($p < .05$). Magnitudes of difference were considered through Cramer's V values, which are often interpreted with values above 0.10 reflecting a small difference, above 0.30 reflecting a medium difference, and above 0.50 reflecting a large difference (Cohen, 1988).

Results

Views about science, scientific research, and science identity

The students within the sample conveyed varying views (Table 1). Many felt informed about science and scientific research and developments (67% very well informed or fairly well informed), and conveyed interest in finding out more from scientists about the research they are conducting (75% very interested or fairly interested), although fewer felt they had a good idea of what working as a scientist would be like (34% strongly agreed or agreed) or knew what scientific research involves (45% strongly agreed or agreed).

Considering science identities (Table 1), around half of the sample considered they were science people (52% strongly agreed or agreed with 'I think that I'm a science person') and were recognised as such (56% strongly agreed or agreed with 'Other people think that I'm a science person'), although fewer saw themselves as scientists now (19% strongly agreed or agreed with 'I see myself as a scientist now') or in the future (33% strongly agreed or agreed with 'I see myself as a scientist in the future'). Overall, 27% of the students were classified as having higher overall science identity (the equivalent of strong agreement to agreement, on average, across the four science identity questions) and 73% as having lower science identity; those with higher overall science identity were more likely to be boys, with family members working in science/science-related fields, in upper-secondary school (Years 12–13, i.e. having already chosen to study non-compulsory science), and tended to convey more positive views through the questionnaire items (Table 1). Students' responses to the four science identity questions differ across the lower/higher overall science identity groups, because the groups were formed from the four questions.

Similarities/differences in views across students' characteristics and circumstances are appended for brevity (**Supplementary Material A**).

Table 1. Summary of the sample and their views about science, scientific research, and science identity.

Questionnaire item (percentage reported)	All students	Overall science identity comparison: Lower (disagree and ambivalent equivalent)	Higher (agree equivalent)	Cramer's V	Sig. (*p*)
Gender (% boys)	25%	**20%**	**35%**	**.152**	**.010**
Ethnicity (% white)	72%	71%	72%	.012	.841
Did either of your parents/carers go to university (% yes)	76%	75%	83%	.091	.127
Does anyone in your family work as a scientist or in a job using science, medicine, engineering, computing, or mathematics (% yes)	66%	**62%**	**80%**	**.171**	**.004**
Do you know anyone else (outside of your family) who works as a scientist or in a job using science, medicine, engineering, computing, or mathematics (% yes)	76%	73%	84%	.113	.058
Academic year group (% in Years 12-13)	37%	**29%**	**56%**	**.245**	**<.001**
How well informed do you feel about science, and scientific research and developments (% very well informed and fairly well informed)	67%	**60%**	**86%**	**.241**	**<.001**
How interested are you in finding out more from scientists about the research they are conducting (% very interested and fairly interested)	75%	**67%**	**96%**	**.299**	**<.001**
I have a good idea of what working as a scientist would be like (% agreeing)	34%	**23%**	**64%**	**.385**	**<.001**
I know what scientific research involves (% agreeing)	45%	**37%**	**66%**	**.268**	**<.001**
I am interested in doing my own scientific research (% agreeing)	45%	**31%**	**82%**	**.460**	**<.001**
I feel confident that I could do scientific research (% agreeing)	42%	**31%**	**71%**	**.367**	**<.001**
Science identity: I think that I'm a science person (% agreeing)	52%	**34%**	**100%**	**.585**	**<.001**
Science identity: Other people think that I'm a science person (% agreeing)	56%	**40%**	**100%**	**.534**	**<.001**
Science identity: I see myself as a scientist now (% agreeing)	19%	**2%**	**66%**	**.724**	**<.001**
Science identity: I see myself as a scientist in the future (% agreeing)	33%	**12%**	**92%**	**.760**	**<.001**

Notes: Statistically significant differences ($p < .05$) are highlighted in bold for clarity.

Views about being a good scientist

Many themes were evident within students' responses to 'What do you think being a good scientist involves?' (Table 2), and illustrative quotations are included in the following. One response could cover more than one theme, so reported percentages can sum to more than 100%.

Working scientifically (conveyed in 27% of responses, 58 of 214) encompassed:

- General capabilities around undertaking research, analysis, and experiments (e.g. 'Investigative skills'; 'Knowing how to do your job, doing the right experiments and predicting things and being confident in your predictions');
- Following scientific methods, including developing and refining hypotheses and theories; some students referred to a singular scientific method (e.g. 'Following the

Table 2. Summary of views about being a good scientist.

'What do you think being a good scientist involves?' theme (% of responses)	All students	Overall science identity comparison			
		Lower (disagree and ambivalent equivalent)	Higher (agree equivalent)	Cramer's V	Sig. (*p*)
Working scientifically	27%	28%	26%	.016	.818
Curiosity and discovery	26%	26%	26%	.001	.985
Determination, resilience, and perseverance	22%	**18%**	**30%**	**.141**	**.039**
Ability and understanding	21%	**25%**	**13%**	**.135**	**.048**
Interest, passion, and motivation	19%	16%	25%	.105	.124
Openness to new ideas and different views	19%	**14%**	**28%**	**.157**	**.022**
Hard work and thoroughness	15%	13%	20%	.093	.174
Collaboration and communication	15%	12%	22%	.131	.055
Problem solving	11%	**8%**	**19%**	**.167**	**.015**
Improving life	5%	5%	6%	.021	.764
Independent working	3%	2%	6%	.098	.152

Notes: Statistically significant differences ($p < .05$) are highlighted in bold for clarity.

scientific method') while others conveyed methods following from hypotheses (e.g. 'Theorising a hypothesis, having the ability to test it and rectifying your hypothesis based on the results, before repeating the tests');

- Replication (e.g. 'To make sure you check your findings a couple of times'; 'Repeating things, even if you are sure on something you must go back and revisit it');
- Being accurate, methodical, and systematic (e.g. 'Getting accurate results that you can verify'; 'Being able to carry out research and experiments accurately and be able to analyse the results'), where some students also mentioned thinking logically (e.g. 'Being able to think logically, have a sense of curiosity, conduct research and being able to challenge their beliefs and conclusions when presented evidence to the contrary'; 'It involves thinking logically and being able to adapt to different circumstances and environments');
- Being objective and impartial (e.g. 'Able to make fair, rational and reinforced judgements as well as results through research'; 'Being impartial and carrying out thorough study').

Curiosity and discovery (26%, 56 of 214) encompassed:

- Being curious, inquisitive, and seeking to learn and discover (e.g. 'Constantly striving for more knowledge'; 'Dedication and a desire to find out more');
- Being creative, generating new ideas, and thinking 'outside of the box' (e.g. 'Being creative and innovative to find answers and solutions. To be flexible in your ideas and accept change but also to be curious and to want to be a scientist'; 'Conducting experiments based on hypotheses, finding the evidence to prove whether something is correct or incorrect. A good scientist is someone who is curious and innovative, sometimes even creative').

Some students also recognised that this may be a continual endeavour (e.g. 'An analytical approach to evaluating results from experiments, accepting you don't know everything, having a hunger for knowledge and answer, and accepting that such a pursuit will never truly be over').

Determination, resilience, and perseverance (22%, 47 of 214) encompassed overcoming challenges:

- Determination, dedication, resilience, or perseverance in general (e.g. 'Dedication, Determination, Application skills, Logical thinking'; 'Resilience, ingenuity, hard work');
- Perseverance in particular through overcoming challenges (e.g. 'Having an open mindset and persevering through challenges'; 'Being calm and analytical in their work and being able combat any obstacles they face in order to complete their work or make new developments');
- Recognising challenges, the potential for failure, and learning from failure (e.g. 'Curiosity, patience and resilience. I believe that scientists are always curious about the world around them, and they want to earn what makes everything work. Also, they know that failed experiments provide answers as often as successful ones do which is why resilience is key; they must keep trying to find a solution, not stopping because they can't').

Some responses illustrated perseverance as relevant to and applied through (experimental) scientific endeavours (e.g. 'Interest in the discovery of new things and principles, and the motivation to be persistent in your research and not give up when presented with an inconclusive or not optimal conclusion'; 'Being able to adapt to different situations and being able to understand why some things change sometimes. Not being let down when you do not find the result you where [were] hoping for in your experiments but use the results to try to find an explanation as why they were different').

Ability and understanding (21%, 45 of 214) included:

- Being good at science, doing well at science, or being clever or smart (e.g. 'Being good at science'; 'Being smart and good at maths');
- Having understanding and knowledge (e.g. 'Understanding science'; 'Having a wide range of knowledge, being passionate about your subject').

Some students conveyed ability or understanding alone (e.g. 'Cleverness', 'Being smart') while others conveyed further aspects such as interest (e.g. 'Being good at science. Enjoying it'), diligence (e.g. 'Having a good work ethic and good academic skills whilst also being a nice person'), and collaboration and communication (e.g. 'Being able to communicate and work well with others and have good knowledge understanding and comprehension of the topic').

Interest, passion, and motivation (19%, 40 of 214) included being inherently interested and passionate about science (e.g. 'Being interested in what you are researching'; 'Having a passion for what you are doing and wanting to find the truth / answer a question. You also need to be determined to succeed').

Openness to new ideas and different views (19%, 40 of 214) encompassed:

- Being open to new ideas in general (e.g. 'Being open minded and open to all ideas'; 'Being open minded and not dismissive over new ideas'), and being open to criticism and being wrong (e.g. 'Being open to criticism and having an open mind'; 'Being able to say when you are wrong. Questioning everything');
- Adapting ideas with new evidence, which sometimes intersected with working scientifically (e.g. 'Being able to think logically, have a sense of curiosity, conduct research and being able to challenge their beliefs and conclusions when presented evidence to the contrary'; 'It involves linking many different understandings to one thing to get a better picture of it. Not being too stubborn, and to be ready for a someone to disprove something you may have thought was right').

Hard work and thoroughness (15%, 33 of 214) encompassed working and approaches to working:

- Hard work, which was often mentioned in the context of interest, motivation, and dedication (e.g. 'Hard work and dedication and an interest in the world around you'; 'Hard work and dedication, wanting to problem solve big problems');
- Being thorough and methodical in general (e.g. 'Being impartial and carrying out thorough study'), and thorough and methodical approaches applied to and intersecting with working scientifically (e.g. 'Being thorough in the research and having good analytical skills').

Embodied working may be understood in different ways. A good scientist may be considered to be someone who works hard, is dedicated to their work/science, and so on (e.g. 'Diligence, hardworking, intuitive, intelligent'; 'Hard working, interested and engaged, curious'). Alternatively, being a scientist could be considered to involve undertaking or having to undertake hard work (e.g. 'Hard work, long hours and loads of information to take in'), which may not necessarily be positive.

Collaboration and communication (15%, 32 of 214) included:

- Collaboration through team working (e.g. 'Work in a team well'; 'Having good teamwork skills');
- Communicating, sharing, and disseminating information (e.g. 'Sharing ideas and working in a team'; 'Being able to actively engage in the project you are conducting and then share your results confidently').

Problem solving (11%, 24 of 214) included problem solving in general, adaptability, and applying knowledge and understanding to solve problems (e.g. 'Problem solving and innovation'; 'Looking at problems from new perspectives and contributing all that you can where possible'; 'Being good at problem solving, and being able to see things logically and rationally. Coming up with good ideas for research and knowing how to carry them out').

Improving life (5%, 11 of 214 responses) included undertaking science to improve life, benefit the world, and make a positive difference (e.g. 'Using your knowledge and findings backed up with research and evidence for the betterment of society'; 'Being fair, researching properly and actively trying to make a difference/discoveries').

Independent working (3%, 7 of 214) was almost always mentioned in the context of someone needing to be able to undertake both independent work and team work (e.g. 'The ability to carry out research as a part of a team or individually to gain a better understanding of an aspect of our world'; 'You need to have a good work ethic and be professional. You are required to work well both independently and as part of a team').

As an incidental finding, there was only one instance of masculine-framing (i.e. 'A good scientist should be objective and not let his emotions impact his judgement') and no feminine-framing, otherwise students used generalised or neutral framing.

Intersecting views

Some differences in the prevalence of themes were revealed across students with different science identities. Within their responses for what being a good scientist involved (Table 2), those with higher overall science identity (compared to those with lower overall science identity) made more mention of: **determination, resilience, and perseverance**; **openness to new ideas and different views**; and **problem-solving**; and less mention of **ability and understanding**.

Considering across each science identity question revealed similar and also further insights (**Supplementary Material A**). Students who agreed that they are a science person (compared to those who did not or were ambivalent) made more mention of **working scientifically**; **determination, resilience, and perseverance**; and **problem-solving**; and less mention of **ability and understanding**. Students who agreed that other people think that they are a science person made more mention of **openness to new ideas and different views**; and less mention of **ability and understanding**. Students who agreed that they saw themselves as a scientist now made more mention of **determination, resilience, and perseverance**; **openness to new ideas and different views**; **interest, passion, and motivation**; **collaboration and communication**; and **problem-solving**, and less mention of **ability and understanding**. Students who agreed that they saw themselves as a scientist in the future made more mention of **openness to new ideas and different views**; and **problem-solving**; and less mention of **ability and understanding**.

Differences across students' characteristics and circumstances are also appended (**Supplementary Material A**). Boys (compared to girls and others) made more mention of **working scientifically**. Those in upper-secondary school (Years 12–13, compared to those in Years 9–11) made more mention of **working scientifically**; and less mention of **ability and understanding**. Those with parents who attended university (compared to other students) made more mention of **curiosity and discovery**. Those with family members who worked as a scientist or in a job using science, medicine, engineering, computing, or mathematics (compared to other students) made more mention of **problem solving**. Those who know others outside of their family who worked as a scientist or in a job using science, medicine, engineering, computing, or mathematics (compared to other students) made more mention of **hard work and thoroughness**.

Discussion

Many students within the sample felt informed about science and scientific research and developments (67%) and were interested in finding out more from scientists about the research they are conducting (75%), although fewer agreed that they had a good idea of what working as a scientist would be like (34%) or saw themselves as scientists now (19%) or in the future (33%). These findings suggest scope for support around science identities and perceptions around scientists, which may be appreciated given the interest from students to know more.

The students' perceptions around 'What do you think being a good scientist involves?' offer new insights to affirm and extend existing understanding. The students' responses most frequently involved a theme of working scientifically, which encompassed good scientists having/applying capabilities around undertaking research, analysis, and experiments. This coheres with scientists essentially being people who undertake science through particular practices (Avraamidou, 2020; Carlone & Johnson, 2007). The students' responses also encompassed some aspects of focus within the contemporary science curriculum in England, which includes highlighting objectivity, accuracy, and replication/repeatability, and also appropriate methods to test predictions or hypotheses (Department for Education, 2014).

The students' responses also included themes around a good scientist being curious and also creative in discovering, and being open to new ideas and different views (in general and applied through working scientifically). Existing research has also revealed that students' perceptions of scientists encompass curiosity, discovery, and gaining new knowledge (Andersen et al., 2014; Finson, 2002; Miller et al., 2018), and contemporary scientific researchers have also described high quality research as involving creativity and openness (Nuffield Council on Bioethics, 2014). From a wider perspective, the 'nature of science' and scientific knowledge has been theorised to involve creativity, and with scientific knowledge being uncertain and subject to change rather than absolute (Deng et al., 2011; Lederman, 2007; Lederman & Lederman, 2014). Focusing on scientists as being open to new ideas and different views may offer an avenue towards exploring more abstracted epistemological principles and ideals within teaching and learning.

The students' responses also included a good scientist manifesting determination, resilience, and perseverance, including overcoming challenges; the responses also included working and approaches to working, including working hard and being thorough and methodical. Contemporary scientific researchers have described high quality research as being rigorous, but have also highlighted challenges in their fields including research being demanding and (for better or worse) needing resilience (Wellcome Trust, 2020). Future research may benefit from considering this area further, including positive, negative, and any wider implications around working practices.

Science identities and perceptions around being a good scientist

Relatively few students in the sample manifested science identities. Overall, 27% of the students were classified with higher science identity and 73% with lower science identity. The students' views around 'What do you think being a good scientist involves?' had some differences across those with different science identities, which inherently provide new insights. Essentially, stronger science identities involved a greater likelihood of particular perceptions around being good scientists.

Students with higher overall science identity (compared to those with lower overall science identity) made more mention of being good scientists involving: determination, resilience, and perseverance; openness to new ideas and different views; and problem-solving; and made less mention of ability and understanding. Within the context of their other responses, students with higher overall science identity conveyed greater confidence around undertaking scientific research, while students with lower science identity conveyed less confidence and were also more likely to convey that being good scientists involved ability and understanding. Essentially, science may be less feasible for some students through their understanding of their own abilities, and compounded through their expectations that being a good scientist requires such abilities (Avraamidou, 2020; Carlone & Johnson, 2007). These findings affirm the wider implications of students' views around confidence, difficulty, ability, understanding, and/or 'cleverness', which have been highlighted as challenges to students' trajectories towards science careers (Archer & DeWitt, 2015; Hamlyn et al., 2020). Science educators may need to reassure students around accessibility to science, especially as some students consider science to be difficult and challenging (Hamlyn et al., 2020) and may consider that science needs 'cleverness' (Archer & DeWitt, 2015). Supporting students may involve developing their own confidence and also their understanding of what being a scientist may entail. Future research may also benefit from exploring how students perceive their science education, science as a field, and scientists, and how these intersect, for example to explore whether/how some perceptions around education (such as potentially being orientated around manifestations of abilities and understanding including through assessment and examinations) might be reflected onto wider perceptions of science and scientists.

Considering students' detailed identities also gave further insights, including where those who currently saw themselves as scientists (compared to those who did not) were more likely to mention that being good scientists involved interest, passion, and motivation around science, and also conveyed greater interest in doing their own scientific research. Existing research across England has revealed differences in interests and motivations across students, including where boys tend to convey more positive interest around science than girls (Hamlyn et al., 2017; Hamlyn et al., 2020). If some students consider that being a good scientist involves being inherently interested in science, then those with less interest may feel less able to become a scientist. However, students may have unequal opportunities for interests to develop or be fostered, for example if curricular topics do not intersect with the science topics that students find interesting, if teaching activities/approaches are considered less positively or engaging by/for some students, and/or if some students receive less encouragement and support (Mujtaba et al., 2018; Mujtaba & Reiss, 2013, 2016). Education would benefit from enhancing access and equity, which may involve diverse teaching/learning topics, activities, and approaches, within inclusive and equitable environments, while enhancing awareness of science fields and providing positive and diverse representation of scientists (Institute of Physics, 2020).

Limitations

This research considered a sample of students encompassing many academic years. A high proportion of the students reported that their parents/guardians had gone to university, and that someone in their family and/or someone they knew worked in science/science-related jobs. The findings may not necessarily generalise further than the sample, and future research would benefit from considering larger samples and/or focusing on particular academic years.

This research considered themes within students' perceptions around being a good scientist; some themes were mentioned less frequently (involving smaller numbers of students), such that any associated findings may be more indicative than conclusive. Additionally, the prevalence of themes does not necessarily reflect extents of understanding across students. Future research would benefit from applying multiple methods, including asking students whether they agree or disagree that a good scientist involves particular aspects of being/doing, as well as asking students to provide narrative accounts, including their reasoning.

This analysis provided one perspective, but it remains unclear whether/how students' identities independently associate with their perceptions around scientists, accounting for their other views, characteristics, and circumstances (all of which can vary/intersect). Students might have identities afforded by their perceptions of scientists, students might have perceptions of scientists afforded by their identities, and/or these may be concurrent or even more complex. It also remains unclear why different students hold different views. Students' perceptions around science and scientists may be influenced by home, school, and other aspects of life, which future research could consider in more detail. For example, existing research has highlighted that some students mention the media together with teachers and textbooks as sources of representations of scientists (Tan et al., 2017), although some students are also aware that some media representations involve stereotypes (Moreau et al., 2010).

Wider implications

Students' views around being a good scientist included themes of working scientifically, curiosity and discovery, and wider aspects of embodied working, such as being determined and exhibiting hard work, which share similarities with views from scientific researchers (Wellcome Trust, 2020). These may offer areas for education to explore further with students, through a wider exploration of what 'working scientifically' may involve, so that more students can gain awareness of contemporary science.

Within science education, students can undertake practical experimentation and (ideally) develop capabilities and skills that can be applied within scientific research, and also other circumstances (Department for Education, 2014). Nevertheless, students' experiences of science in school (undertaken within/for education) may not necessarily or entirely reflect practices within science (undertaken as scientific endeavours), which may limit the potential for students to develop science identities via being a scientist. Science education has been broadly encouraged to provide more opportunities for varied practical activities, including undertaking open-ended and extended investigative research projects (Gatsby Charitable Foundation, 2017). Investigative research projects for secondary students often (although not necessarily always) associate with benefits, including confidence and capabilities around undertaking research and working scientifically, and wider awareness, understanding, and positive views around science and scientists (Bennett et al., 2018). Further research may benefit from exploring these and other avenues towards supporting and clarifying students' understanding around being scientists.

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Ethics statement

The research was reviewed and approved by the ethics committee of IOE, UCL's Faculty of Education and Society, University College London, before data collection commenced (approval reference REC1401).

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