‘Making potions and jumping on the moon’: exploring young children’s understanding of science and scientists using the Draw a Scientist Test (DAST).

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Abstract

Misconceptions and stereotypical ideas about science and scientists can be a barrier to children and young people choosing to study or follow a career in science (Zúñiga-Mejías and Huincahue 2024). This study explores young children's understanding of scientists' roles using the Draw-a-Scientist Test (DAST) and semi-structured interviews with children aged 4-8 (n=75) who were visiting a Science Museum in England. A mixed methods design was adopted in order to address the following research questions: (i) How do young children represent scientists? (ii) What do children's drawings reveal about their understanding of scientists' gender, appearance, and specialties? (iii) How do children's characteristics such as gender influence their depictions, perceptions, and stereotypes of scientists? (iv) How do children explain their choices?

A statistically significant correlation was found between the gender of the child and the gender of the scientist depicted in their drawings. Regression analysis revealed that school year predicted children's overall scores on the DAST, while family characteristics did not predict their depictions and perceptions of scientists. A content analysis of children's responses provided insights into their thoughts about scientists, the importance they attribute to scientists' work, and a notable number of participants expressed a desire to attend university and pursue science studies when they are older. The findings inform a set of recommendations for teachers and parents in supporting children's future science ambitions.

SDG Keywords: SDG 4: Quality education, SDG 5: Gender equality, SDG 10: Reduced inequalities.

Keywords: science; scientists; Draw-a-Scientist Test (DAST); STEM education; semi-structured interviews with children; mixed methods research design

Introduction

There is currently a global shortage of young people pursuing careers in science (including medicine), technology, engineering, and mathematics (STEM) and STEM education (Tal et al 2024), a situation which is exacerbated by the shortfall of women in many STEM careers (Appiah-Castel et al. 2020). Given the future workforce is predicted to depend ever more strongly on well qualified STEM professionals (Tay et al. 2024), it is important that any barriers to children's perceptions and aspirations in relation to science are identified and addressed. Understanding who scientists are and what they do has been demonstrated as being crucial for scientific literacy and influences children's self-perception as users or potential future producers of scientific knowledge (DeWitt et al. 2013). The aim of the study is to explore the perceptions and representations of science and scientists by young children to identify any persistent and/or progressive stereotypical constructions as demonstrated through their drawings of science and scientists and associated narrative explanations. This is important for early childhood education and their social development as aspirations for a career in science have been demonstrated to begin in the earliest years of a child's education (Archer et al. 2013).

As children's perceptions of scientists and their ideas about science are shaped by their early developmental experiences and exposures (Dickson et al. 2021) it is of particular interest to explore their emerging perceptions and cognitive constructions of these concepts at a young age.

This study reports on a mixed methods study with 75 children aged 4 to 8 who were visitors to a science museum in a UK city. The research questions were as follows: (i) How do young children represent scientists? (ii) What do children's drawings reveal about their understadning of scientists' gender, appearance, and specialties? (iii) How do children's characteristics, such

as gender, influence their depictions, perceptions, and stereotypes of scientists? (iv) How do children explain their choices?

The children were asked to complete the Chambers (1983) Draw a Scientist Test (DAST) and were interviewed about their perceptions of science and scientists and their further study and career aspirations. The findings form the basis of recommendations for parents and educators in supporting young children to explore and understand what science is and what scientists do, in order to make informed decisions about their future study and career ambitions.

Literature review

Previous research into children's perceptions of science shows that children like science but often hold stereotypical views of scientists and commonly do not see themselves with a career as a scientist (Shimwell et al. 2021). In this article we are using the term 'stereotype' to refer to 'a set idea that people have about what someone or something is like, especially an idea that is wrong' (Cambridge Dictionary), in this case scientists and science. Understanding stereotypes held by children is important educationally and developmentally as previous research has demonstrated that, for example, gender stereotypes can influence children's STEM motivation (Master 2021)**.**

It has long been recognised that children's drawings can be a window into their inner worlds and that their drawings can represent what they feel, think and know about the surrounding reality (Quaglia et al. 2015). This makes drawings a particularly useful way of understanding the stereotypical views children may hold about certain groups of people, objects and activities.

Chambers (1983) designed his Draw a Scientist Test (DAST) as a tool to explore children's representations of scientists in order to explore the ways in which stereotypical ideas informed their drawings. He found that children under ten often depicted scientists as middle-aged men

wearing lab coats and glasses, with beards and sometimes surrounded by laboratory equipment. Finson et al. (1995) conducted a meta-analysis of studies using the DAST and confirmed that children's drawings of scientists were heavily stereotyped, reflecting the same traits found by Chambers (1983) and suggested the persistence of these stereotypes across different cohorts, highlighting the importance of interventions to address these biases.

More recent investigations (Ferguson & Lezotte 2020; Miller et al. 2018) using DAST have shown that a large proportion of students across various countries and cultures have a stereotypical view of scientists suggesting a prevailing universal similarity in the stereotypical depiction of this group as white male, with a specialism in Chemistry.
Miller et al. (2018) conducted a comprehensive review of 50 years of DAST studies which revealed that although the percentage of children drawing female scientists has increased over time, male scientists are still more commonly depicted. Thomson et al. (2019) found that children's depictions of scientists are also influenced by their exposure to science through various media and educational experiences.

In terms of younger children, a DAST study by Buldu (2006) identified differences in the way 5- to 8-year-old children drew scientists according to age, gender and socio-economic status. Focusing on a similar age group Quílez-Cervero et al. (2021) analysed drawings by primary school students aged 6 to 8 in Spain to determine their perceptions of scientists, their activities, and their environments. The results indicated that the students' images of scientists showed evidence of deviating from traditional stereotypes. Both young women and men were depicted working in science, with girls more frequently illustrating broader and non-traditional scenes, suggesting a movement towards a more egalitarian perception of scientists in beginning to prevail in the younger generation. This will be reflected on in relation to the findings of this study in the discussion section of the paper.

This study will extend understanding in this area by exploring how children's representations of science and scientists may be changing within the context of contemporary British society and the associated cultural shifts towards gender equality in work and education, including the recent UK government commitment to improving inclusivity and diversity in STEM (UK Parliament 2023).

Theoretical model

The study is framed by the theoretical position of social constructionism. From this perspective knowledge is understood as historically and culturally variable. Furthermore, an individual's perception of 'truth' is understood as a product of social processes and the interactions that an individual is engaging in rather than objective observation (Burr 2015). In this study children's perceptions and depictions of science and scientists are theorised as being socially constructed, as well as being influenced by individual characteristics of the children such as age and gender, which have been demonstrated to influence their drawings of scientists in past research (e.g. Bozzato et al. 2020). In terms of social influences Emran et al (2020) found that parental occupation and attitudes toward science can shape children's interest and understanding and Kim & Dopico (2016) found that museum visits, can enhance children's understanding of science. Our enquiry and interpretation were informed and inspired by the notion that children are agentive and can bring about social change through their views and choices, reinforcing the concept that knowledge is constructed socially.

Methodology

The study adopted a mixed methods approach to explore children's representations of scientists and understanding of their role using DAST and a semi-structured interview with the children. DAST (Chambers 1983) involves asking children to draw a scientist and analysing the drawings for common themes and indicators, such as lab coats, eyeglasses, and symbols of

research, knowledge and technology. DAST can also incorporate quantitative elements when researchers use standardised checklists or coding systems to analyse the drawings. In our study, we created a coding grid adapted from Hansen et al. (2017) and Mason et al. (1991). This coding grid (Table 1, Appendix C) was used to code the drawings for stereotypical characteristics. The coding categories for six stereotype indicators are as follows: attributes of the figure, attributes of the background, symbols of research, symbols of knowledge, signs of technology, and speciality of scientist.

Our research study was guided by the following research questions, with a detailed explanation provided for how each question was investigated:

(i) How do young children represent scientists? To investigate this, the DAST was employed. Children's drawings were coded for stereotypical characteristics and analysed against six stereotype indicators. Additionally, semi-structured interviews with the children provided deeper insights into their understanding of scientists, utilising a mixed-methods research approach.

(ii) What do children's drawings reveal about their understanding of scientists' gender, appearance, and specialties? This research question was investigated using the DAST. The elements of gender, appearance, and specialties were identified in the children's drawings and then quantitatively coded and entered into SPSS as variables.

(iii) How do children's characteristics, such as gender, influence their depictions, perceptions, and stereotypes of scientists? This research question was investigated using children's drawings, which were coded, quantified, and entered into SPSS as variables. Demographic information, including age, gender and school year, was collected from parents via questionnaires and were entered into SPSS.

(iv) How do children explain their choices? This research question was thoroughly explored through semi-structured interviews with the children, which helped clarify their views.

In the first part of the study, children were given the DAST to complete. Their parents were administered a series of questions exploring demographic information, such as socio-economic status. After completing the DAST, children participated in a semi-structured interview with researchers, where they explained their drawings and shared their thoughts on scientists, school subjects, future career aspirations, and their interest in attending university. The study followed the British Psychological Society's ethical guidelines which included specifying strategies for minimising potential issues of power and bias in the data collection and analysis, and received ethical approval from the Ethics Committee of …….. University. Informed consent/assent was obtained from all subjects involved in the study. All data were anonymised using numerical identifiers, and personal information was securely stored in compliance with data protection regulations. Participants were clearly informed that their involvement was entirely voluntary, and children retained the right to withdraw from the study at any time, independently of parental consent. The research team acknowledged potential issues of power and bias in the data collection an analysis

The data was collected in a Science Museum in a major UK city on a day in the school holidays when large numbers of children were visiting with their parents. Families visiting the museum were informed about the research activity and participating families were selected at random to ensure representation across diverse ethnic and socioeconomic backgrounds. The semi-structured interviews were conducted in a designated area within the museum. Members of the research team first collected demographic information from the parents. Following this, each child created a drawing and responded to the researcher's questions, which were adapted by the team to suit different age groups.

Participants

Seventy-five children 4-8 years of age participated in the study (42 girls and 33 boys).

Table 1: Participants' distribution per gender and year group at their school

		School year					
		Reception	Year 1	Year 2	Year 3	Year 4	Total
Gender	boy	9	8	4	5	7	33
	girl	8	15	8	9	2	42
Total		17	23	12	14	9	75

Participants were from Reception (age 4) to Year 4 (age 8). The highest percentage of participating parents were professionals with a responsibility role (47%), followed by freelancers and self-employed workers (24%) and public servants (16%). The majority of families (51%) visited a museum, cultural site or festival at least once every half term.

Research tools

The DAST (Chambers, 1983) was used in conjunction with semi-structured interviews conducted with the children (see Appendix A).

A preliminary coding grid was created, adapted from Hansen et al. (2017) and Mason et al. (1991). The DAST was employed as a qualitative tool to explore children's perceptions of scientists. Each drawing was coded using a structured template that included attributes of the figure, attributes of the background, symbols of research, symbols of knowledge, signs of technology and speciality identification. The two frameworks complemented each other by covering different dimensions of scientific representation: Mason et al. provided a lens for analysing individual identity and stereotype markers. Hansen et al. offered a broader view of

the scientific context and tools, enriching the analysis with environmental and symbolic cues. By integrating both, our coding scheme achieved a holistic view of how children conceptualise science and scientists, enabling nuanced insights into both personal and contextual representations.

The members of the research team used the grid to code a set of drawings, then came together to discuss what was found; this was done over multiple rounds, each time refining the coding grid, simplifying it until a simple, effective grid that touched on the majority of the aspects found in the drawings was obtained. The refined coding grid (see Table 1, Appendix C) was then used to code the rest of the drawings. The inter-rater reliability of the grid was calculated and found to be 99%. Scores ranged from 0-21, 0 being no specific stereotypes, 21 indicating the highest stereotype score; in this case based on literature it would be a white male chemist with white hair and a dishevelled appearance. Children's parents were also administered a series of questions exploring demographic information, socio-economic status and family habits (Appendix A).

Children's scores on their drawings and demographic information were analysed quantitatively; to answer each research question, chi-square tests, correlation and regression analysis were conducted. A content analysis (CA) (Neuendorf 2017) was performed on the semi-structured interviews. Each transcript was reviewed multiple times to develop categories that captured children's representations of scientists, their beliefs about whether individuals are born as scientists, perceptions of astronauts as scientists, understandings of doctors' roles in hospitals, and views on the importance of scientific work. The analysis also explored participants' favourite school subjects, career aspirations, and interest in attending university.

Two members of the research team independently coded the data, achieving a high interrater reliability (95%), which ensured consistency and validity in the categorisation process. The

emergent categories were refined collaboratively with the full coding scheme available in Appendix B. Once the categories were finalised, each transcript was re-examined, and responses were systematically assigned to the relevant category for each variable. Frequencies of responses were then tallied and entered into SPSS for descriptive statistical analysis. This content analysis provided valuable insights into children's conceptualisations of scientists and science-related careers. The categories, codes, and illustrative responses are presented in Supplementary Table III (Appendix C), offering a comprehensive overview of the themes identified.

Results

The findings from the DAST and the quantitative analyses addressing the first three research questions are presented first. This is followed by the results of the content analysis of the interviews, along with examples of responses. Our use of the word 'representation' in our analysis of findings refers to the way the child has drawn the picture and 'image' refers to the picture as a whole.

How do young school children (4-8 years) represent scientists?

Most participating children added attributes to the figure of the scientist in their drawings (84%); an unkempt appearance, lab coats, glasses, baldness, facial hair and pens and pencils were common features in drawings of both male and female scientists, as in Fig 1 in which a child has drawn a 'scientist with glasses and pens' in line with these stereotypical features:

Fig 1: DAST Female, age 7

And Fig 2 by a child who drew a scientist with his white hair, a signifier of the ‘mad scientist’ stereotype, specifically labelled:

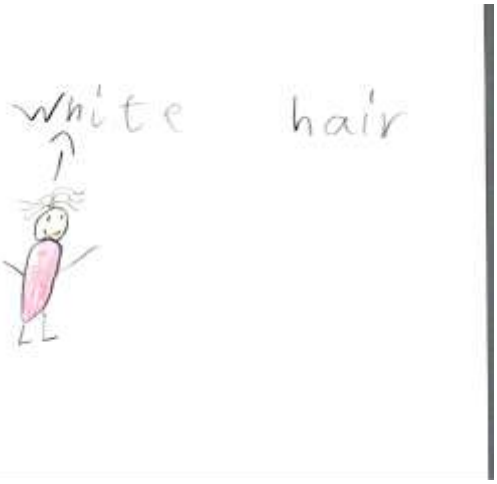

Fig 2: DAST Male age 6

The participants indicated that scientists work in different environments and depicted "laboratories" as the most common working environment of scientists. Young children also depicted scientists' working environment as an office or nature. A significant number of children (57.3%) indicated in their drawings that scientists use lab materials, test tubes, flasks, microscope, Bunsen burner and living things. For example, the child who drew Fig 3 describes a scientist as being surrounded 'with test tubes, to test stuff' and illustrates this by including pictures of Bunsen burners and smoke in his drawing:

Fig 3: DAST Male, age 7

A few drawings (5.33%) included symbols of knowledge, books or boards and in some of the drawings (13.33%), scientists were surrounded by computers, laptops and machines (signs of technology) as evident in Fig 4. The child who drew this explained that scientists make

'caravans and stuff like cars and stuff' and has included a picture of a house on wheels to represent a caravan:

Fig 4: DAST Male, age 7

Drawings were also analysed to identify the number of indicators in children's depictions of scientists. The mean number of indicators per pupil was found to be moderate (M=2.71), with a relatively small standard deviation (SD=.90). We then performed a crosstabulation of school year and indicators' score. However, a chi-square test of independence showed that there was no significant association between school year and number of indicators demonstrated in the scientist drawing, $x2$ (16, N = 75) = 14.88, p = .53.

What do children's drawings reveal in relation to scientists' gender and speciality?

A slightly bigger proportion of male scientists (24%) were drawn compared to female scientists (22.7%). A statistically significant correlation was found between the gender of the child and the gender of the drawing (r=.370** p=<.001). Female participants who took part in the study (unlike similar studies in the past), were more likely to draw the scientists as female. For example, in Fig 5 the child explained that she drew a 'girl scientist, because girls can be scientists', indicating a loosening of traditional stereotypes around scientists being male. The

figure's long green hair and colourful clothes are additional markers of progress, as the enduring image of a scientist wearing a white coat has clearly and deliberately been replaced:

Fig 5: DAST Female, age 7

Only one male participant drew a scientist as female (a counter stereotypical example), although for the greatest proportion of drawings (53.33%), the research team were unable to define the gender of the drawing. In 85.33% of the drawings, the students reported that the scientist does not have a clear speciality. The remaining 14.66% revealed that the scientist could be a chemist, an inventor or a space person or astronaut.

How do children's characteristics influence the total score on the Draw-A-Scientist-Task?

A regression analysis was performed to investigate if the characteristics of the children and their families predicted their depiction, perceptions and stereotyping of scientists, as it is measured with the DAST and it is reflected on the overall score calculated. All assumptions were met, and the results are presented below. Using the enter method it was found that the

experimental condition, gender of the child, school year, profession of mother and father and visits to museums and festivals did not explain a significant amount of the variance in the overall score of children on the Draw-A-Scientist test (F (6, 67)=1.89, p=.085), R^2 =.165 $R^2_{Adjusted}$ = .078.

The analysis showed that the order of birth (*Beta* = .25, $t(74) = 2.11$, $p = .039$) and the school year did significantly predict the overall score of children on DAST (*Beta* = .32, $t(74) = 2.75$, $p = .008$). None of the other variables examined could predict the overall score of children on the DAST (see Supplementary Table II, Appendix C).

How do children reason their choices?

A content analysis was conducted on the children's responses during their semi-structured interviews with the researchers. The children described their drawings, explaining how they imagined scientists and sharing their thoughts about scientists. The content analysis shed light on how they represent scientists, whether they believe people are born as scientists, if astronauts are considered scientists, what doctors do in hospitals, and whether they deem scientists' work as important. The analysis also revealed the participants' favourite school subjects, their future career aspirations, and their interest in attending university. The categories that emerged were refined by the researchers, and their codes and example responses are presented in Supplementary Table III (Appendix C).

The analysis of children's responses to each question revealed distinct codes that reflect their understanding and perceptions of scientists. For example, when asked what they drew or what a scientist does, children's answers ranged from basic descriptions (e.g., 'they make potions and jump on the moon', "man/woman, potions, crazy hair" or "exploring, experiment") to more advanced depictions (e.g., '"laboratory setting, equipment often used by scientists" or "archaeology and other specific scientific areas"), showcasing varying levels of understanding

and development of the concept of a scientist. Similar patterns emerged in later questions, where children's views on whether people are born as scientists revealed a divide. Some children believed it to be an innate talent (“Born as a scientist”), others thought scientific skills had to be learned (“they don’t know how to do science when born”), some believed it depended on the individual, and others took the question literally, stating that people cannot be born scientists because they are “too little” (meaning they are babies and babies cannot do science). Responses to whether astronauts and doctors were seen as scientists also yielded mixed results. Some children affirmed that these job roles were those of scientists too (e.g., “Yes, they explore the moon” or “Yes, they make medicine”), while others distinguished them as different from scientists (e.g., “No, they go on rockets” or “Scientists don’t help people”). Similar to the previous question, some children offered a combination of the two perspectives, suggesting that some astronauts and doctors could be considered scientists depending on their specialised roles. This highlights how children’s perceptions can be influenced by their exposure to and understanding of various job roles, including that of a scientist.

Further questions were coded to reveal children's interests and future goals. Favourite subjects ranged widely indicating diverse areas of interest within the sample. Career aspirations reflected a broad spectrum and were categorised into five main codes: performing arts, public service roles, science and engineering roles, combinations of various fields, and imaginative roles showcasing creativity. Table 2 illustrates these responses, showing that a significant number of children expressed a desire to become scientists and engineers, followed by those aspiring to be actors, musicians, singers, and those interested in public service roles.

Table 2: ‘What would you like to do when you are older?’

Professions	Frequency	Percent	Cumulative Percent
No response	5	6.7	6.7
Performing and creative arts	17	22.7	29.3
Science and Engineering	29	38.7	68.0
Public service	19	25.3	93.3
Combination	2	2.7	96.0
Imaginary	3	4.0	100.0
Total	75	100.0	

Discussion

The findings of this study provide valuable insights into children's perceptions of scientists enabling researchers to draw parallels and highlight differences between this study and previous studies. The findings indicate that while traditional stereotypes are still present, there is also a significant number of children who depict scientists more accurately and inclusively, particularly female participants drawing female scientists. Notably, our participants envisioned and depicted scientists in settings beyond laboratories, which constitutes a significant finding that could indicate a new direction for this line of research. Children's mixed responses regarding the roles of scientists, astronauts and doctors highlight varying levels of understanding and exposure to different scientific professions. The sections below consider the findings from a social constructionist perspective around the following key themes: children's representations of scientists, gender and specialty of scientists, children's characteristics and the DAST test and children's reasoning for their choices.

Children's representations of scientists

Regarding the first research question, which examines how children (4-8 years) represent scientists, we found that most boys and girls included specific attributes in their drawings, such as an unkempt appearance and lab coats. These findings align with those reported in the original study by Chambers (1983), as well as subsequent studies (including Blagdanic et al. 2019). A significant number of children did not depict a specific environment, but in settings beyond laboratories. This finding is in alignment with Christidou et al. (2012), who found that lower primary school students depicted scientists working in the field rather than in a laboratory setting, contradicting previous studies. This may indicate a new understanding of the role and space where scientists develop their ideas and contribute to science.

The limited presence of symbols of knowledge such as books or boards and the occasional inclusion of computers, laptops, and machines in the children's drawings suggest a nuanced perception of scientists. These findings align partially with previous studies (Finson, 2002) that highlight the persistence of certain stereotypical images but also reveal some evolving views (Christidou et al. 2021). However, the relatively moderate number of indicators and the occasional depiction of modern technology suggest an emerging recognition of the broader, more contemporary nature of scientific work.

The absence of a significant association between the school year and the number of indicators suggests that these perceptions are relatively consistent across different age groups within the 4–8-year range. This finding is consistent with research by Finson (2002), which indicates that stereotypical views of scientists can be ingrained at an early age and remain stable over time without targeted educational interventions (Miller et al. 2018). Moreover, the limited inclusion of symbols of knowledge could indicate that young children may not fully appreciate the scholarly and theoretical aspects of scientific work. This aligns with Driver et al. (1996), who found that young students often view science primarily as a practical endeavor focused on

solving technical problems, rather than as a discipline deeply rooted in theoretical and academic study.

Gender and specialty of scientists

In terms of what children's drawings reveal about scientists' gender and specialty, our data revealed a slight preference for male scientists over female scientists. A significant correlation between the child's gender and the gender of the scientist drawn was found, with female participants more likely to draw female scientists. Same gender reference evidenced in the tendency of girls to draw female scientists, and boys to draw male scientists, was a finding common to many other studies (eg including Quílez-Cervero et al. 2021; Farland-Smith 2017; Buldu 2006). Similar to other studies, boys in our study were more likely to depict gender stereotypes (Blagdanic et al. 2019) and stereotypical images (Emvalotis & Koutsianou 2018) about scientists than girls. The fact that in our study, only one boy drew a female scientist could suggest that boys hold more entrenched gender stereotypes (Leavy et al. 2023). However, there is an important and encouraging shift, and that relates to the number of images of female scientists drawn overall; as studies in the past showed the tendency of both males and females to draw male scientists (Miller et al. 2018). Over the past decades, several studies have attested to an increase in drawings of female scientists especially by female students (Blagdanic et al. 2019; Farland-Smith 2017). These drawings may well reflect aspects of their own personal and gender identity. Thus, they draw 'someone like me', in this case, a girl or a boy doing science.

Children's characteristics and the DAST test

Regarding the third research question, which examines how children's and family characteristics influence their overall score on the DAST, the regression model indicated that school year emerged as significant predictors of the overall DAST score. The significance of school year as a predictor is consistent with the developmental perspective that older children have more advanced cognitive and perceptual abilities. Research by Farland-Smith (2017),

Quílez-Cervero et al. (2021) and Türkmen (2008) supports this, showing that older students tend to have more complex and less stereotypical views of scientists compared to younger students.

The fact that our study's regression model did not identify gender as a predictor of children's total score on the DAST may indicate a shift towards more gender-neutral perceptions or reflect the sample's specific characteristics. The non-significant influence of parents' professions also contrasts with findings by Emran et al. (2020), who reported that parental occupation and attitudes toward science can shape children's interest and understanding. This discrepancy might be due to the age of the participants or the cultural context of the sample. It is worth noting that participants in this study were recruited during their visit to a Science Museum, indicating that these families had chosen to engage in a science-related activity. Previous research has demonstrated that informal science education experiences, such as museum visits, can enhance children's understanding of science (Kim & Dopico 2016). However, the non-significance in this study might suggest that occasional visits are insufficient to significantly alter deep-seated perceptions or that these experiences have led to a homogenous sample in terms of science exposure and interest.

Children's reasoning for their choices

Regarding the fourth research question about how children reason their choices, the content analysis of the responses revealed that children's descriptions of scientists varied significantly, from basic portrayals like "man/woman with potions" to more detailed depictions involving "experiments" and "lab equipment." This range in descriptions indicates varying levels of understanding and familiarity with the scientific profession. It seems that children's perceptions are shaped by their immediate surroundings, such as family and school, as well as broader societal influences, aligning with the social construction of science and scientists. Children's responses about becoming a scientist ranged from believing in innate talent to considering it a

learned skill. This diversity in reasoning suggests different levels of cognitive development and exposure to scientific concepts, as also noted by Chionas and Emvalotis (2022). The mixed responses about whether astronauts and doctors are scientists highlight varying levels of understanding about the scope and nature of scientific professions (Thomson et al. 2019).

Children's interests spanned STEM subjects, humanities, creative arts, and practical subjects, indicating diverse areas of engagement. Career aspirations were equally varied. This aligns with findings by Garriott et al. (2017) and Christidou et al. (2021), which emphasise the importance of early perceptions in shaping academic and career choices. Our participants' views on attending university varied, possibly reflecting different levels of exposure to the concept of higher education and individual aspirations, which can be influenced by family expectations and socioeconomic factors (Emran et al. 2020).

Conclusion

The children's drawings in this study indicate that certain stereotypical aspects of science and scientists still prevail in their representations, whereas other features seem to be fading. For example, there was less emphasis on laboratories as the only environment in which scientists work, more images of female scientists and occasional inclusions of modern technology in the drawings. Whether this weakening of the stereotypical image is mainly due to our sample's young age, or reflects a broader trend, needs further investigation. Future research including a larger sample of children representative of a range of backgrounds would help to clarify this.

The significant influence of school year on DAST scores underscores the importance of cognitive development and familial dynamics in shaping children's perceptions of scientists. The non-significant influence of other factors suggests that while external and familial influences do play a role, intrinsic developmental factors and perhaps broader societal stereotypes might have a more substantial impact. These findings highlight the need for

ongoing, targeted educational interventions to reshape children's perceptions of scientists, moving beyond superficial changes to address deeper cognitive and social factors. The non-significant influence of the parents' professions and visits to museums, suggests that while external and familial influences do play a role, intrinsic developmental factors and broader societal stereotypes might have a more substantial impact.

The mixed-methods design of this study was a deliberate strategy to capture the multifaceted nature of children's understandings of science. The quantitative data provided measurable patterns in how scientists and science were represented which offered a broad overview of trends across participants, such as recurring stereotypes, new trends or aspirational themes.

However, it was through the qualitative interviews that we were able to unpack the meanings behind these patterns. For example, while drawings often depicted scientists in stereotypical ways, the interviews revealed nuanced perspectives, including children's aspirations to challenge these stereotypes. This interplay between the two data types did not highlight any tensions: the drawings suggested some conformity to traditional images, while both the drawings and the interviews revealed a desire for change and more inclusive representations.

By critically interpreting these data sets together, we were able to triangulate findings, validate interpretations, and uncover the change that would have remained hidden if either method were used in isolation. This approach aligns with Creswell and Plano-Clark's (2017) emphasis on explanatory depth in mixed-methods research and supports Aramide et al.'s (2023) argument that such integration enables researchers to peel back complex layers of understanding.

Recommendations from study

Although generalisation of the findings of this study is limited due to the relatively small sample size and non-representative demographics of the participants, the findings do highlight

the need to develop of ongoing, targeted educational interventions to reshape young children's perceptions of scientists. Such interventions should move beyond superficial changes and address deeper cognitive and social factors through reflection, discussion and age-appropriate child-led activities, such as helping children develop a growth mindset through play (Law et al. 2021). As Miller et al. (2018) and others have noted, without targeted educational efforts, stereotypical views can become ingrained and stable over time. However, stereotypes about science can and do shift, as evidenced in the way the young participants of this study envisioned and depicted scientists in settings beyond laboratories.

This article highlights the importance of early, targeted interventions to challenge science-related gender stereotypes, supporting policy and practice in promoting inclusive STEM learning. Formal and informal science education should systematically engage in modernising the image of scientists and their work particularly through child-led, play-based approaches that broaden young children's understanding of who scientists are and what they do (see Heywood & Adzajlic 2023). Familiarising students, as future citizens and potential scientists, with the achievements of contemporary science is crucial (Christidou et al. 2016). It is also important to acknowledge the positive influence of parental and community involvement in science education as activities that children can do at home with their families reinforce learning and engagement. In this way, we can help to ensure that children are inspired to pursue fulfilling scientific careers and contribute to the global advancement of scientific knowledge.

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Appendix A – interview questions

(i) Questions for the parents

The following demographic information is obtained from the parent, carer/guardian regarding the child:

Age of the child:

Gender of the child:

Order of birth:

Profession (parents):

Area of living (urban, rural):

School year:

Family members who live in the house:

Ambitions of the parents: What do they want their children to do in their lives?

Do they visit museums, festivals, go on day trips? How often?

(ii) **Questions for the child** *(these are a guide only. The researchers are led by the child):*

What have you drawn and why?

Do you think people are born as scientists? How come?

Do you think astronauts are scientists? What about doctors at the hospital?

What do you think a scientist does? Do you think this is important?

What would you like to do when you are older?

What is your favourite subject at school?

Would you like to go to a university to study when you are older?

Appendix B – DAST coding schemes

(i) Draw a Scientist coding scheme for children's drawings

Basic information

Drawing_ID: type in the file number of the drawing

Coder: type in your initials (e.g., ECT)

Condition: Experimental condition; should be written at the top of the drawing

1 = draw a scientist, 2 = draw someone doing science

Attributes of the figure

Gender: What is the gender of the character in the drawing? 1 = female, 2 = male, 3 = unable to tell

Lab_coat: is the person wearing what appears to be a lab coat? 1 = no, 2 = yes, 3 = unable to tell

Glasses: is the person wearing glasses? 1 = no, 2 = yes, 3 = unable to tell

Facial_hair: Does the person have facial hair (e.g., moustache, beard, stubble)? 1 = no, 2 = yes, 3 = unable to tell

Pencils_pens: Does the person have pencils/pens in their pockets? 1 = no, 2 = yes, 3 = unable to tell

Baldness: Does the person have a bald head? 1 = no, 2 = yes, 3 = unable to tell

Unkempt: does the person have a scruffy/untidy/wild appearance? 1 = no, 2 = yes, 3 = unable to tell

Attributes of the background

Setting: does the background depict an indoor or an outdoor setting? 1 = indoor, 2 = outdoor, 3 = unable to tell

Symbols of research

Symbols_research: do any of the below items appear in the drawing? 1 = no, 2 = yes, 3 = unable to tell

Lab_materials: are there depictions of lab apparatus (e.g., flasks, Bunsen burners, test tubes, etc)? 1 = no, 2 = yes, 3 = unable to tell

Test_tube (narrow, same width all over) 1 = no, 2 = yes, 3 = unable to tell

Flask (may be wider at the base than the top, or wide all over) 1 = no, 2 = yes, 3 = unable to tell

Microscope 1 = no, 2 = yes, 3 = unable to tell

Bunsen_burner 1 = no, 2 = yes, 3 = unable to tell

Living_things: are there depictions of plants or animals? 1 = no, 2 = yes, 3 = unable to tell

Earth_space: are there depictions of rocks, soil, planets, stars etc, and/or tools for investigating these (e.g., telescopes, archaeology tools)? 1 = no, 2 = yes, 3 = unable to tell

SOR_other: if there is anything else that you think could come under the 'symbols of research' category but is not covered by the above, type it in here

Symbols of knowledge

Symbols_knowledge: do any of the below items appear in the drawing? 1 = no, 2 = yes, 3 = unable to tell

Books: are there depictions of books, notebooks, bookcases, etc? 1 = no, 2 = yes, 3 = unable to tell

Boards: are there depictions of blackboards, whiteboards, flipcharts, etc? 1 = no, 2 = yes, 3 = unable to tell

SOK_other: if there is anything else that you think could come under the 'symbols of knowledge' category but is not covered by the above, type it in here

Signs of technology

Signs_technology: do any of the below items appear in the drawing? 1 = no, 2 = yes, 3 = unable to tell

Machines: are there depictions or any machines that are NOT computers/laptops (e.g., lab machines, etc)? 1 = no, 2 = yes, 3 = unable to tell

Computer: are there depictions of laptops, computers, IT-related things? 1 = no, 2 = yes, 3 = unable to tell

Tools: are there depictions of any tools, e.g., for cutting, gluing, etc? 1 = no, 2 = yes, unable to tell

Artefacts: are there depictions of any technological objects/artefacts, e.g., robot, model vehicles, etc? 1 = no, 2 = yes, 3 = unable to tell

SOT_other: if there is anything else that you think could come under the 'signs of technology' category but is not covered by the above, type it in here

Profession

Speciality: does the scientist have a clear speciality (e.g., chemist, biologist, archaeologist, doctor, etc)? 1 = no, 2 = yes, 3 = unable to tell

Speciality_ID: if yes to the above, what speciality have you identified? Type in the speciality

Notes: type any other notes relating to the drawing here

(ii) Draw a scientist coding scheme for interviews with children

Children's data

What have you drawn and why?

Code 1: Imaginary elements

Description: Code relates to imaginative or fantastical elements in drawings; these may not reflect actual real-life scientific practices but show creativity

Code 2: Symbolic and tool representation

Description: Any symbolic representations that are most often associated with scientists (lab coats, glasses, crazy hair, being in laboratory settings, etc.) Mention of tools can include masks, test tubes, liquids, etc.

Code 3: Physical appearance, Female

Description: Any mention of female scientists can include any physical characteristics and mentions of any clothes/outfits they might wear

Code 4: Physical appearance, Male

Description: Any mention of male scientists can include any physical characteristics and mentions of any clothes/outfits they might wear

Do you think people are born as scientists? How come?

Code 1: Innate talent

Description: Yes, scientists are born as scientists. Any reference to that being a natural talent. rather than it being something that's acquired.

Code 2: Learned skill

Description: This is something they would have to be taught about; they would have to learn about and study. Can accept any mentions of going into further education (e.g. university) or working towards it.

Code 3: Passion

Description: Any mentions of people pursuing science as a passion, or because they are interested in it, they like science or they want to do it.

Code 4: Combination

Description: Mentions of it being innate for some, not for others. Can accept answers of being unsure or being in the middle.

Do you think astronauts are scientists?

Code 1: Astronauts are scientists

Description: Any mentions of yes they are scientists

Code 2: Specialised training

Description: Mentions of astronauts having to undergo specialised training to become astronauts. This may include mentions of scientific knowledge and skills, making them either scientists or similar to scientists.

Code 3: No

Description: Any mention of no, they're not scientists, they do different things to scientists etc.

Code 4: Combination

Description: Mentions of yes and no, maybe, a little bit etc. Can accept mentions of yes if they do certain things (such as testing like scientists conduct tests) but no if they don't do them.

What about doctors at the hospital?

Code 1: Yes treatment

Description: Yes doctors are scientists, any reference to them diagnosing and treating people, helping people and saving people

Code 2: Yes Research

Description: Yes, doctors are scientists, any reference to conducting their own research, making medicines, doing tests and learning about humans.

Code 3: Combination

Description: Any mention of yes and no, a little bit, maybe and some are, some aren't.

Code 4: No

Description: Doctors are not scientists; this may be because they don't do the same jobs scientists do; they don't do their own research or experiments.

What is your favourite subject at school? [This one could potentially be done as a thematic analysis also]

Code 1: STEM subjects

Description: Any subjects such as science, mathematics, chemistry, biology, computers etc.

Code 2: Humanities

Description: Subjects such as English, Literature, Geography, History

Code 3: Creative arts

Description: Subjects such as art, drama, music, dance, and creative writing.

Code 4: Practical and active subjects

Description: Subjects such as P.E, sports, cooking, woodwork etc.

Appendix C – Supplementary tables

Supplementary Table I: Coding categories for six stereotype indicators

		Categories				
Attributes of the figure	Attributes of the background	Symbols of research	Symbols of knowledge	Signs of technology	Profession (speciality of scientist)	
Gender	Setting	lab materials	books	machines	chemist	
lab coat		test tube, flask, microscope, Bunsen burner	boards	computers	biologist	
glasses		living things		tools		
facial hair		earth space		artefacts		
pencils						
Pens						
baldness						
unkempt						

Supplementary Table II. Regression analysis coefficients

Model		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	1.319	2.256		.585	.561	-3.183	5.821		
	gender of the child	-.824	.624	-.154	-1.322	.191	-2.069	.421	.914	1.094
	order of birth	1.281	.607	.253	2.111	.039	.070	2.492	.871	1.149
	profession of mother	.148	.200	.090	.740	.462	-.251	.546	.838	1.194
	profession of father	-.094	.206	-.058	-.459	.648	-.504	.316	.786	1.272
	school year	.629	.229	.316	2.750	.008	.172	1.085	.946	1.057
	visits to museums, festivals	.366	.352	.123	1.042	.301	-.336	1.068	.892	1.121

experimental condition	-.068	.670	-.012	-.101	.920	-1.405	1.270	.916	1.091

a. Dependent Variable: Total_score

Supplementary Table III: Content analysis of children's responses, categories, codes and examples

Category	Code	Example Answers
Scientists' drawings	1-Basic description	When you are a scientist, you do lots of experiments
	2-Symbolic representation	Scientist as a genie or Person doing fair test on liquids, someone making sure it is a fair test with a check list
	3-Advanced understanding of science and scientists	Table for experiments, goggles to stop chemicals from getting into eyes
Scientists' work and 'portfolio'	1-Uncertain, naïve understanding, not appreciation	
	2-Specific areas	Studies things such as archaeology and learn about things

	3-Learning and discovery	Experiments, explore, if you don’t do it, it might break rules of the job
Are people born as scientists?	1-Innate talent	Born a scientist or Yes, lots of children go to museums, want to be a scientist
	2-Learned skill	No, they learn and don't know how to do science when born or Not really, when first born no clue about science, might like it when older
	3-Combination	Not sure, some are, some aren't
	4-Question taken literally	No, scientists cannot be little
Are scientists astronauts?	1-Astronauts are scientists	Yes, explore the moon OR Yes, bring data back from space, learn science
	2-No	No, go on rockets
	3-Combination	Depends on what they do, space-no, testing things-yes
What about doctors?	1-Yes	Yes, make medicine, help people

	2-No	No, help people and scientists don't
	3-Combination	Some are, do different jobs
What is your favourite subject at school?	1-STEM subjects	Maths
	2-Humanities	History
	3-Creative arts	Art
	4-Practical subjects	Design Technology
	5-Combination of subjects	Art, music, science
What would you like to do when you are older?	1-Performing and creative arts	Actress
	2-Science and engineering-based	Nurse/fix computers
	3-Public service	Police officer
	4-Combination	Artist/photographer/historian
	5-Imaginary	Princess
Would you like to go to university?	1-Yes	Yes, learn about history, animals and fossils
	2-No	No, because it's very hard
	3-Don’t know/maybe	Maybe yes if I'm studying singing or a teacher