Elimination before imagination: How children's early understanding of scientists may limit aspirations for broader STEM careers

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***Abstract*—This research full paper presents a study that examines emerging understanding of science careers among very young children (aged 5-7) and seeks to identify the factors that influence their understanding. Knowing that early interest in science is a strong predictor for future engineering pathways, and that children begin eliminating careers as incompatible with their future self at a very young age, the results are interpreted in the context of what this means for engineering education. Grounded theory approaches were applied to qualitative data collected through focus groups and used to sort and categorize data and identify themes. The study finds that despite science being a core subject in elementary schooling in the UK, young children's awareness of scientists and science careers remains low. Four categories to describe the patterns of children's understanding were identified: undeveloped, introductory, stereotypical, and diversifying. For most children, their perceptions of scientists remained either under-developed or confined to ideas with clear labels, such as stereotypes. Young children's understanding of engineers may be even more restricted due to engineering not being a taught subject within elementary education in the UK. The factors identified as influencing young children's understanding of scientists differ somewhat from those presented in studies with slightly older children. Young children did not commonly relate science learning in school with scientists or to a broader spectrum of science-related jobs. Children within the diversifying group highlight the value of personal experiences with science and STEM professionals. By identifying the potential of careers-related learning to shape young children's understanding of engineering and engineering careers as distinct from that of science and mathematics, these findings have implications for future engineering education practices.**

Keywords— Elementary school, STEM, engineering recruitment, underrepresentation, focus groups, grounded theory

I. Introduction

Considerable effort has been put into trying to improve participation in STEM careers over past decades [1], yet challenges of workforce shortages and under-representation of women in certain science, technology, engineering and mathematics (STEM) sectors endure [2][3]. This problem is widespread globally [1][4]. The engineering and manufacturing industry is currently the worst affected within the UK, with 85% of businesses reporting a lack of skilled workers, and 50% identifying that recruiting a more diverse workforce would help resolve their skills shortage [5].

Engineering is widely acknowledged to be the link between science and society [6] and between applications of science and real-world contexts [7]. Learning engineering in schools can therefore support children to create connections between their understanding of scientific curriculum content, theories and processes and their understanding of the world, by creating opportunities for them to engage with real-world problems and applications [4] [7]. Yet, the majority of children in the UK do not have the opportunity to study engineering formally in their elementary education, and as a consequence, understanding of engineering and engineering careers among young children remains low [8] [9]. This understanding remains limited even among older groups, with a recent survey reporting that 47% of 11 – 19-year-olds know very little about what engineers do [10].

Many of the efforts to increase participation in the STEM sectors have significantly under-estimated the very young age that children's careers aspirations develop [11] [12]. The ages of three to seven are recognized to be pivotal in children's vocational development [13][11] with many children having made up their mind about which occupations are not for them by the end of elementary education [13]. Previous research by the authors has highlighted how children's aspirations for different STEM sectors are mediated by gender [14]. Despite their limited understanding of the subjects or sectors, many girls eliminate the possibility of careers in engineering, physical sciences and digital technology before the age of 11, viewing these careers as incompatible with their imagined selves [14]. Elementary school age is important for the development of aspirations, yet few studies have explored the influences on emerging aspirations of young children [15].

The authors are interested in understanding how young children's emerging understanding of STEM subjects, STEM workers and STEM careers influence the development of their aspirations. Previous studies, such as [9] have shown the complexities of trying to explore the understanding of subjects, such as engineering, that children have not yet studied or encountered. The decision was therefore taken to focus the research on young children's understanding of scientists, an area where they could be expected to have more understanding due to the positioning of science as a core subject within the National Curriculum in England. A solid understanding of both science and mathematics are considered the initial building blocks for developing understanding of other STEM subjects such as engineering and technology [8]. Research shows that an early interest in science followed by achievement in mathematics are important predictors of continuing with engineering to degree

This research was supported by a STFC Nucleus Award ST/S000070/1.

level [16]. This study looks at young children's (aged 5 – 7) emerging understanding of science occupations, considering what young children know and do not yet know about scientists, and the routes of influence on the development of their early understanding. The review of the findings considers the implications for improving children's access to careers in the broader spectrum STEM disciplines, particularly engineering.

II. BACKGROUND

A. Where does engineering fit within elementary schooling?

Engineering is not part of the curriculum in elementary education in England. Consequently, the route through which children can be taught engineering education within elementary schooling is not clear.

A number of possible routes for including engineering learning in schools have been identified [17] [18]:

1) inclusion within one of the core subjects of the National Curriculum
2) as part of cross-curricular or topic-based learning
3) one-off projects and company visits.

Lucas et al mapped opportunity for the inclusion of engineering within education for children aged 4-16 across National Curriculum in England, Scotland and Wales [17]. Within science, an overlap was identified between the concept of 'working scientifically' within engineering disciplinary thinking: such as observing over time, finding patterns and relationships, identifying and classifying, researching using secondary sources, comparative and fair testing. Mathematics was identified as offering the foundations and vocabulary necessary for further engineering enquiry [17]. Lucas et al also find potential for building understanding of engineering via 'computational thinking' within the ICT curriculum, and the 'design, make and evaluate' approach within Design and Technology curriculum [17]. In reality however, the space for including engineering within a packed curriculum is limited. The pressures on teachers are such that even within the core subject of science, most elementary school age children in England receive less than 2 hours teaching per week, with younger children having even less time allocated to science learning than older children [19].

Cross-curricular teaching and learning recognizes the importance of making connections between subjects, with the aim of building deeper knowledge about the world around us [20]. Cross-curricular approaches have been acknowledged to offer a more motivating and enjoyable experience for children, while supporting them to develop problem-solving skills and build relevance and meaning into their learning [20] [21]. Cross-curricular learning may be delivered alongside subject-based learning, for example on alternative curriculum days or themed weeks (such as STEM weeks), as an adaption of the published topic approach, or through a focus on play-centered learning [21]. The Wellcome Trust found that younger children more commonly experienced science learning through cross-curricular approaches than older children [19]. Engineering learning can offer children the opportunity to apply their curriculum learning in science and mathematics to real-world problems and contexts [17].

Projects, events and engagement with STEM companies and employees are a common route for raising awareness of the nature of engineering [18]. A mapping exercise conducted by the Royal Academy of Engineering in 2016 identified at least 600 providers actively involved in supporting engineering education in the UK [10]. Some providers offering engineering focused activities, such as Primary Engineer [22], support engagement with engineering via other subjects, by mapping their activities across the mathematics, science and English curriculum.

Although there are a number of possible routes to engineering learning that could be adopted within elementary schooling [17] [18], currently their inclusion relies on the personal interest, commitment and bravery of individual teachers or school leadership [18] [23]. As a result, many elementary age pupils lack access to engineering through their school education [6].

B. The risk of lack of early exposure to STEM careers

The lack of awareness of STEM careers among young children is problematic for improving participation in STEM sectors. This is because young people's study choices and career decisions have been shown to have their roots in early childhood [24], and the effects of these been found to be lasting [25] [26]. Research has shown that the pattern of jobs chosen by seven-year-olds mirrors those selected by 17-year-olds [27].

Career development theory describes an individual's orientation to possible careers as a life-long process of learning about the vocational world and society more broadly and understanding how they fit within these. It provides a framework for understanding the career exploration undertaken by children and adults and describes how awareness, interests and aspirations develop with age and how social and environmental factors intersect to influence these [12]. Gottfredson's Theory of Circumscription and Compromise outlines how children's aspirations evolve from a broad spectrum of possible career alternatives, to be further eliminated and defined during four stages of their childhood [13]. In stage 1, usually between the ages of 3 and 5, children begin to classify people based on their orientation to size and power. In stage 2, usually between 6 and 8, children categorize based on their understanding of gender roles, and start to eliminate based on the perceived fit with their gender identity [13] [25]. This elimination is often made using naïve or inaccurate understandings about occupations and stereotypes. In stage 3, usually between 9 – 13 years, children further eliminate occupations as out of reach due to their growing awareness of social class and developed intelligence [13]. Then in the last stage, from around 14 years old, young people's focus is on exploring their unique personal interests, values and competencies. They develop a notion of work fields and how their self-concept is related to these [24]. In this stage many children compromise on their preferred choices and settle for more available and acceptable alternatives, this due to their new understanding of structural constraints and social circumstances [13] [28].

Young children understand that work exists and, from around ages 3 or 4, can express their own ideas about what they might like to do in the future [29]. Accurate knowledge about STEM professions and professionals are shown to be key elements of orientation to STEM careers [4]. However, young children's understanding in elementary schooling commonly represents stereotypes and misconceptions [30]. For example, children in elementary and middle school commonly view engineers as people who fix engines and vehicles, or as technicians or labourers who fix and build [31] [9], whilst it is rare for children's descriptions of engineers to include design or problem-solving [9]. The 'Draw a Scientist Checklist' has been widely used to explore the perceptions and understanding of scientists, including with young children. A review of studies using this approach finds that children's perceptions of scientists have largely remained consistent over time [32]. The perception of a scientist is one of a white male, wearing a lab coat and working long hours alone in a lab, who is highly intelligent but with limited social skills [33] [32].

C. *The influences on young children's early understanding of careers*

Deeper and more fine-grained understanding of what young children know and think about scientists and STEM professionals is needed to help address these misconceptions and stereotypes before they take root. Similarly understanding the influences on these early understandings is important for designing effective counterstrategies [34]. However, much existing literature concerns the influences on young children's future aspirations rather than their understanding or perceptions of a broader range or specific sector of careers [15][34]. A child's personal characteristics and beliefs have been shown to be important influences on aspirations, with factors such as gender, ability beliefs, self-efficacy, task-value, motivation widely reported [24][35]. Environmental factors and the characteristics and circumstances of their families, communities, school and neighborhood are also key contributory factors [28] [15] [36]. Drawing the Future, an international survey of 7–11-year-olds found that 36% of children based their career aspirations on people they knew, and for those who did not, media (TV, film and radio) was the biggest influences on their choices [27].

Science capital is a useful framework for understanding the influences on children's understanding, aspirations and career development that concern STEM. Science capital describes different types of economic, social and cultural capital that specifically relate to science, especially those that have the potential to leverage support and enhance a person's attainment, engagement and participation in science [36]. The eight dimensions of science capital describe different influences: scientific literacy; science related attitudes, values and dispositions; knowledge about the transferability of science; science media consumption; participation in out-of-school science learning contexts; family science skills, knowledge and qualifications; knowing people in science-related roles; and talking about science in everyday life [37].

III. METHODOLOGY

A. *Intervention and Research Questions*

Few studies have examined what very young children perceive and understand about scientists. This study addresses this knowledge gap through consideration of the following research questions: '*What do young children understand about scientists and science occupations*? And '*What are the factors of influence on their early understandings of science occupations*?'. The approach taken in the research is inductive, informed by grounded theory. Grounded theory is a research approach and methodology concerned with the generation of theory which is grounded in the data [38]. Data is collected and analyzed qualitatively, and meaning is generated by identifying patterns and relationships and then developing a theory to explain the patterns seen. Qualitative approaches provide rich data and are well suited to exploring attitudes, perspectives and understanding.

B. *Scope of Research and Study Sample*

The data presented in this paper are taken from a larger educational intervention for children aged 4-11 in the North-East England called Exploring Extreme Environments [39]. The intervention was a cross-curricular school science and arts project which brought scientists, public engagement experts and artists, together with children and their key influencers from eight primary (elementary) schools to investigate extreme environments across the Sun-Earth connection: the intense heat of the Sun's corona and the sub-zero conditions of Antarctica [39].

Of the eight schools participating in the educational intervention, four were selected as research schools to take part in the research activities. The study sample is therefore baseline data drawn from four co-education primary schools (serving children aged 4 – 11) in areas of socioeconomic disadvantage in the North-East of England in the UK. The sample comprised 79 children (49% girls and 51% boys) from Years 1 (age 5-6) and 2 (age 6-7). Following the researchers' request for mixed gender and mixed ability groups classroom teachers selected a sub-set of children from their class to take part. Twenty focus groups with four children at a time were conducted in spaces outside the main classroom. Each session took around 20-30 minutes.

C. *Research Instruments*

Young children are developmentally capable of sharing information about a wide variety of subjects, provided the researcher ensures a contextualized environment specific to the data sought [40]. Focus groups are well suited to collecting in-depth data on attitudes and perspectives and are particularly relevant for research with young children. They can be used to address some of the power imbalances between researcher and participants by creating a safe peer environment for children [41], and additionally reduce barriers to participation since reading and writing skills are not needed to take part [42].

This study utilizes the conceptualization of science capital as a framework to guide the topics within the focus groups

TABLE I. FOCUS GROUP SCHEDULE

Activity	*Focus Group Questions*
Career Aspirations Discussion *Science related attitudes, values and dispositions; Knowing people in science-related roles*	Do you know what a job is? What would you like to be when you a grown-up? Why would you like to do this job? Do you know anyone who does this job?
	Do you know if your parents have a job? Do you know what they do?
What is a Scientist Like? Concept Maps *Scientific literacy; Science related attitudes, values and dispositions*	Do you do science in school?
	What is the scientist like? What do you think they do? What do you think a scientist needs to be good at? Do you think you would make a good scientist?
TV Programmes Photo Elicitation and Sorting *Science media consumption; Participation in out-of-school science learning contexts*	Do you like watching tv at home? Have you seen any of these programmes before? Do you know what happens in them? Does this person have a job? Why do you like/not like this programme?

and consider the key areas of influence on young children's understanding [37]. However, as the science capital framework was developed from studies with an older age group, not all dimensions were found to be appropriate for consideration among this younger one. The focus groups schedule therefore covered five dimensions of science capital, as listed in italics alongside the activities and focus group questions in Table 1. The dimensions of 'family science skills, knowledge and qualifications'; 'knowledge about the transferability of science'; and 'talking about science in everyday life'; were not included within the discussion topics of the focus groups as they required more complex understanding of concepts and situations.

As well as questioning and facilitated discussions, concept mapping was included in the focus groups to guide children to express what they thought scientists are like, do in their jobs and might be good at. Photo elicitation and sorting activities were used to aid children's engagement on the topic of scientists and engineers in children's TV shows. By engaging them in a familiar task or activity these methods can support children feel more comfortable and can help conversation to flow more easily [43]. Photo-elicitation refers to the use of photographs during interviews to elicit responses from participants [44]. In this study images of children's TV shows that featured engineering, science and mathematics were used to guide conversation and elicit children's views.

D. Data Analysis

Focus groups were transcribed before they were analyzed together with data from the elicitation sheets using the qualitative data analysis software NVivo (12). Grounded theory methodology was used to examine the concepts and themes that make up children's understandings of scientists [38]. The first stage of analysis generated initial codes and grouped similar words. Initial codes were then sorted, clustered and duplicate codes merged to categorize data under larger categories and sub-categories [38] [45]. Frequency counts of incidents were later generated for each category, sub-category, and code, see Table 2.

IV. RESULTS

A. Knowledge of Jobs and Career Aspirations

The young children in this study were able to easily answer questions about what jobs are, and if their parent/carers worked, provide information what they did. Their responses indicated awareness that jobs exist, that they are done by adults and are where you go to work and get money. They were also able to express coherent ideas about what they might like to do as a job in the future. Children were enthusiastic about their possible career aspirations but drew from a narrow pool of 24 jobs. STEM jobs represented within children's aspirations were vet (10), doctor (6), nurse (1), paleontologist (1), and mechanic (1). Police (9) and teacher (7) were other popular aspirations. Three children aspired to be fantasy characters (superheroes, ninjas) and one an inanimate object (fire engine).

B. Understanding of scientists and what they do

A range of questions were used to prompt contributions on children's understanding of scientists, '*What is a scientist like*?', '*What does a scientist do*?', '*What does a scientist need to be good at*?'. If children were unable to elucidate many answers on the topic, an additional prompt '*what does a scientist look like*?' was used to encourage contributions. Analysis of the data finds low understanding of the term scientist and the role of the scientists among many young children. Four groups were identified from the data which categorize children's understanding about scientists and science careers: *Undeveloped, Introductory, Stereotypical*, and *Diversifying*. Each category has a number of sub-categories, with some sub-categories breaking down further into commonly used codes. The summary of categories and sub-categories, and the counts of each time they are referenced within the data set are presented in Table 2. More of the comments from older children were classified within the *Diversifying* category, and more of younger children's responses in the *Undeveloped* and *Introductory*

TABLE II. BREAKDOWN OF CATEGORIES AND SUBCATEGORIES WITH FREQUENCY COUNTS

Undeveloped		*Introductory*		*Stereotypical*		*Diversifying*	
32 (13%)		54 (23%)		92 (39%)		60 (25%)	
Guesses	21	Powerful	33	Appearance	33	STEM jobs	24
Mirroring	11	Magic	21	Makes stuff	25	Finding out	10
				Experiments	11	Curriculum	10
				Clever	11	Work hard	8
				Explosions	8	Work environment	5
				Fixing stuff	4	Testing	3

Interviewer	Can you tell me what a scientist might be like? [silence] Can you tell me what a scientist might be like (child A)?
Child A	He paints faces.
Interviewer	He paints faces. What might the scientist be like? Did you have your hand up (child B)? What do you think the scientist might be like?
Child B	Erm who gives them pictures.
Interviewer	OK. Anyone else any ideas? Does anyone know what a scientist might look like?
Child C	No
Interviewer	Child A? Child B?
Child B	He has a curly moustache. [Laughs].
Child C	Curly moustache? [Laughs].
Interviewer	And Child D?
Child D	He's got a hat.
Interviewer	A hat. What does his hat look like?
Child D	Like stripey down the middle.

Fig 1. Discussion excerpt under category 'undeveloped'.

categories, but comments from each age group were classified across all categories.

Children's responses in the *Undeveloped* group showed no, or only limited, understanding of a scientist or their role. When asked '*Do you know the job a scientist*?' 17% of children said that they did not know the term. It was also found that many of the children studied appeared not to know what science is or realize that they study science in school.

Responses categorized as 'guesses' (21) were children's guesses at what a scientist might do when asked to contribute on a topic on which they have little understanding. Fig.1 provides an extract from one of the focus groups with Year 1 children, that highlights the guessing behaviors of children who would like to contribute to the focus group activity but do not have a lot of knowledge of the topic in hand to offer. 'Mirroring' (11) includes children's responses that largely repeat the language used in the focus group questions, such as a scientist 'does science' or 'has a job'.

The *Introductory* category includes descriptions which show an elementary understanding of scientists. Within introductory the largest sub-category is 'powerful'. In 'powerful' children's descriptions of scientists are often framed around power and influence (33). Scientists are "big" and "important" who can use this power either to enact good "*Science people can help you and they are kind and helpful*" or bad "*experiment on people*". Some children also referred to scientists as similar to superheroes, with one description likening scientists to 'Power Rangers'. The 'magic' sub-category contains children's responses (21) about scientists doing magic or being magical. Scientists "make magic stuff" and "potions", and can make things disappear, "*Once we seen a science in the hall, and we saw some paper and when the scientist dropped it, it vanished*".

The largest category within the dataset is *Stereotypical*, which contains children's contributions themed around scientists' appearance, behaviors and activities that match common stereotypes. The most prevalent sub-category within stereotypical is 'appearance' (33), children commonly described a scientist as wearing a white lab coat, safety goggles and having sticky up white hair *"every time it goes bang it makes their hair stick up*". The next category is 'makes stuff' with 25 incidents. Children reported that the scientist "makes stuff" more generally or "make potions" or makes "volcanoes" or "slime". A smaller number of children's comments (11) expressed the stereotype of a scientist being clever, using terms like "super clever" and "good at maths". Scientists were also described as people who did experiments (11) and made explosions (8). Children very rarely expanded on the nature of these experiments beyond a simple explanation of "*mixing things together*" or for explosions "*Makes stuff in different bottles that explode*". The last sub-category within stereotypical is 'fixing stuff'. A small number of children (4) reported that scientists "fixed things" generally, but also fixed people medically such as "fixed eyes" and fixed teeth". It was found that children's descriptions in the stereotypical category were expressed easily within the discussions but could not be further elaborated on when prompted.

The final category represented in the data is *Diversifying*. Here, the view of science was more developed, and children presented knowledge about different types of science jobs as well as showing a greater understanding about what these jobs may involve. There is a progression from a stereotypical image of a scientist to one with greater understanding of a scientist's role in the world. One example, "*There is loads of stuff to do, do maths, stop spreading germs, find out what kinds of germs there are, and stop lots of stuff.*"

'STEM jobs' is the largest sub-category within *Diversifying* (24), and groups the variety of STEM jobs that children have included within the scientist umbrella. Those commonly reported can be grouped into medicine and healthcare (9), vets and animals (4), dinosaurs (4) and space (2). Children also expressed ideas about a scientist's work environment (5) such as in a lab, using computers and the internet and that they might need to travel. Another of the big sub-categories within diversifying is 'finding out' (10). Children described scientists' approach as involving thinking, learning, "*finding out and discovering more stuff*", and research to "*find out what makes people happy or not*". Scientists also 'work hard' by concentrating and not messing around, while they focus on their work (8). Diversifying also includes responses where children have made the links between the idea of a scientist and the science curriculum or working scientifically (10). Consistent with the subject content of the National Curriculum in England children referenced identifying, describing and comparing different materials (5) and colors (3). Children additionally reported the scientist's role in 'testing things' (3).

C. *Influences on Children's Understanding*

In the focus groups, children were asked what their parents/carers did for a job, and analysis of these responses indicated few STEM-related careers among the parents/carers of children in the study cohort. Some jobs that children reported their parents as having can be classified at STEM-related: nurse (1), fixing computers and phones (2), and mechanic (1). Some children reported parents working in non-medical roles in hospitals, GP practices and healthcare

Interviewer	Do you do something called science in school?
Child A	No.
Child B	Erm, yes.
Child A	No, no.
Interviewer	Yes? Can you tell me what it is? Yeah? What is it? What kind of things do you do in science?
Child B	I don't remember.
Interviewer	You can't remember? Okay. Anyone else? Have you heard that word or is it a new word?
Child C	New word.
Interviewer	New word. Speaker A, B have you heard that word or is it a new word?
Child A	A new word.

Fig. 2. Discussion excerpt under Theme 'School Influence'

settings (5). Two children whose parents worked in non-medical healthcare roles reported aspirations for medical roles (doctor and nurse). Brothers, sisters and cousins were mentioned on a number of occasions as an influence on the young children. Siblings were referred to in terms of them choosing what media to watch on the TV, and in guiding their interests of things to play with. One participant referred to their sister as a scientist, "*My sister is a scientist. At home and after school she is. She makes models and mixes potions at a scientist desk. She is nine*".

School and the school curriculum were mentioned as an influence within the discussions but not frequently. Some groups were asked if they did science in school, and 68% of those asked said they did not know what science is or whether they did it in school. One excerpt reflects the lack of knowledge about science of some children within the group as shown in Fig. 2. However, some children made reference to elements of the school curriculum in their descriptions of scientists' activities (11) e.g., considering different types of materials. Another child referenced a teacher as informing her understanding of a scientist, "*when we were in school, we heard that they do germs – they concentrate on germs*". While another child made reference to an after-school science club that they would be attending in the future, "*I will be a scientist in a couple of weeks*".

Media was a commonly reported influence on children's understanding of scientists. However, rather than children's TV shows being influential (as initially posited by the research team), the major influence reported by children was watching YouTube videos. One participant when asked if they knew any scientists replied, "*no but I just watch it on a film*". The children reported watching videos about a wide range of topics including volcano experiments, making giant bubbles, explosions, "science math" and science facts. One example that explains this is, "*Well I've learned this stuff off a YouTuber. He was a scientist – I think this is what their thingy [called]. Erm, but sharks can live in salt water and fresh water*." The children's TV shows containing elements of engineering, science and mathematics that were used as prompts within the discussion did not generate much discussion around the roles of scientists or engineers. Children had seen and enjoyed some of the shows presented but others were much less commonly watched by the children. Apart from the doctor in a show about a hospital, children could not identify names of job roles presented within them. Therefore, the influence of children's TV shows

Interviewer	What is the scientist good at?
Child A	Good at making lots of potions and they can make toys.
Interviewer	Make toys?
Child B	Yeah I had a toy from a scientist before
Interviewer	Did you?
Child B	Yeah it was a potion one
Interviewer	A potion toy?
Child B	Yeah where it was a volcano.
Interviewer	Oh a volcano?
Child B	Yeah but you had to make it as a scientist
Interviewer	You made it?
Child B	No not yet. I lost all the pieces.

Fig.3. Discussion excerpt on Theme Influence of 'Play and Toys'

was not found to be a great influence on the perceptions of scientists and STEM professionals with this sample. The influences on children in the *Diversifying* group were often built on personal experiences or personal interests in science. For example, in personal experiences, one child referred to the experience of breaking their leg and having an operation. A few children reported that visitors to school as influencing their aspirations, such as a visit from someone at the People's Dispensary for Sick Animals, a veterinary charity in the United Kingdom. A few children referred to their personal interests in science and STEM topics. One child reported to know all about Paleontologists, "*I am already one. I just like dinosaurs and I want to start a collection of dinosaur fossils and I have got three already*." He described how this interest started when he went to buy something from a shop and was told there were dinosaur fossils there.

Toys and play were frequently referred to in the focus groups. Children described the activities of scientists as similar to the type of science-type activities they play with at home. Scientists were referred to as 'making volcanoes', 'making slime' and 'making potions'. During the discussions, children also referred there being science kits and toys at home, but two commented that they had not actually had the opportunity to use them (see Fig. 3). One child explained, *"I haven't done it before but I've got a volcano science, but I can't do it because I've got two dogs and I'm not allowed to do it. It's going to make too much mess*".

V. DISCUSSION

This study has shown that it is possible to examine the understanding and perceptions of scientists among young children. Four categories were identified to describe what children understand about scientists. The findings show however that the understanding of scientists among most children is limited. For three categories children presented no (*Undeveloped*) or limited knowledge of scientists (*Introductory*) or represented common stereotypes without any deeper understanding (*Stereotypical*). One group of children *(Diversifying*) were able to express deeper understanding about the scientists and their work, drawing on personal interests, experiences and making links between the science curriculum and scientists.

This research however highlights the challenges of researching children's understanding of STEM careers when their understanding of the topic is weak. While the authors' research interests lay in children's perceptions of all STEM careers, including engineers, it was not thought possible to ask children to report their understanding of a topic they may not have studied or encountered. Knowing that an early interest in science is a strong predictor for future engineering pathways, the authors chose to focus the direction of their research on scientists, an area that young children were more likely to have knowledge of, due to science having core subject status. However, while some children were able to recognize the science curriculum, others were found to have no knowledge of the word 'science'. For one of the schools within the sample, science was taught to younger children through cross-curricular approaches in the form of 'topics', and this appears to have led some children to confuse science with history. This use of cross-curricular learning could mean that children may not recognize what they are learning as science, which may be a problem for developing an interest in science and other STEM disciplines and careers. Young children's understanding of engineering careers is likely to be even more restricted, as children do not commonly encounter engineering in their elementary education. This makes exploring understanding of engineering and engineers among this young age group difficult.

In keeping with Gottfredson's Theory of Circumscription and Compromise [13] children in this study were beginning to classify people in terms of their place in society. In the *Undeveloped* and *Introductory* categories children were observed in the cognitive growth phase. Most children in the study understood jobs as something done by adults and could express their ideas of what they would like to be when they are older, though one child expressed their aspiration to be an inanimate object 'a fire engine', and three children wanted to be fantasy characters. Children in the *Introductory* category expressed their understanding of the job of a scientist under the classifications of power and magic, these sub-categories are also been identified within other studies [46]. Children's descriptions of scientists include descriptions of scientists as big and important people, or like superheroes with the power to help or to harm. The sub-category of magic showed children's understanding of scientists blended with the fantastical, where scientists are seen as people with magical powers who make magic potions and make things disappear.

39% of children's comments were classified under *Stereotypical*. Children commonly reported the appearance of the scientist (white lab coat, goggles) and the types of activities that scientists might perform (making stuff, experiments, explosions). These descriptions are consistent with common stereotypes of scientists found in other studies [46]. However, while research with older children in elementary schools has found intelligence to be the most popular stereotype of scientists [33] [32], intelligence did not feature heavily in the understanding of scientists among this younger age group. Similarly, the male stereotype found in other studies such as those which use Draw a Scientist Checklist [46] [32], was not prominent in this sample. By using focus groups discussions to examine children's understanding and perceptions of scientists, rather than asking children to draw a picture, children were not pushed to make a choice about the gender of their imagined scientist. Whilst a few children described the scientist as a he, children generally contributed to the discussion using "they" or without the use of pronouns.

Limited evidence was found of Gottfredson's orientation to gender roles phase within this study [13]. This may be because the focus of this study was exploring the understanding of the scientist more broadly rather than in the context of children's own aspirations. Children of both genders expressed their understanding of the scientist similarly. However, the aspirations for STEM reported by children tended towards the medical and healthcare sectors (doctor, vet, nurse) and were more favored by girls (14) than boys (3), while the paleontology and mechanic aspirations were held by boys.

This study has also highlighted the broad range of influences on young children's emerging understanding of scientists. From parents and families, science-related media, engagement with after-school activities and play, teachers and school curriculum, and personal experiences and interests. Many of these influences have also been found in studies with other elementary age children [15] [28]. This study however points to new areas of influences on young children's understanding: particularly that of siblings and cousins in guiding interests; the role of YouTube within the umbrella of science-related media; and the influence from children's toys and play interests, such as slime making, and volcano science kits. Historically and to the present day, science has been likened to magic in the marketing of children's toys to enhance the appeal. Marketing has been found to blend the idea of science, wizards and potions [47] and can partially explain the blending of science with magic in children's perceptions of scientists.

Improving both the understanding of, and perception of, science, engineering and other STEM sectors is widely acknowledged to be necessary. One possible route is through the adaption of the curriculum to include more of a focus on STEM, and the specific inclusion of engineering. There have been few opportunities to assess what engineering might look like within elementary education [18], though a number of ways have been suggested. A recent call from the IET and over 150-world-leading engineers, STEM ambassadors, and professional intuitions, to the UK government with #EngineeringKidsFutures asked for practical support for primary teachers to embed engineering within existing STEM learning [48]. If successful, this would pave the way for engineering learning outcomes to be established within the primary syllabus for science and mathematics. Another approach forwarded has been that of 'integrated STEM' (iSTEM), a movement which advocates for a more student-centred approach to STEM learning, amalgamating the content and concepts from multiple STEM disciplines in one integrated STEM curriculum [49] to be considered within the context of a problem, project or task [50]. However, as the pace of curriculum change is slow, adoption of either of these strategies must be viewed as a long-term rather than short-term solution to the problem.

Crucially, this study finds the influence of school science on perceptions of this younger age group is limited and that young children's understanding of scientists does not draw heavily on their knowledge of science as a subject. Instead, young children's perceptions of scientists draw on popular stereotypes. Children do not, as a matter of course, relate the subject of science with their understanding of scientists and the scientist that children imagine does not yet encompass the wider sectors of science-related jobs (doctor, engineer, chemist). For example, 23% of children in the sample reported aspirations within medicine and health care (doctor, vet, nurse), but this knowledge and interest in these roles, did not often bridge or spill over into their description of what a scientist is and does. Whilst children's core ideas about science as a subject are still in development, their views of scientists remain restricted to ideas clearly labelled as such, such as stereotypes. Consequentially improving children's engineering disciplinary knowledge may not necessarily improve their understanding of engineers and engineering careers, if this is not included as a particular focus.

Another approach is to enrich the existing curriculum by creating opportunity for career-related learning in new and different contexts. Here the focus is on broadening horizons and giving children a wide range of experiences of the world, particularly those they do not encounter in their daily lives. The data from this study highlight deeper understanding of scientists within the *Diversifying* group, and points to the important influence of creating opportunity for personal encounters with STEM, such as in-school visitors. Tailored use of STEM role-models can be used to challenge and counter stereotypical perceptions of scientists and generate positive first ideas about who works in the STEM sectors [34] and what they do. One of the models used within the linked intervention of this study is to counter existing negative stereotypes by presenting a more diverse and accessible view of people who work in STEM, while supporting children to identify attributes and characteristics they share with people who work in STEM [33] [51].

VI. LIMITATIONS OF THE STUDY

The authors have shown that using this methodology, deeper and more fine-grained understanding of young children's perceptions and understanding of scientists can be gained. However, the scope of this study is limited, focused on a specific region at a specific point in time. Further research could explore whether the patterns seen in young children's understanding of scientists is applicable in different contexts and persist over time.

VII. CONCLUSION

Encouraging greater numbers of young children to follow STEM pathways, particularly those not routinely included in the school curriculum such as engineering and technology, rests on strategic support to build children's awareness of the work done by these sectors and the people who work in them. This study has shown that while young children are only at the beginning of their education journey in science and may have not yet encountered other STEM pathways such as engineering, they are already forming ideas and understanding about what a scientist might be like. These ideas are often stereotypical, drawing on the influences of media, the people that they encounter, the things they play with and the attitudes and perspectives within their families, rather than building on their experiences within the science curriculum. The emergence of stereotyped understanding of scientists among young children can be damaging. Studies have shown that some stereotypes are resistant to intervention [33], that the effects the early elimination of possible careers is lasting [13]. Introducing careers-related learning about STEM early, by offering counter-stereotypical role-models, while nurturing emerging interests and aspirations for STEM, can support children keep their options open for longer [51].

ACKNOWLEDGEMENTS

The authors would like to thank all staff, children and families from the eight primary schools participating in the Exploring Extreme Environments for their continued commitment and enthusiasm in the project.

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