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Using action research to design and evaluate sustained and inclusive engagement to improve children's knowledge and perception of STEM careers

Itoro Emembolu, Annie Padwick, Joe Shimwell, Jonathan Sanderson, Carol Davenport and Rebecca Strachan

Faculty of Engineering and Environment, University of Northumbria at Newcastle, Newcastle Upon Tyne, UK

ABSTRACT

Previous research suggests that early experience of and exposure to the world of work is an important predictor of a child's future involvement in a STEM career. Many interventions have focused on those in secondary education age 11 years and above. Far fewer interventions have explored the impact of STEM outreach engagements among younger age groups. This study investigates the impact of a project that delivered career-driven STEM interventions on young children's (7–10 years old) career knowledge and perceptions over time. Using an action research approach, this study outlines 10 distinct features for designing child-centred STEM interventions. These were delivered in 6 primary schools across North-East England over a 2-year period. A STEM Career Knowledge and Aspirations Tool was used to collect data to evaluate the impact of these interventions. Children sorted 30 job cards (mix of STEM and non-STEM) into jobs they knew, and also into jobs they would like to do. Baseline data and follow up data were collected in 2015 ($n = 352$) and 2017 ($n = 356$). Data analysis suggests the sustained interventions had a particularly positive effect on girls. In 2015 prior to the interventions, girls were significantly less likely than boys to know the following STEM jobs: surveyor, technician and game tester. In 2017, following the sustained intervention, there was no significant difference between boys and girls. Furthermore, one of the STEM jobs, Engineer, showed the greatest increase in the percentage of boys and girls that wanted to do it in 2017 compared to 2015.

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Introduction

There is considerable research that highlights the importance of Science, Technology, Engineering, and Mathematics (STEM) and the need to increase the numbers and diversity of those choosing these disciplines to meet future workforce demands (EngineeringUK, 2018; Herman, 2018; van den Hurk, Meelissen, & van Langen, 2019). Young people have a positive attitude to science but this does not translate into STEM career aspirations

CONTACT Rebecca Strachan rebecca.strachan@northumbria.ac.uk
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(DeWitt & Archer, 2015). A number of countries continue to report a STEM skills gap, particularly in the engineering and technology disciplines. For example, in the United States the manufacturing industry reports a potential workforce shortfall of 2.4 million over the next 10 years (Deloitte, 2018), the Australian Government Department of Jobs and Small Businesses (2018) reports a skills shortage in many construction, health and engineering occupations and EngineeringUK (2018) suggests an annual workforce shortage of between 83,000 and 111,000 people for core engineering roles.

Across many STEM sectors, there are under-represented groups that further highlight the skills gap and show imbalances within the existing workforce. These under-represented groups are identified by characteristics such as gender, ethnicity and socio-economic status (SES) and this under-representation is not uniformly distributed across the STEM areas (DeWitt, Archer, & Mau, 2016). For example, in 2018, the percentage of women within the core[1] STEM workforce in the UK is reported to be 22%, but there is considerable variation within this, with women making up only 12% of engineers and 16% of IT professionals compared to 43% of science professionals (WISE, 2018). On the other hand, the health and social care sector has a high female representation of 79% (Powell, 2019) and has the highest workforce by industry in the UK (ONS, 2019).

There have been many interventions for young people aimed at widening participation in core STEM careers, particularly under-represented groups including females and people with low SES (Morgan, Kirby, & Stamenkovic, 2016). With regards to SES, the North East, the target intervention region for this study, has one of the highest unemployment rates in the UK (Powell, 2018); the highest percentage of 16–24 year olds 'Not in Education, Employment or Training (NEET)' in the UK (Powell, 2018); and the lowest rates of participation in full time Higher Education (Higher Education Funding Council of England, 2013).

Young people's career knowledge and perception

Some evidence suggests that the critical period in which career aspirations are formed is between 10 and 14 years (DeWitt & Archer, 2015). However, Gottfredson's Theory of Circumscription and Compromise (2005) links the development of a child's self-concept with their occupational aspirations at a much earlier age. From before the age of three, children make use of societal cues to identify jobs that are suitable for them. Over time, this creates a Zone of Acceptable Alternatives: a range of occupations that match the child's perceived gender, social prestige and intellectual achievement (Gottfredson, 1985). Whilst children may not know exactly what these occupations involve 'their naïve early understandings have already turned them toward some possible futures and away from others' (Gottfredson, 1985, p. 78).

Supporting this theory, Hughes, Mann, Barnes, Baldauf, and McKeown (2016) found that young people start discarding occupational options based on their preferences as early as 9 years of age or even younger. Kim (2018) highlights the difficulty of re-establishing an interest in science among young people aged 14 years and above particularly when those science interests have not previously been nurtured. Thus, interventions aimed at increasing the diversity of STEM occupations that start in secondary school might not have the desired effect or may be too late because those young people have already made limiting decisions or closed themselves to choices on occupational aspirations in primary school[2] (Aschbacher, Li, & Roth, 2010; DeWitt & Archer, 2015).

Early experiences and exposure to the world of work before 14 years of age have been associated with later involvement or pursuit of a STEM career (DeWitt et al., 2013; Kang & Keinonen, 2017; Lindahl, 2007). Learning experiences have been shown to be influential on a young people's career knowledge and understanding (Department for Education, 2015; Ferrari et al., 2015; Watermeyer, Morton, & Collins, 2016). They can also be a good predictor of young people's future career aspirations (Kang & Keinonen, 2017).

It has been suggested that interventions, including experiences of science and occupational education, should start early in a young person's life (Hughes et al., 2016; Kim, 2018) and that the curriculum taught in schools, and how it is conveyed, influences young people's occupational aspirations (Liu, McMahon, & Watson, 2014; Rowan-Kenyon, Perna, & Swan, 2011). Activities that are linked to the curriculum and have careers information embedded in them can be used to highlight the range and usefulness of STEM careers (Reiss & Mujtaba, 2017).

Despite many research studies highlighting the need for engagement early in a young person's life, many intervention programmes and research studies have focused on secondary education and above (Kang & Keinonen, 2017; Masnick, Valenti, Cox, & Osman, 2010; Sáinz & Müller, 2018). Few studies have explored STEM interests and how they develop over time, particularly in young people under 11 years of age (Hughes et al., 2016). This study investigates the impact of career-driven STEM interventions, developed as part of a wider sustained STEM engagement project, on children's (aged 7–10 years) career knowledge and preferences over time.

The authors argue that STEM interventions should incorporate career awareness and draw attention to the usefulness and application of STEM disciplines in primary schools and the careers associated with these (Macdonald, 2014). This focus on career awareness in primary school is not to direct young people to choose a particular career path but rather to open up opportunities for them by widening their career knowledge and keeping career options open for longer. This should also prevent early circumscription of some career options and pathways by young people. In addition, presenting the applications of STEM and career knowledge has been found to be particularly beneficial on female participation in physics (Murphy & Whitelegg, 2006) and by extension other STEM disciplines linked to physics. The aim of this research study is to explore the impact of carefully designed inclusive and sustained careers-driven interventions[3] on children's career knowledge and perceptions.

Materials and methods

The research adopted an action research approach (Cabaroglu, 2014; Reason & Bradbury, 2001). It is an exploratory action research study exploring ways to support career knowledge and preferences in young children through a carefully designed sustained set of interventions. This paper presents the interventions and the research tools used to evaluate these interventions over time. This approach was appropriate for the study because it is robust enough to adjust for uncertainties, which might arise when implementing designed interventions, and has a feedback loop that supports critical reflection, evaluation and learning from this to inform future interventions.

The study was designed using the action research iterative cycle; evaluate, plan and act. It began with the evaluate phase in which baseline data was collected from the participants in 2015 (Evaluate, Cycle One), while the second phase was a combination of plan and act where a set of interventions were designed and implemented (Plan, Act, Cycle One). The designed interventions were broadly in alignment with the school science curriculum increasing the likelihood of teachers valuing the intervention. Further data for this study was collected in 2017 to evaluate the impact of Cycle One on the children (Evaluate, Cycle Two) and to inform Plan and Act phases of Cycle Two.

Sustained STEM engagement

This research study is part of a sustained STEM engagement project by a STEM Outreach Group situated within a University in the North East. The group has partnerships with 30+ primary and secondary schools in areas of lower SES in the North East and works with children and young people in these schools, and their key influencers,[4] to broaden opportunities for children and young people in STEM, with the long-term aim of increasing the diversity and number of young people choosing a career in STEM post-18. The larger STEM engagement project specifically targets groups under-represented in STEM careers and therefore adopts an inclusive approach to appeal to individuals from a variety of backgrounds including low SES and gender. It draws on some necessary conditions for good career guidance (Holman, 2014): linking careers to the taught curriculum (GOV.UK, 2018); acquiring more knowledge of the 'world of work' (Ferrari et al., 2015; Hirschi, 2011) and providing more occupational experiences (Ferrari et al., 2015; Liu et al., 2014). The approach to the interventions in the larger project supports teachers and schools to teach science (and STEM) by linking curriculum topics with career-driven narratives.

A Theory of Change (ToC) was developed to evaluate the success of the project against a number of short-term and medium-term outcomes (Davenport et al., 2019) of which the evaluation presented herein is a part.

Project interventions included Continuing Professional Development (CPD) for teachers, family-learning activities, and interactions with children, however, this paper focuses only on those interventions involving children in the primary schools.

A suite of 22 different one-hour interventions was offered during the course of the project, each with a primary focus on increasing children's knowledge of, and aspirations towards, STEM jobs particularly the core STEM jobs covering physical sciences, engineering and technology. Schools were offered this choice so they could select interventions that complemented what they were already doing in STEM. Consequently, the diet of interventions was different in each school (Table 1). Interventions were delivered by trained male and female outreach professionals over the course of two years, with in-school support from the classroom teachers. The interventions were categorised into 'in-class workshops', 'whole school', 'informal learning activities' and 'family activities'.

In-class workshops

The majority of the interventions involving children were in-class workshops. Each workshop was planned around a specific topic linked to the school curriculum and either based on real-world career applications or co-created with university subject specialists (Macdonald, 2014).

Table 1. Intervention activities undertaken in six schools (A to F) during the study period between 2015 and 2017.

In-class workshops	School	Whole school engagement	School	Informal learning and family activities	School
Materials Scientist	C, D, F	Space Assembly	A, B, E	School Fair science stall	E*
Aeronautical Engineer	B, F	Seeing in Infrared	B, F	Explore your Universe Science Show	A, F*
Civil Engineer	F	Polar Scientist Assembly	F	University tour	D, E
Acoustic Engineer	C, D			Planetarium visit	B, C, E
Medical Physicist	F			Science for families	D, F
Space Geologist / Meteorites	B, D, E			Automata maker workshop	A*, D*, E*, F
Volcanologist	D				
Botanist	B, D, E				
Geologist	A, B D, E, F				
Geographer	E				
Who is a Scientist	B*				

*Identifies interventions that were delivered more than once in the same school to different age groups.

Activities included in a workshop were designed to be hands-on, meaningful, accessible and age-appropriate to the target children (Ferrari et al., 2015; Liu et al., 2014). Children were able to explore 'trying on the career' through role-playing (Kang & Keinonen, 2017). Working scientifically terminology and practice was used to help build children's understanding of observed phenomena, processes and methods of enquiry (Department for Education, 2013), and support teachers in the delivery of this aspect of the national curriculum. Care was taken to ensure that images presented and the vocabulary used in the workshop countered stereotypical images, vocabulary and mitigated against unconscious bias (Damer, Webb, & Crisp, 2018). Workshops were designed to be collaborative experiences through paired and group discussions (Watters & Ginns, 2000), replicable by teachers (if desired) for sustainability and continuity, and embedded with feedback loops to ensure a constant review process. At the end of workshops, participating children are sent home with postcards containing a weblink that allowed the children, their parents and carers to engage with online content associated with the career promoted (Archer, DeWitt, & Wong, 2014; Sáinz & Müller, 2018).

Participants

One of the aims of the wider STEM engagement project was to address the under-representation of individuals from lower SES groups in STEM careers. Therefore, primary schools were recruited on the basis of the percentage of children in the school that received free school meals (FSM); a widely used proxy for identifying schools in areas with low SES (Gorard, 2012; Hobbs & Vignoles, 2007). Schools were initially approached if they had a higher percentage of children in receipt of FSM than the regional average, which was 17.8% at the time of recruitment. For the broader STEM engagement project, fifteen project schools were recruited and then for the purpose of this study, six of the project schools were selected at random as research schools to participate in evaluation activities. The mean FSM figure for the research schools was 27.3% (SD 7.5%) compared with 23.3% (SD 13.3%) for all the project schools.

Data were collected from two cohorts: Year 3 (7–8 years old) and Year 5 (9–10 years old). Headteachers in each schools provided in loco parentis consent for children to take part in the research activities, and parents and carers were provided with an information leaflet two weeks prior to data collection informing them of the research study and activities, and giving them the opportunity to opt their child out of participation in the research. Children who opted out of the research study still took part in the intervention activities in their school. Baseline data was collected in 2015 before any interventions in the school. Follow up data was collected in 2017 after two years of interventions in each school to measure the changes over time in careers knowledge and understanding in the cohorts. The samples were all children in Year 3 and Year 5 on the date that data collection took place in their school, who had not previously opted out of research activities. The sample size in 2015 was 377 young people (47.5% boys, 52% girls and 0.5% no response on gender; 50.4% year 5 cohort, 49.3% year 3 cohort, 0.5% no response on year group). In 2017, the sample size was similar with 372 young people (50% boys, 47.8% girls and 2.2% no response on gender; 50.5% year 5 cohort, 48.7% year 3 cohort, 0.8% no response on year group). Data points that contained missing data or which could not be read due to photographic data capture issues were removed to produce the analysis sample. The resultant sample size in 2015 was $n = 352$, and in 2017 was $n = 356$. The study tracks year group cohorts rather than tracking individual children. This reduces the need to collect a child's personal data, and therefore reduces the risk of identification. The year 3 cohort in 2015 were tracked until they reached year 5 in 2017, as indicated by arrow Z in Figure 1. The year 5 cohort in 2015 ($n = 183$, 46% male, 54% female) who had received no interventions at the time of data collection was used as a comparison group for the year 5 cohort in 2017 ($n = 187$, 48% male, 51% female) who had participated in intervention activities. This comparison group was deemed adequate because the cohorts were from the same school, with similar characteristic sets including gender split, and similar educational experiences. The intervention group had 48.1% male and 50.8% female, while the comparison group had 46.4% male and 53.6% female.

Research tool

While there are many tools used to evaluate young people's (ages 11+) attitude and aspirations for science, few tools have been found appropriate for use with children less than 10 years old (Kerr & Murphy, 2012). This research study uses a previously created job sorting activity tool 'STEM Career Knowledge and Aspirations Tool' (Padwick, Dele-Ajayi, Davenport, & Strachan, 2016). This was developed in a pilot study that consisted of children in Years 3–6 in a project partner school with a similar demographic as the research

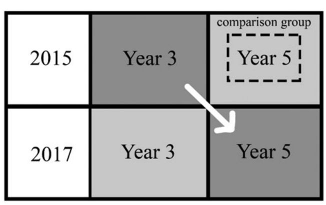

Figure 1. Tracked cohorts and comparison group.

Table 2. Job titles used for the sorting activity.

Actor/Actress	Detective	Farmer	***Mechanic***	***Surveyor***
Athlete	*Doctor*	***Game Tester***	*Nurse*	Teacher
Astronaut	***Engineer***	Hairdresser	***Pilot***	Tennis Player
Author	Entrepreneur	Judge	Politician	***Technician***
Banker	Estate Agent	Lawyer	Shopkeeper	*Vet*
Civil Servant	Firefighter	Librarian	Soldier	*Zoologist*

Italicised jobs shows occupations classified as general STEM.
Jobs in bold show jobs classified as core STEM.

schools. The children were asked the following questions: 'What jobs do you know the names of?' and 'What would you like to be when you grow up?'. Responses to these two questions produced a list of 180 jobs, which after a process of discussion and review among the research team was reduced to a final set of 30 jobs including a mix of STEM and non-STEM jobs (Table 2). The process of selection of job titles using the pilot ensured the tool was relevant and appropriate for use with children of the same age within the research schools. During the selection process consideration was given to ensure the tool included: jobs that most children would know and some they might not; a mix of traditionally male or female dominated jobs; some neutral jobs, and jobs of different social and economic status. Of the thirty possible jobs, eleven were classified as general STEM careers, of which seven were core STEM careers (WISE, 2018). While the focus of this research is on core STEM careers, the 30 jobs were classified using general STEM careers (including health occupations) since exposure to STEM in primary schools focuses on general science, including biological and health sciences. This approach also enabled exploration of children's occupational inclinations across all sectors including general and core STEM. As a further check of suitability, the job list was compared to lists of jobs used in similar career-focussed research (e.g. Oakland, Stafford, Horton, & Glutting, 2001; Sinclair & Carlson, 2013) and a similar selection found in the literature. Less well known jobs were also included to test for reliability of participants' answers: because participants were not expected to know, e.g. entrepreneur, a low reporting rate of these jobs would indicate that the data were reliable.

Family background and family attitudes have been shown to exert considerable influence on a child's attitudes and aspirations (Goodall et al., 2011), so the research team also developed and issued a questionnaire, following work by Archer and DeWitt (2013), intended to complement the 'STEM Career Knowledge and Aspirations Tool'. This questionnaire was designed to elicit information about a child's family background, social contacts and out-of-school environments and included questions such as 'How many books do you have in your house?', 'Which of these [science learning venues] have you been to with your family?' and 'Who do you know who works in a job using science'. However, in practice, children found the questions very difficult to understand and answer, putting the reliability of this dataset in doubt. The data from this questionnaire is therefore not presented within this paper. To mitigate against the loss of this dataset, the research team explored what information could be gained about SES of children and their families from examination of publicly available data sets, considering the Index of Multiple Deprivation (IMD), POLAR data giving the representation in higher-education by area, and the Income Deprivation Affecting Children Index (IDACI) for the proportion of all children aged 0–15 living in income deprived families, alongside

FSM information. All 6 schools are situated in areas described as within the 40% most deprived areas in the country by IDACI, 5 of the schools are situated in areas described as the most 30% deprived in England by IMD, and 4 of the schools are in areas under-represented in higher education (POLAR4 quintiles 1 and 2). While examination of these measures does not take into account variation between individuals in an area, it can be assumed that many children in this study come from low SES backgrounds and are therefore less likely to have parents who are involved in STEM (DeWitt et al., 2016).

Procedure

The research tool consists of two printed sheets, and thirty small cards with one job per card. The activity is made up of two stages. Using the first sheet, each child is given a set of 30 job cards ordered alphabetically. Each occupation is read aloud by the facilitator, without explanation on the word's meaning, in order to ensure participation irrespective of reading capabilities. The children are then asked to sort the 30 jobs cards into two sorting fields: 'jobs I know' and 'jobs I don't know'. The jobs not known are set aside and not used in the later stage. Then in the second stage, children move the 'jobs I know' cards onto the second sheet and sort into three sorting fields 'would like to do; 'would not like to do'; and 'not sure'. Images of the sorted activities were then captured using a camera for analysis. A sample of a sorted response from a participant is shown in Figure 2.

Data analysis

The data were coded and analysed using SPSS 24 statistical package (IBM Corp., 2016). Descriptive statistics was used for frequency counts overall, by gender and by year

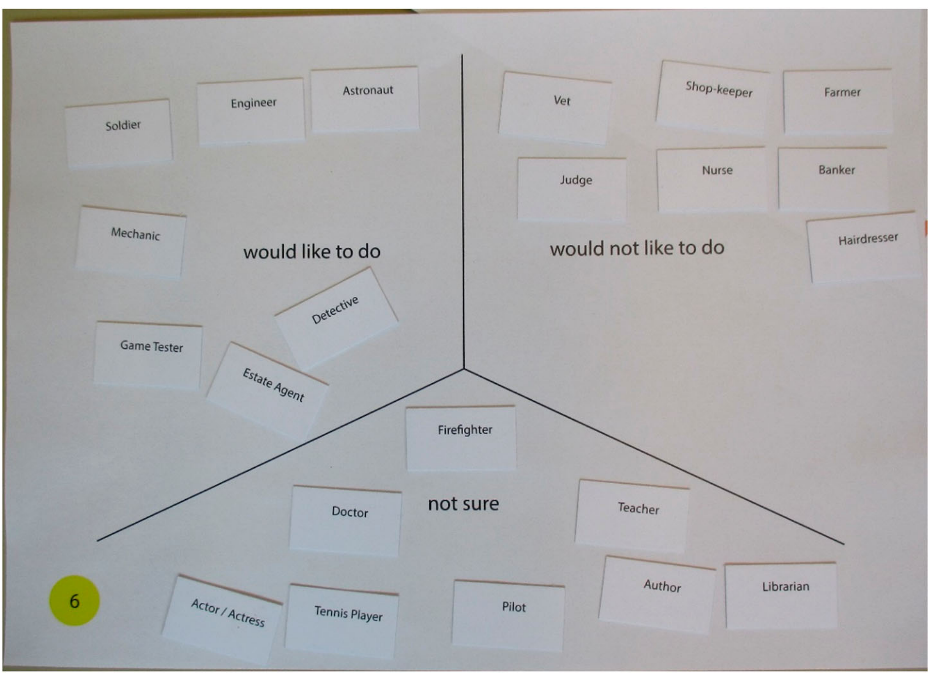

Figure 2. Sample of a sorted response from a participant.

group in jobs known, jobs participants would like do, jobs they would not like to do and jobs they are not sure if they would like to do or not. Due to the categorical nature of the data in the primary-age STEM Careers Knowledge and Aspirations Instrument, Chi-square and Fishers Exact tests were used to determine statistically significant relationships between variables. Chi-square tests of independence were used to compare group differences based on gender and year group. Fishers Exact tests were used instead of Chi-square tests when cell counts were less than five. For all tests, significance is reported at the $p < .05$ level.

Results

Known and unknown jobs

Of the thirty jobs presented to participants in 2015, 23 were known by over 75% of the participants (see Table 3). In 2017, 21 of these jobs were known by over 75% of participants (with athlete and lawyer reducing in recognition). Of the 15 jobs the participants confidently identified, 5 of them were classified as STEM jobs (astronaut, doctor,

Table 3. Percentages of all participants, Year and Year 5 participants, reporting that they knew a job in 2015 and 2017.

Job title	All children 2015 $n = 352$ % that know job (2015)	All children 2017 $n = 356$ % that know job (2017)	Y3 children 2015 $n = 169$ % that know job (2015)	Y3 children 2017 $N = 169$ % that know job (2017)	Y5 children comparison group 2015 $n = 183$ % that know job (2015)	Y5 children intervention group 2017 $n = 187$ % that know job (2017)
actor	87.5	86.8	78.7	77	95.6	95.2
athlete	83	69.4	72.8	52.5	95.6	87.2
astronaut	**95.5**	**92.7**	**95.3**	**90.6**	**92.3**	**94.1**
author	92.9	89.6	88.2	79.9	97.3	95.7
banker	83	80.3	80.5	71.9	85.2	88.2
civil servant	36.6	17.4	33.3	17.4	39.3	16.6
detective	91.8	88.5	88.9	80.6	93.4	93
doctor	*97.2*	*96.1*	*95.3*	*95.0*	*98.9*	*96.8*
engineer	**84.7**	**84.8**	**78.1**	**77.7**	**90.7**	**92**
entrepreneur	26.1	11.8	29.0	12.2	23.5	10.8
estate agent	54.5	53.1	44.4	41.0	63.9	59.9
farmer	97.2	94.7	96.4	92.8	97.8	95.2
firefighter	97.4	96.1	96.4	93.5	98.4	97.9
game tester	**83.8**	**82**	**79.3**	**71.2**	**88.0**	**89.3**
hairdresser	96.6	96.1	95.3	96.4	97.8	96.8
judge	93.5	89.6	89.9	82.6	96.7	94.7
lawyer	76.1	64	63.3	49.6	88.0	78.1
librarian	87.5	87.9	79.3	85.6	95.1	90.9
mechanic	**77.8**	**75**	**71.0**	**63.3**	**84.2**	**82.4**
nurse	*96.9*	*94.4*	*95.9*	*92.8*	*97.8*	*95.2*
pilot	**90.9**	**91.3**	**87.0**	**86.3**	**94.5**	**95.2**
politician	49.1	34.6	41.4	24.5	56.3	45.5
shopkeeper	96.3	94.9	94.1	94.2	98.4	95.7
soldier	96	92.7	94.7	89.2	97.3	96.3
surveyor	**22.8**	**21.6**	**32.5**	**17.3**	**35.0**	**25.1**
teacher	97.2	96.6	94.7	95.0	99.5	97.3
technician	**48.9**	**37.4**	**39.1**	**20.1**	**57.9**	**51.3**
tennis player	96.3	93.3	94.1	92.1	98.4	94.7
vet	*96.3*	*93.5*	*94.7*	*92.1*	*97.8*	*95.2*
zoologist	*55.1*	*44.4*	*47.9*	*35.3*	*61.7*	*51.9*

Note: Italicised jobs refer to general STEM jobs, jobs in bold refer to core STEM jobs.

engineer, game tester, mechanic, nurse, pilot and vet). The STEM jobs of surveyor, technician and zoologist were less well known by participants in both the 2015 and 2017 datasets. With only three exceptions (astronaut, entrepreneur and civil servant) participants in Year 3 consistently reported that they knew fewer jobs than participants in Year 5.

In 2015, fewer girls than boys reported knowing the following jobs from the whole set of jobs: engineer ($p = .008$), game tester ($p = .006$), mechanic ($p = .008$), politician ($p = .01$), surveyor ($p = .001$) and technician ($p = .014$) (Table 4). Notably, all but one of these are STEM jobs. However, in the 2017 data, these significant gender differences had disappeared, for all jobs except 'mechanic' ($p = .001$). The 2017 data, however, produced significant differences between the genders reporting knowledge of the following jobs: doctor ($p = .008$), firefighter ($p = .043$) and politician ($p = .046$) with fewer girls reporting to know these jobs than boys.

Desirability of different jobs – would like to do, would not like to do, not sure

For all jobs, there was a decrease in the percentage of participants classifying them as 'would NOT like to do' between 2015 and 2017. This decrease was matched by increases in the 'would like to do' and 'not sure' categories for each jobs, as can be seen in Table 5. Furthermore, the changes in the categorisation of jobs was significant for twelve of the jobs.

For 13 jobs, there was an increase in the percentage of participants categorising them as 'would like to do' in 2017, compared to 2015; with STEM jobs accounting for 5 of those 13 jobs. 'Engineer' had the largest increase in participants choosing it as 'would like to do', from 25.6% in 2015 to 33.1% in 2017.

In 2015 and 2017 from the list of jobs presented, boys wanted to do the following jobs more than girls: astronaut, detective, engineer, game tester, mechanic, pilot, estate agent and surveyor. Of these, the STEM jobs largely fall into occupations within the physical sciences. On the other hand in both years, girls reported wanting to do the following jobs more than boys; actor, doctor, hairdresser, nurse, shop keeper and vet. Of these, the STEM jobs largely lie within the health sciences. Supplementary material S1 provides the full breakdown by gender of participants' preferences for all jobs.

Table 4. Differences in jobs known by gender for all participants.

Job Title	% of males that know job (2015)	% of females that know job (2015)	*p*-value (Fishers exact)	% of males that know job (2017)	% of females that know job (2017)	*p*-value (Fishers exact)
civil servant	54.3	45.0	.034	.	.	.
doctor	.	.	.	*50.0*	*49.4*	*0.008*
engineer	**50.7**	**49**	**.008**	.	.	.
entrepreneur	58.7	41.3	.024	.	.	.
estate agent	52.6	46.9	.032	.	.	.
firefighter	.	.	.	50.0	48.8	0.043
game tester	**50.8**	**48.8**	**.006**	.	.	.
mechanic	**51.5**	**48.2**	**.008**	**55.8**	**43.4**	**0.005**
pilot	48.4	51.6	.045	.	.	.
politician	54.3	45.1	.01	59.3	40.7	0.046
surveyor	**59.7**	**39.5**	**.001**	.	.	.
technician	**54.1**	**45.3**	**.014**	.	.	.

Table 5. Percentages of all participants' preferences for jobs including Core STEM jobs (bold) and general STEM jobs (italics). * X^2 tests had 2 degrees of freedom.

Occupation	% that would like to do Job (2015)	% that would like to do Job (2017)	% that would NOT like to do Job (2015)	% that would NOT like to do Job (2017)	% not sure about Job (2015)	% not sure about Job (2017)	X^2 *	Sig
actor	39.8	37.6	37.8	32.3	9.9	16.9	4.358	0.113
athlete	41.5	36.0	31	21.3	10.5	12.1	2.474	0.29
astronaut	**27.8**	**25.3**	**58**	**52.0**	**9.7**	**15.4**	**4.354**	**0.113**
author	31.5	33.7	50	35.7	11.4	20.2	8.538	0.014
banker	27.3	28.7	45.2	35.1	10.5	16.6	9.214	0.01
civil servant	3.1	3.4	27	9.6	6.3	4.2	8.265	0.016
detective	36.4	34.8	44.3	34.8	11.1	18.8	17.104	0.001
doctor	*31.8*	*35.7*	*54.3*	*42.7*	*11.1*	*17.7*	*8.971*	*0.011*
engineer	**25.6**	**33.1**	**48.3**	**34.8**	**10.8**	**16.9**	**9.862**	**0.007**
entrepreneur	4.3	2.2	14.8	6.7	7.1	2.5	1.047	0.592
estate agent	14.8	13.5	32.4	27.5	7.4	12.1	0.987	0.61
farmer	18.5	21.9	70.5	59.3	8.2	13.5	4.347	0.114
firefighter	24.1	29.2	61.6	48.6	11.6	18.3	8.994	0.011
game tester	**48.6**	**51.4**	**25.3**	**20.5**	**9.9**	**10.1**	**0.09**	**0.956**
hairdresser	44.3	42.1	43.5	39.9	8.8	14	7.347	0.025
judge	26.1	27.5	56.8	44.1	10.5	17.5	8.071	0.018
lawyer	23	15.2	43.8	37.4	9.4	11.5	3.303	0.192
librarian	21.3	24.7	54	43.8	12.2	19.4	2.293	0.318
mechanic	**24.7**	**28.4**	**46**	**33.4**	**7.1**	**13.2**	**6.303**	**0.043**
nurse	*30.4*	*27.8*	*54.3*	*49.2*	*12.2*	*17.4*	*0.777*	*0.678*
pilot	**30.4**	**30.3**	**50.3**	**45.5**	**10.2**	**15.4**	**4.308**	**0.116**
politician	8.5	8.1	28.1	18.8	12.5	7.6	0.153	0.926
shopkeeper	39.2	36.2	42.9	40.4	14.2	18.3	0.394	0.821
soldier	30.7	32.6	56.8	47.8	8.5	12.4	2.192	0.334
surveyor	**4**	**3.9**	**23.6**	**13.8**	**6.3**	**3.9**	**2.157**	**0.34**
teacher	52.3	46.6	33	32.0	11.9	18	2.459	0.292
technician	**9.9**	**10.7**	**31**	**19.1**	**8**	**7.6**	**4.331**	**0.115**
tennis player	32.7	34.3	52	40.4	11.6	18.4	4.705	0.095
vet	*45.5*	*44.9*	*39.5*	*30.9*	*11.4*	*17.7*	*9.741*	*0.008*
zoologist	*16.8*	*14.3*	*30.4*	*21.6*	*8*	*8.4*	*1.555*	*0.46*

Year 5 comparison and intervention groups

Changes in participant choices of jobs can be investigated further by using the children in Year 5 in 2015 and the children in Year 5 in 2017 to provide comparison and intervention groups.

No discernible differences were observed in the jobs known between the Year 5 comparison and Year 5 intervention groups. Overall, however, a lower percentage of participants in the intervention group indicated that they 'did NOT want to do' the jobs compared to the comparison group across all the jobs, except entrepreneur and lawyer. Supplementary material S2 provides the full breakdown of intervention and comparison groups preferences for all jobs.

Table 6 shows participants' preferences for STEM jobs for the comparison and intervention groups. There were higher percentages of participants that 'would like to do' jobs across all the STEM jobs (except pilot) in the Year 5 intervention group compared to the Year 5 comparison group.

When looking at all participants, the change in preference was significant for five STEM jobs: doctor, engineer, mechanic, surveyor, and vet. However, when preferences were examined by gender (Table 7), it can be seen that the significant changes were in

Table 6. Percentages of participants' preferences for STEM jobs in year 5 comparison and intervention groups (Chi Square Test) *X^2 tests had 2 degrees of freedom.

	Comparison group (2015)			Intervention group (2017)				
Jobs	Like to do %	Not like to do %	Not sure %	Like to do %	Not like to do %	Not sure %	X^2	Sig.
astronaut	45.0	41.4	13.6	51.5	30.7	17.8	4.319	.115
doctor	*25.4*	*62.4*	*12.2*	*34.3*	*45.9*	*19.9*	*10.342*	*.006*
engineer	**25.9**	**63.3**	**10.8**	**40.1**	**36.6**	**23.3**	**24.782**	**.001**
game tester	**54.0**	**34.8**	**11.2**	**62.3**	**27.5**	**10.2**	**2.413**	**.229**
mechanic	**26.0**	**64.9**	**9.1**	**37.0**	**45.5**	**17.5**	**12.395**	**.002**
nurse	*21.8*	*65.9*	*12.3*	*28.1*	*56.7*	*15.2*	*3.187*	*.203*
pilot	**28.9**	**60.1**	**11.0**	**28.7**	**55.1**	**16.3**	**2.201**	**.333**
surveyor	**6.3**	**89.1**	**4.7**	**14.9**	**66.0**	**19.1**	**9.11**	**.011**
technician	**19.8**	**68.9**	**11.3**	**27.1**	**53.1**	**19.8**	**5.534**	**.063**
vet	*24.0*	*61.5*	*12.8*	*30.9*	*46.6*	*17.4*	*9.429*	*.002*
zoologist	*24.8*	*57.5*	*17.7*	*34.0*	*51.5*	*14.4*	*2.219*	*.33*

different jobs, with three of the four jobs being general STEM jobs for girls (doctor, nurse, vet), and both jobs being core STEM for boys (engineer, mechanic). Only the job 'engineer' was significant for both genders (girls $p = .001$, boys $p = .001$). The percentage of girls that 'would like to' be engineers in the comparison and intervention group were similar (20% and 21.8% respectively), but the percentage of girls that 'would not like to do' engineering decreased from 70.6% before the intervention, to 47.1% after the intervention, with the percentage that were 'not sure' increasing from 9.4% to 31%. In contrast, the percentage of boys that 'would like to' be engineers increased from 32.1% in the comparison group to 59.0% in the intervention group, and the percentage that 'would not like to do' engineering decreased from 55.6% to 25.3%.

Discussion

This paper has outlined a project that aimed to broaden the aspirations towards STEM jobs for children in under-represented groups. The results presented in the paper show an increase in the percentages of young people that would 'like to do' specific jobs, and that were 'not sure' if they would like to do specific jobs within the 30 offered. There was a concomitant decrease in the percentage of young people that 'would not like to do' specific jobs.

The finding of significant differences in jobs known by the different year groups, with year 5 more likely to know jobs than year 3 children is consistent with research that shows an increase in occupational knowledge and awareness with age (Noack, Kracke, Gniewosz, & Dietrich, 2010).

The participants in the study were from schools in areas of deprivation (low SES) and, according to popular narrative, might be assumed to have low aspirations towards school and success in high status careers (see e.g. Turner, 2018). However, this narrative has been challenged, and evidence suggests that families from low SES backgrounds have high aspirations (Carter-Wall & Whitfield, 2012; Treanor, 2017). The data in this study current study aligns with this, with participants recognising both high and low status jobs, and identifying them as jobs they 'would like to do'. Rather than raising aspirations 'there is a real need for children and parents to be offered support to learn more about

Table 7. Percentages of participants' preferences with statistically significant differences between intervention and comparison groups by gender (Chi Square Test) *X2 tests had 2 degrees of freedom.

		Comparison group (2015)			Intervention group (2017)				
	Jobs	Like to do %	Not like to do %	Not sure %	Like to do %	Not like to do %	Not sure %	X^2	Sig.
Girls	**doctor**	**34.0**	**53.6**	**12.4**	**44.7**	**33.0**	**22.3**	**8.803**	**.012**
	engineer	**20.0**	**70.6**	**9.4**	**21.8**	**47.1**	**31.0**	**13.978**	**.001**
	nurse	*33.7*	*50.5*	*15.8*	*28.6*	*28.6*	*24.2*	*9.397*	*.009*
	vet	*45.3*	*38.9*	*15.8*	*23.1*	*23.1*	*14.3*	*6.434*	*.04*
Boys	**engineer**	**32.1**	**55.6**	**12.3**	**59.0**	**25.3**	**15.7**	**16.15**	**.001**
	mechanic	**36.0**	**52.0**	**12.0**	**56.4**	**28.2**	**15.4**	**9.181**	**.01**

educational and career options so that they can make more informed decisions about their future' (Carter-Wall & Whitfield, 2012, p. 4). The interventions developed during the study were developed to support children and parents in this way, and the data suggest that children have an interest in a broader range of careers following the two year project.

While there was no significant change in young people's preference from 'would not like to do' to 'would like to do' jobs, there was a clear shift from children who had closed off the option of a career (by saying they 'would not like to do' the jobs) to being more open about whether they wanted to do the jobs or not (by adding these to the 'not sure' box). For this cohort of children, between 2015 and 2017, the Zone of Acceptable Alternatives (Gottfredson, 1981) broadened, with more jobs being considered as possibilities. This finding is important because it suggests the children remain open to pursuing those jobs, thereby leaving the possibilities of those job paths available to them should they wish to choose to pursue them in the future. The general decline in percentages of participants across all the jobs that 'would not like to do' them also supports the argument that the participants were more open to a variety of job pathways in 2017 than 2015. Gottfredson (2005) indicates that providing a broad menu of potential occupations to children from a young age helps to broaden their horizons. The current study used a repeated interaction model in which children were exposed to different careers over the course of two years and the results presented indicate the broadening of aspirations to include more possible jobs, as posited by Gottfredson.

It is also worthwhile considering in more detail the results for the job 'engineer'. A number of the STEM interventions in two-year study focused on different engineering disciplines, as can be seen in Table 1. Comparison of the Intervention Group of Year 5 children with the comparison group of Year 5 children shows a significant decrease in the number of children who say that they would not like to do this job (26.7% decrease), and this decrease is also significant for girls (23.5% decrease) and boys (30.3% decrease) separately. These data supports the suggestion that sustained engagement can lead to impact (Macdonald, 2014). Engineer was also the only job that shows a significant decrease in 'would not like to do' for both boys and girls between the comparison and intervention groups. Looking at the data for girls in these groups, it can be seen that the decrease in 'would not like to do' leads mainly to an increase in 'not sure' (from 9.4% to 31%), whilst for the boys the decrease is more evenly spread between 'not sure' and 'would like to do'. Thus although the girls were more positive about the possibility of engineering as a job, they were still less definite about it than the boys in the study. However, given the under-representation of both females and people from low SES background in engineering, then these results for both girls and boys from schools in areas of high deprivation suggest a promising start in redressing this imbalance.

Comparing the 2015 and 2017 Year 5 boys shows that during the project there was not a significant increase in the number of boys that were interested in biological or healthcare careers. This could partly be explained by the focus of the project on core STEM jobs, which does not include healthcare related careers. Thus, although there were two biological based in-class workshops ('Botanist' and 'Medical Physicist'), the majority of in-class workshops focussed on physical sciences, technology and engineering. One interesting avenue of further research would be to explore whether a similar project to the one reported here, but with a stronger focus on health STEM careers, would result in a similar increase in interest in those careers amongst boys.

These findings highlight the entrenched stereotypical views about the roles of men and women in society, and are consistent with findings from the 'drawing the future' study (Education & Employers, 2018), where females wanted nurturing roles and males wanted the traditional male dominated careers. Although overall more participants expressed an interest in STEM careers, the type of STEM careers that they oriented towards were those that fit within acceptable gender roles within society (McMahon & Patton, 1997). Further iterations of the action research cycle will allow the researchers to adapt interventions, and investigate this effect further, highlighting the benefit of using an action research approach in this study.

Targeting under-represented groups in STEM, such as females and those from low SES backgrounds, is one way to widen participation and increase diversity in the STEM workforce. Results from this research study suggests that repeated interventions as part of a sustained project including career-driven, and inclusive child-centred STEM activities with children and their key influencers have a positive effect on girls. Girls were significantly less likely to know the jobs surveyor, technician, and game tester compared to boys in 2015, but did not show any significant difference with their male counterparts in 2017.

This study is not without its limitations. The study does not, and cannot, account for other external factors that could also influence the children's knowledge and preferences, some of which are identified in the Science Capital model (Archer, Dawson, DeWitt, Seakins, & Wong, 2015), particularly teacher effects and family/carers' influences. Although interventions were targeted at teachers and families, changes in attitude in these groups were not measured in the current study. Furthermore, this study is only one part of a wider set of educational experiences for any child, and that the time-delay between the intervention and children's eventual choice of job limits any causal relationship that could be drawn. The research team have a longer term research plan which will revisit the cohorts of children from the intervention schools, using the National Pupil Database, when they are 18 and compare their choice of A-levels with cohorts of children whose schools did not take part in the study.

Due to the challenges associated with assessing SES background in young children, it has not been possible within this study to explore how family background or parental attitudes and behaviours for science may be directly associated with children's knowledge and aspiration for STEM jobs. However, because the study sample has higher than average numbers of children from lower SES backgrounds, the intervention findings can be interpreted as having relevance for children from lower SES groups.

The study is also restricted to the use of self-reported feedback from the children on their knowledge of jobs without further testing if they actually knew what those jobs involved. This limits the findings to the perception of knowledge of the children on occupations. However, even if children do not know the details of a particular job, if they have decided that they do not want to do it based on what they (do not) know, then they are still potentially removing that job for future consideration. Children in primary schools tend to describe careers in terms of activities or behaviours they associate with the career(s), and so as they advance in age, their focus shifts more to their own interests and competence (Ferrari et al., 2015; Watson & McMahon, 2005). If the children do not know the name of a job, they cannot have accurate perceptions about it or consider that job. By broadening the career knowledge and awareness of children, they can make decisions that are more informed, rather than basing them on limited perceptions of jobs, and thereby avoid self-excluding themselves from a wide range of future careers.

Conclusion and future work

This study contributes to research conversations on influences of learning experiences on children's career knowledge, perceptions and understanding, and provides an evidence base for the career inclinations of young children. Its main contribution is due to its focus on children in primary education, whereas most previous interventions and research studies have focused on young people in secondary education and above. By focusing on career awareness and experiential learning, children are able to widen career options available to them without excluding themselves and limiting future career opportunities. Results suggest that there can be positive effects of carefully designed and sustained career driven STEM engagement on children from schools in areas of low SES. These finding provide evidence of a pathway to tackling the STEM skills gap by organisations. The study also explores how the STEM Career Knowledge and Aspirations Tool can be used to measure the effectiveness of a sustained career driven intervention on children's career preferences with suggested evidence of broadened career knowledge and career preference shifts over time. However, further work is needed to improve the tool and to explore children's understanding of the individual jobs included. This study extends conversations in career research and provides an evidence base for the career inclinations of young children**.**

Notes

1. This study categorises STEM into general STEM and Core STEM generated from the ONS Standard Occupational Classification (SOC) code (WISE, 2018). Core STEM includes science, engineering, and information and communications technology. Health occupations (medical STEM) sit within general STEM with less predicted future skills shortage, therefore the focus on core STEM occupations in this study.
2. The primary (children aged 5–11) and secondary (young people aged 11–17 years) school system is the common system used in the UK and references will be made to this throughout the paper.
3. In this paper 'interventions' refers to a range of workshops and activities developed during the project.

4. Key influencers refers to persons or groups that have an impact and influence on the decisions of the children, such as teachers, families and carers (Epstein, 2011).

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ORCID

Itoro Emembolu http://orcid.org/0000-0002-5765-4668
Annie Padwick http://orcid.org/0000-0001-9042-0209
Joe Shimwell http://orcid.org/0000-0003-3211-1541
Jonathan Sanderson http://orcid.org/0000-0003-1769-8647
Carol Davenport http://orcid.org/0000-0002-8816-3909
Rebecca Strachan http://orcid.org/0000-0003-3694-2158

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