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Let's do Engineering broadens young children's understanding of engineers

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This study developed and applied a new job card methodology to investigate what 5-year-old children in Scotland understand in relation to engineers and engineering. Children were shown images of different jobs and asked to identify the jobs and select the cards showing engineers. The methodology was utilized pre- and post-intervention to determine whether an intervention combining engineer role model imagery and hands-on activities (specifically Let's do Engineering) would successfully broaden perspectives of engineering, and whether there would be any differences between boys and girls in terms of the effectiveness of the intervention. In total, 16 children of 5–6 year old from one school participated and prior to the intervention could only correctly recognize an average of 1.5 engineers. After intervention, however, all children were able to successfully identify multiple engineers within the job cards, achieving in excess of a three-fold increase in the number of engineers correctly identified, even 2 months after the end of the intervention. When comparing data for boys and girls, analysis showed that there were no between-group gender differences in either perceptions or in strength of impact of the intervention. The engineers identified were well spread across the different engineering fields, indicating that the children developed a broad understanding of different engineering disciplines.

KEYWORDS

early engineering education, perceptions, STEM, engineers, role models

Introduction

Engineering as a profession suffers from a skill shortage and a lack of diversity (Perkin report, 2019; EngineeringUK, 2022). For example, in the UK, in 2022, only 16.5% of engineers were women (EngineeringUK, 2022). Scotland, where this study was undertaken, has engineering included in the curriculum from the earliest level. However, research shows that young people in general have little idea of what engineering involves (Capobianco et al., 2011; Armitage et al., 2020).

Misconceptions and stereotypes that can lead to early career-eliminating decisions (Gottfredson, 1981; McMahon and Watson, 2022; Padwick et al., 2022), with studies highlighting how STEM stereotypes at early years are linked with later STEM interest, motivation and career choices (McGuire et al., 2020; Master, 2021), and that career aspirations aged seven are similar to those aged 17 (Archer et al., 2020).

Understanding what young children know and think about engineers and engineering is key to tackling misunderstandings and stereotypes. However, existing methodologies for determining what young children think of engineers have some drawbacks. Previously, in order to investigate how children perceive engineers, the Draw-an-Engineer (DAET) test has been utilized (Knight and Cunningham, 2004). Two recent studies used DAET with 3–8 years old children, finding that the engineers drawn are predominantly male and involved in work with buildings/construction or vehicles (Hammack et al., 2020; Ata-Aktürk and Demircan, 2022), in common with the results of DAET across a longer time and with a broader age range (Knight and Cunningham, 2004; Xu and Jack, 2023).

One potential problem with the DAET is that requesting just one image of an engineer is likely to elicit a more stereotypical result and as such not reveal any broader understanding that children might have of engineering (Xu and Jack, 2023). One solution is to use alternative methods such as image cards to prompt discussions or to gather broader data (Cunningham et al., 2005; Padwick et al., 2016; Emembolu et al., 2020; Lampley et al., 2022).

Work by the NUSTEM group has used cards to explore what children understand in relation to different STEM occupations (Padwick et al., 2016; Emembolu et al., 2020). Children were shown 30 job cards (with written jobs rather than images; cards were read aloud) and asked to sort them into jobs they knew and those they did not and then assigned the jobs they knew to those which they would like to do, would not like to do, or not sure. In one study, this was also coupled with diamond nine card sorting of characteristics (e.g., friendly, clever, creative) based on whether scientists were like these characteristics or not (Padwick et al., 2016). Cunningham et al. asked children the circle images showing the work that engineers do, achieving similar results to the DAET, i.e., selection of pictures relating to buildings, machinery, and cars reflecting ideas of engineers being involved in construction and repairing of vehicles (Cunningham et al., 2005). This image set was utilized again by Lampley et al. in 2022, with a large sample of US children, and there was a slight shift in perceptions with more understanding that engineers design things (Lampley et al., 2022).

NUSTEM also utilized focus groups with 4-year-old children to probe their understanding of scientists and science careers, finding that most children had limited understanding, often stereotypical (Lampley et al., 2022). Additionally, children were unable to link ideas of science as a subject with scientists, suggesting to tackle career-related stereotypes, and increasing disciplinary knowledge alone is insufficient and a focus should be placed on understanding engineers/scientists and their careers (Padwick et al., 2016; Emembolu et al., 2020; Padwick et al., 2022).

Overall, little is known about how young (3–7-year-old) children perceive engineers and engineering. Existing research using DAET suggested stereotypical ideas around engineers being males working with constructions and vehicles are present, although this methodology might not have been ideal to explore the understandings of a broader range of engineering disciplines. Here, we introduce a new approach to investigate what young children understand in relation to engineers and engineering, addressing the following research questions:

- What do 5-year-old children in Scotland understand in relation to engineers and engineering?
- Does an intervention combining engineer role model imagery and hands-on activities (specifically Let's do Engineering) broaden perspectives of engineering?
- Are there any gender differences in either perceptions or in the impact of the intervention?
- Are there differences in the understanding of different engineering disciplines?

Method

Participants and data collection

Participants were recruited through a convenient sampling method, via researcher contacts and university school liaison officers, to identify participating schools as part of a larger research project. One school had already utilized job cards to engage their youngest class in discussions around careers and support the teachers in developing the children's understanding of STEM roles and were keen to extend this study. In this study, schools were provided with the new job card set, incorporating seven different engineers. The teacher then facilitated delivery of the data collection before and after the intervention, sitting with each child individually and interviewing them using the job cards. The children were all from one P1 class and were aged between 5 and 6 year old. Sixteen children participated in the data collection before and after the Let's do Engineering intervention (Let's Do Engineering Ltd, n.d.). The classroom teacher and the school STEM lead who co-taught some classes were both female. The school is based in Fife, Scotland with the school postcode returning an SIMD ranking of six, but has a mixed demographic in terms of deprivation with the catchment covering areas ranked from 1 to 7. The school describe themselves as being rich in diverse cultures and religions, with 17% of children having English as a second language.

Design of study and intervention details

The study involved use of a job card measure to investigate perceptions of engineers before and after participation in Let's do Engineering. The study ran from November 2022 to September 2023, with the initial and final interviews taking place during those months and Let's do Engineering teaching activities taking place from December 2022 to June 2023.

Let's do Engineering is a research and engagement project funded by the Engineering and Physical Sciences Research Council (EPSRC) through their Engagement Champions program. The project recruited 20 engineers and created a range of resources ranging from role model-based career information and hands-on classroom activities. Resources were developed in collaboration with engineers, creative practitioners along with education, engineering and psychology (child development), and researchers and refined through testing in schools. A review of this process and teacher feedback is under review elsewhere. The information on role models included short engineer films aimed at the children, engineer profiles hosted on the website (Let's Do Engineering Ltd, n.d.) with some child-friendly information, and additional details to support educators and engineer posters to display in the classroom. The classroom activities were each linked with engineer role models and involved hands-on engineering challenges, e.g., build a wind turbine and a variety of creative expressive arts-based ideas including drama, dance, and circus. In addition, an activity book with a double-spread page for each engineer, with activities such as dot-to-dot and spot the difference was produced; the intention was for each child to receive their own copy which would go home to facilitate conversations with parents. Teachers can select and implement the different activities as they wish, according to their aims and the interests of the children.

In this study, the classroom teacher delivered nine activities, including making and launching a rocket, an acoustical engineering noise-maker build, a robot-related coding activity, and a geotechnical engineering building activity, with the engineering challenges scaffolded by a three-stage Engineering Design Cycle (Explore, Create, and Improve). In addition, engineer role model classroom posters and a top trumps style card game were used to showcase the range of different engineers. There was not a set day of the week in which the activities were delivered; sessions were fitted around other curriculum activities, with activities taking place every couple of weeks. Typical sessions involved an introduction, watching a role model video, and participating in the activities (timings varied between 30 min and 1 h and resources remained available for children to continue investigations after the initial session). Children also received an activity book to take home, including the nine engineers from the classroom activities and an additional 11 engineer role models.

Measures

In this study, a set of 20 job cards were utilized as visual aids during individual interviews with the children. Custom-made job cards were designed, using a gender-neutral figure in black and white, incorporating a variety of familiar roles, e.g., police and teacher and seven different engineering examples.

Data collection

Children were individually interviewed by a teacher at their school, being first asked to sort the cards into jobs that they knew while naming or describing the job. The teacher wrote down their response for each card. Second, children were shown the whole set of cards again and asked to select those which they thought were engineers and to explain why if possible. An Excel sheet was used to compile the responses, noting for each child what they said about each card in one row along with an X to indicate whether the card was selected as an engineer. The job cards utilized in this study depicted a range of 19 jobs, including a range of seven different engineers (aeronautical, biomedical, chemical, civil, electrical, mechanical, and robotical) (Figure 1). The other jobs were selected based on the previous job card work, especially that by NUSTEM which depicted a range of jobs (Padwick et al., 2016; Emembolu et al., 2020), LMI data (LMI, n.d.), and literature examining children's career aspirations (Chambers et al., 2018; NUSTEM, n.d.), which are linked to jobs that they know, i.e., most children name jobs that they commonly see around them, with one study finding the top 20 job roles account for 75% of career choices (NUSTEM, n.d.). The aim was to represent a range of jobs likely to be known to children with a mixture of traditionally male- or female-dominated roles and some neutral jobs, in addition to a variety of engineers along with a scientist and a mechanic, to observe if the children would differentiate these roles from engineering. Black and white drawings were developed aiming to be gender neutral; however, stick people are often interpreted as male, although the teacher noted that the children more commonly referred to the person in the image as it rather than he/she. The cards were initially tested with a local school during an MSc project, indicating that the children understood the process and could use the cards to recognise different jobs. The initial pilot used small groups of children; subsequently, we updated the approach to individual interviews with a question script. The pre-intervention interview took place in November 2022. After the intervention, the individual interviews with the teacher were repeated, at the start of the P2 year on 1 September 2023 (1.5 weeks after the start of term after a 6.5 week summer holiday) and over 2 months after the last Let's do Engineering activity. After being asked which jobs they knew, children were reminded that they had learnt about engineers in P1 and asked to identify which cards depicted engineers.

Data analysis

The data were analysed to address the original research questions. To determine what children understand about engineers and engineering, the children's responses were analysed as follows. For each card, if the child successfully named or described the job, one point was allocated; incorrectly identified or unknown responses were marked as zero. A total score was then obtained for each child in terms of jobs known. Subsequently, the responses to the second question of which cards depicted engineers were scored; the number of cards they selected in response to this question was calculated (i.e., number of X recorded); next, each response was checked to observe if the selected card showed an engineer, and the number of correctly identified cards was summed. To determine the impact of the intervention, data were collected and analysed in this way pre- and post-intervention. Descriptive results are shown in Table 1 and Figure 2. During the statistical analysis, the second and third research questions were addressed. For inferential statistics, a mixed factorial ANOVA was utilized to evaluate the impact of the intervention considering both time (pre- and post-intervention) and gender. For the fourth research question relating to the differences in understanding of different engineering disciplines, the number of children who correctly recognized each different engineer was summed (pre- and post-intervention) (see Table 1), and a paired samples t-test was used to investigate if the intervention resulted in an increase in correct identification of the different engineering job roles.

Ethics

Ethical approval was obtained from the Heriot-Watt Engineering and Physical Sciences Research Ethics Committee. Children verbally assented to take part when the teacher introduced and explained the tasks, with one child choosing to opt out and not participate. Each participant was given a code to hide their personal identity, with the identifier file being destroyed subsequent to completion of the analysis.

FIGURE 1
Images of the job cards and the Let's do Engineering activity book and some of the engineer role models. Engineer films and profiles can be found on www.letsdoengineering.com, and the lesson plans utilized are available on request.

TABLE 1 Pre- and post-test number of children who correctly identified the different engineering job roles being engineering.

Job role	Pre-test	Post-test
Aerospace engineer	5	13
Biomedical engineer	4	10
Chemical engineer	2	11
Civil engineer	6	13
Electrical engineer	3	14
Mechanical engineer	3	13
Robotical engineer	6	13
Mechanic	8	11
Scientist	1	9

Mechanic and scientist data are included for comparison.

Results

To measure engineering perception pre- and post-intervention, teacher interviews with 16 children (eight boys and eight girls) aged between 5 and 6 years old (P1 in the Scottish education system) were undertaken using job cards to prompt discussion about jobs and engineering jobs in particular. Card-based sorting tasks have previously been applied in investigating engineering perceptions in young children, e.g., by NUSTEM to study the understanding of scientists (Padwick et al., 2016; Emembolu et al., 2020), by Mulvey et al. to probe counter-stereotypical career choices (Mulvey and Irvin, 2018), and by Cunningham and then Lampley to gather data on engineering perceptions (Cunningham et al., 2005; Lampley et al., 2022).

First, the children were asked which jobs they knew, and second, which cards showed engineering jobs and why. Before the intervention, children were able to identify approximately 60% of the jobs shown in the images, with the average number of jobs correctly identified being 12.4. Let's do Engineering activities were delivered for 7 months with the children being exposed to nine different engineers during classroom studies. Subsequent to the intervention, children were able to identify over 75% of the jobs shown in the images, with the average number of jobs correctly identified as 16.56, an increase which was mainly due to an increasing recognition of engineers. The results are discussed below in relation to each of the article research questions.

What do 5-year-old children in Scotland understand in relation to engineers and engineering?

Before participating in the Let's do Engineering activities, there was little understanding of what engineering was and what engineers do. One child commented:

> *"I do not know that word. I know a similar word – engine."*

Meanwhile, another said:

> *"I do not think any of them are engineers. Engineers drive trains."*

Overall, 31% of children were unable to correctly identify a single engineer from the job card set. Two children were able to make a connection to their father's job ("that is what my daddy does") and, therefore, correctly identify one engineer working in the same sector as their parent. In general, the average number of people suggested by the children to be engineers was 2.8, with the average correctly identified engineers being 1.5, giving an average of a 43.5% successful identification rate (Figure 2A).

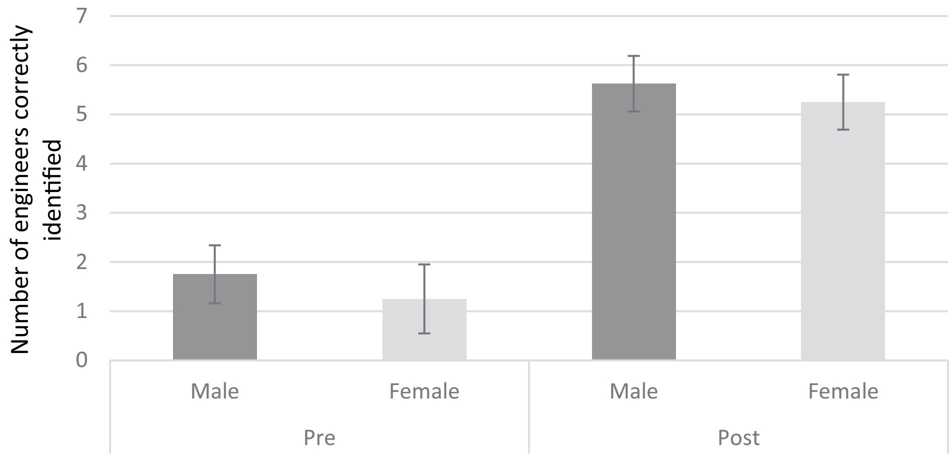

FIGURE 2
Pre- and post-intervention performance, by participant gender, relating to the number of cards suggested to be engineers and the number of engineers correctly identified. The *y* axis represents the number of successfully identified engineers (seven being the maximum score; error bars represent standard error of the mean).

Not all children were able to explain or justify some or all of their selections. However, from those children who did explain their choices, conceptions of engineering were related to ideas of fixing (12 mentions), building (11 mentions), and making (3 mentions). Additionally, engineering was associated with items such as cars (8 mentions), bridges and robots (both 4 mentions), and space and planes (2 mentions each).

Are there any gender differences in engineering perceptions?

Before the intervention, the boys made more suggestions of which people could be engineers (3.375 on average as opposed to 2.25 for the girls) and correctly identified more engineers (1.75 as opposed to 1.25) (Figure 2). However, in terms of percentage success rate, the figures were very similar with the girls being correct in 43% of choices, whereas the boys achieved 44%. Overall, there was little difference in how well boys and girls successfully identify engineers.

What was the impact of Let's do Engineering on engineering perceptions?

All children participated in nine Let's do Engineering activities (Figure 1B) after the pre-test, virtually meeting a diverse range of engineer role models through a short video and, subsequently, participating in a linked activity. The engineer role models selected were three males and six females covering a variety of engineering disciplines including acoustical, chemical, civil, electrical, mechanical, and software. Activities undertaken by the children ranged from hands-on engineering challenges, e.g., build a tower or make a rocket, to more expressive art activities such as songs (Wonderful Amy), dance (Mission to Mars), and circus (structures and balances; hula hooping and orbits). During the same classroom session, children were given time to complete the linked page in the Let's do Engineering activity book. After 7 months, children took home the activity book. Post-testing occurred 2 months later, including a period of 6 weeks of summer holiday. The results indicated that the intervention had a significant impact on the children's ability to recognise different engineering jobs, with children now identifying on average 7.8 people as engineers, 5 of which were correctly identified (Figure 2A), a successful recognition percentage of 69.30% (Figure 2A). Previously, children only correctly identified an average of 1.5, so the shift to being able to point out five engineers is in excess of a three-fold increase. The rise in successful recognition percentage represented 59% increase (in absolute terms, a rise of over 25% points) and was statistically significant. A Mixed Factorial ANOVA showed a significant repeated measures subject factor of time: $F = (1, 14)$ 59.0, $p < 0.001$, $\eta^2 = 0.60$.

Afterwards, the discussion and language used still reflected ideas of building and fixing but now included new references to making things and to being an inventor as well as a much broader use of science when describing engineer jobs. This might reflect a confusion about the difference between science and engineering or could evidence that the children have a recognition of the role science plays in engineering. Let's do Engineering was delivered after British Science Week, in which the school delivered various science activities and received visits from scientists and engineers.

There were 43 instances of incorrectly assigned engineers, which spread across a range of 12 different jobs, though 2 occupations dominated the incorrectly identified categories, i.e., scientist with 9 mentions and mechanic with 11 mentions. Before Let's do Engineering, the mechanic card was selected by 50% of the children as an engineer, whereas this increased to 68.75%, showing that the association of engineering with fixing and vehicles persisted. The card shows a person shining a torch into a car bonnet. Before Let's do Engineering, children did not particularly associate science and engineering with only one child incorrectly identifying the scientist card as an engineer and describing it as potions. Afterward, however, the scientist card was selected by 56.25% of the children (Table 1). The card shows someone in a lab coat working on a small-scale science experiment as opposed to the chemical engineer card which shows the engineer working with larger pipes and a scaled-up chemical process.

The high rate of selection of these cards might simply reflect the difficulty of clearly depicting in one black and white image the difference between a mechanic, a scientist, and an engineer. More in-depth discussion with the children, directly asking them to explain the differences between a mechanic, scientist, and engineer, would be useful to understand their perspectives.

Were there any gender differences in terms of the impact of Let's do Engineering?

After Let's do Engineering, both boys and girls suggested a higher number of people who they thought were engineers than girls, with the girls now suggesting slightly more (8.5 on average for the girls as opposed to 8.25 for the boys). Both boys and girls considered a greater number of the job cards to represent engineering, with the data showing an increase of over double the number for the boys and over three times as many for the girls. In terms of correctly identified engineers, boys achieved 5.625 to the girls 5.25, over a three-fold and four-fold increase, respectively. Before the intervention, both genders had a similar percentage success rate, and this was repeated after the intervention, where boys now reached 71.13% in comparison to the girls' post-test success rate of 69.30%. A Mixed Factorial ANOVA showed a non-significant interaction between gender and time [$F = (1, 14)$ 0.015, $p = 0.905$] and a non-significant interaction between subject factor of gender [$F = (1, 14)$ 0.405, $p = 0.535$]. Overall, the Let's do Engineering intervention appears to equally benefit girls and boys, with them both significantly broadening their perspectives of engineers.

Were particular engineering disciplines easier for the children to identify?

Before Let's do Engineering, every different engineering discipline was correctly identified by at least two children, with the most popular categories being aerospace, civil, and robotical engineers (Table 1), showing an association between large technologies such as planes and robots as well as ideas of building and fixing. Even the biomedical engineer was recognized as an engineer most likely due to image of the biomedical engineer working with a prosthetic leg, and while the children often did not fully understand this, they could identify with something being fixed. After Let's do Engineering, all engineering categories were correctly identified by at least nine children, with the majority of engineering fields being recognized by 75% of the children. Post-test biomedical and chemical engineering were the least identified engineering areas. Electrical and mechanical engineering observed the largest increases, possibly mainly due to these types of engineers not being well-known prior to the intervention and also that these types of engineers made up one-third of those studied in the classroom. The results from the pre-test ($M = 4.14$, SD = 1.57) and post-test ($M = 12.4$, SD = 1.40) of the Let's do Engineering intervention resulted in an increase in correct identification of the different engineering job roles being engineering, $t(7) = 12.18$, $p < 0.001$, Cohen's $d = 5.57$.

Discussion

This study has explored what five-year-olds in Scotland understand in relation to engineers and engineering. The study used a job card methodology to measure changes resulting from participating in a set of classroom activities using the Let's do Engineering resources. Exposure to the intervention resulted in at least a three-fold increase in correctly identified engineer job cards, which was statistically significant ($p < 0.001$, $\eta^2 = 0.60$). A meta-analysis by John Hattie in 2009 averaged effect sizes for multiple interventions in education, reporting 0.4 as a level above which an intervention could be considered worthwhile, with changes not due to other influences such as teacher effects of developmental effects (Higgins and Simpson, 2011). More recent study by Kraft on interpreting the effect size of field-based educational interventions incorporated work from the last 15 years proposed that an effect size of 0.2 or greater can be considered large and discusses important interpretation features (Kraft, 2020). Considering our study in light of these features, a somewhat larger effect size is expected due to features such as the small sample size and targeted outcome measures, which is further discussed under limitations. However, given this initial data and considering the costs and scalability, the Let's do Engineering intervention shows considerable promise in tackling stereotypes about engineering.

In the post-test results, conducted 2 months after the end of the original intervention, all engineering disciplines depicted in the image set were recognized by at least 10 out of the 16 children, indicating that the increases in understanding were well spread across the different engineering fields. Additionally, no gender differences were noted in relation to the success of the intervention with both boys and girls, with all children increasing their successful engineer identification percentage to over 69%. A similar intervention with older children, the NUSTEM STEM person of the week, had a different outcome measure asking children to use six words to describe scientists but also reported that a medium-term, teacher-led intervention using real-world role models could reduce stereotypes in young people, with little difference between genders (Shimwell et al., 2023). In contrast, other studies using DAET as an evaluation method have found that poorly designed interventions can reinforce stereotypes (Rodrigues-Silva and Alsina, 2023).

There are several limitations to this study. First, the small sample size concentrating on just 16 students from one school in Scotland, without the use of a control group (the school has one P1 class, all of whom participated and therefore no control group was available); this is likely to increase our effect size and limits our ability to establish causal effect (Kraft, 2020). Ongoing research is extending the use of the job card methodology with an increasing number of children, across different age ranges in order to gather further insight into how young Scottish children perceive engineers, to track any changes in perceptions with age and confirm the utility of the method across a broader age range. Second, one of the teachers in this study is a STEM lead and is highly enthusiastic, experienced, and confident teacher who could have contributed to the high level of positive impact recorded in this study. The teacher co-delivered four of the activities with the classroom teacher, leaving the classroom teacher to deliver the remaining activities on her own. Teacher self-efficacy is known to impact the effectiveness of STEM learning and STEM interventions and has also previously been associated with the degree of engineering play behaviors observed in preschool settings. We are not aware of any research linking teacher experience with broadening perspectives in science and engineering, though it is a factor to consider, and data will be collected to further investigate this point during the ongoing research. Additionally, further feedback will be gathered from the participating school and teacher to identify what factors they felt were most important to the successful implementation of Let's do Engineering and any particular pedagogical strategies adopted. Another factor is that the delivery of the intervention was undertaken independently from the researchers, with no observation of how the activities were presented and delivered; it would be useful to have more control over this aspect, particularly if extending the study and comparing the effects across a range of different schools. However, one advantage of this approach is that it indicates that the intervention works well for independent application by teachers and does not require specific staff to deliver.

Third, the suitability of the job card methodology has not been validated, and the selection of images could benefit from further review with possibilities to remove examples that were not recognized by any children and explore whether the scientist and mechanic images could be tweaked to further differentiate them from engineering. Additionally, this study used gender neutral illustrations, and it is unclear whether this could have influenced children's ideas, although they did not use gendered pronouns in their discussions. Stick people are often perceived as male (stick men), and while the people in illustrations are more rounded, this conception of an apparently gender-neutral figure as male could still persist. In fact, since this study we have developed two sets of cards, one male/gender-neutral and one female (depicted by the use of a pony-tail) and ongoing studies will explore whether the use of the different sets of cards impacts results. Finally, while it is positive that the effects of Let's do Engineering on broadened engineering perspectives persisted over the summer holiday period, it is unknown how long such effects might remain and whether long-term follow-up would confirm any lasting impact.

Overall, this study has demonstrated that Let's do Engineering has successfully broadened the perspectives of 5 and 6-year-old school children in terms of understanding the variety of job roles that make up engineering. Furthermore, the job card methodology developed here is useful to both gather data on understanding engineering perceptions with children as young as 5 years and measure the success of interventions designed to tackle misconceptions and stereotypes about engineering. We suggest this methodology be taken up by others as a straight-forward way to rapidly gather data on engineering perceptions with young children. Future studies will concentrate on validation of the method and application to a wider cohort of children.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Heriot-Watt University Engineering and Physical Sciences Ethics Committee. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not obtained from the participants or the participants' legal guardians/next of kin and teachers conducted the study and data was passed to us as child number, gender and results. There was no interaction between the researchers and the children and no way to identify the children. Teachers explained the purpose of the study and received verbal assent from the children to participate.

Author contributions

HB: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. GR: Conceptualization, Formal analysis, Methodology, Writing – review & editing.

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Conflict of interest

Let's do Engineering is in the process of being spun out from the university as a business, providing activities and resources to schools and nurseries.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

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References

Archer, L., Moote, J., Macleod, E., Francis, B., and DeWitt, J., (2020)."*Aspires 2: young People's science and career aspirations age 10 -19*" In London: UCL. Institute of Education,

Armitage, L., Bourne, B., Di Simone, J., Jones, A., and Neave, S.Engineering UK (2020). *Educational pathways into engineeringet*:2020.

Ata-Aktürk, A., and Demircan, H. O. (2022). Engineers and engineering through the eyes of preschoolers: a phenomenographic study of children's drawings. *Eur. Early Child. Educ. Res. J.* 30, 495–514. doi: 10.1080/1350293X.2021.1974067

Capobianco, B., Diefes-dux, H., Mena, I., and Weller, J. (2011). What is an engineer? Implications of elementary school student conceptions for engineering education. *J. Eng. Educ.* 100, 304–328. doi: 10.1002/j.2168-9830.2011.tb00015.x

Chambers, N., Rehill, J, Kashefpakdel, E.T., and Percy, C. (2018), *Drawing the future*, London, UK: Education and Employers

Cunningham, C., Lachapelle, C., and Lindgren-Streicher, A. Assessing elementary school students' conceptions of Engineering and technology. In Proceedings of the 2005 annual conference proceedings, Portland, Oregon, 12–15 (2005).

Emembolu, I., Padwick, A., Shimwell, J., Sanderson, J., Davenport, C., and Strachan, R. (2020). Using action research to design and evaluate sustained and inclusive engagement to improve children's knowledge and perception of STEM careers. *Int. J. Sci. Educ.* 42, 764–782. doi: 10.1080/09500693.2020.1729442

EngineeringUK. (2022). *Women in Engineering: Trends in women in the engineering workforce between 2010 and 2021*

Gottfredson, L. (1981). Circumscription and compromise: a developmental theory of occupational aspirations. *J. Couns. Psychol.* 28, 545–579. doi: 10.1037/0022-0167.28.6.545

Hammack, R., Utley, J., Ivey, T., and High, K. (2020). Elementary teachers' mental images of engineers at work. *J. Pre-Coll. Eng. Educ. Res.* 10:3. doi: 10.7771/2157-9288.1255

Higgins, S., and Simpson, A. (2011). Visible learning: a synthesis of over 800 Meta-analyses relating to achievement. By John A.C. Hattie. *Br. J. Educ. Stud.* 59, 197–201. doi: 10.1080/00071005.2011.584660

Knight, M., and Cunningham, C. (2004), Draw an engineer: development of a tool to investigate students' ideas about engineers and Engineering paper presented at 2004 annual conference, Salt Lake City, Utah.

Kraft, M. A. (2020). Interpreting effect sizes of education interventions. *Educ. Res.* 49, 241–253. doi: 10.3102/0013189X20912798

Lampley, S. A., Dyess, S. R., Benfield, M. P. J., Davis, A. M., Gholston, S. E., Dillihunt, M. L., et al. (2022). Understanding the conceptions of Engineering in early elementary students. *Educ. Sci.* 12:43. doi: 10.3390/educsci12010043

Let's Do Engineering Ltd. www.letsdoengineering.com

LMI. www.lmiforall.org.uk

Master, A. (2021). Gender stereotypes influence Children's STEM motivation. *Child Dev. Perspect.* 15, 203–210. doi: 10.1111/cdep.12424

McGuire, L., Mulvey, K. L., Goff, E., Irvin, M. J., Winterbottom, M., Fields, G. E., et al. (2020). STEM gender stereotypes from early childhood through adolescence at informal science centers. *J. Appl. Dev. Psychol.* 67:101109. doi: 10.1016/j.appdev.2020.101109

McMahon, M., and Watson, M. (2022). Career development learning in childhood: a critical analysis. *Br. J. Guid. Couns.* 50, 345–350. doi: 10.1080/03069885.2022.2062701

Mulvey, K. L., and Irvin, M. J. (2018). Judgments and reasoning about exclusion from counter-stereotypic STEM career choices in early childhood. *Early Child. Res. Q.* 44, 220–230. doi: 10.1016/j.ecresq.2018.03.016

NUSTEM. Slide 8: https://nustem.uk/wp/wp-content/uploads/2022/06/Using-the-Primary-Careers-Tool.pdf

Padwick, A., Davenport, C., and Strachan, R. (2022). Elimination before imagination: how children's early understanding of scientists may limit aspirations for broader STEM careers. *IEEE Front. Educ. Conf.* 2022, 1–9. doi: 10.1109/FIE56618.2022.9962614

Padwick, A., Dele-Ajayi, O., Davenport, C., and Strachan, R. (2016). "Innovative methods for evaluating the science capital of young children," in *Frontiers in education conference (FIE), 2016 IEEE.* IEEE.

Perkin report, (2019), *Engineering skills for the future, Royal Academy of Engineering.* Available at:www.raeng.org.uk/perkins2019

Rodrigues-Silva, J., and Alsina, Á. (2023). Systematic review about students' conceptions of Engineering accessed through drawings: implications to STEAM education. *Int. J. Cogn. Res. Sci. Eng. Educ.* 11, 199–211. doi: 10.23947/2334-8496-2023-11-2-199-211

Shimwell, J., DeWitt, J., Davenport, C., Padwick, A., Sanderson, J., and Strachan, R. (2023). Scientist of the week: evaluating effects of a teacher-led STEM intervention to reduce stereotypical views of scientists in young children. *Res. Sci. Technol. Educ.* 41, 423–443. doi: 10.1080/02635143.2021.1941840

Xu, T., and Jack, L. (2023). Engineers in young Children's minds: an exploratory case study of young Children's drawings and narratives. *Early Childhood Educ. J.* 52, 435–442. doi: 10.1007/s10643-023-01442-6