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An Investigation of Children's, Parents' and Teachers' Perceptions of Engineers and Engineering

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ABSTRACT

CONTEXT

Historic and recent trends indicate that there is a decline in the number of Australian students pursuing engineering careers, with this field also suffering from a lack of gender and ethnic diversity. One explanation revolves around perceptions of engineers and engineering, which are "extremely powerful and influential in human thought and behaviour" (Given, 2008).

PURPOSE OR GOAL

The aim is to develop a richer, more holistic understanding of children's, parents' and teachers' perceptions of engineers and engineering, to better inform the engagement of students in STEM subjects and ultimately, a career in engineering. This paper reports on the pilot investigation of perceptions. Findings from the main study will inform an intervention, to ascertain whether perceptions can be changed.

APPROACH OR METHODOLOGY/METHODS

Underpinned by the Social Cognitive Theory, this research will follow a sequential explanatory mixed methods approach, where a large-scale, cross-sectional study will be implemented, in which data will be collected via self-completion questionnaires followed by semi-structured interviews.

ACTUAL OR ANTICIPATED OUTCOMES

This paper reports on the results from the pilot study, in which a sample of 42 children's and parents' perceptions reported a significant level of familiarity with engineering, perhaps due to sampling bias of parents that happened to have STEM backgrounds. Most of the parents encouraged participation in STEM subjects and communicate mostly accurate information about the Engineering profession to their children, potentially impacting children's self-interests, abilities and positive perceptions of engineers and engineering. Despite these reasons, misconceptions around the Engineering profession still existed.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

The pilot study demonstrates that further studies with children, parents and teachers from more diverse backgrounds and demographics of schools need to be performed, as the collected sample is currently biased towards STEM literate parents and children.

KEYWORDS

Perceptions, Diversity, Engineers, Primary School, Parents

Introduction: Situating the Research

The Australian Engineering Landscape – Study and Employment

Engineers contribute value through creatively applying the principles of science, technology and mathematics to solve global problems, meet societal needs and enhance quality of life.

Alarmingly, commencements in Australian domestic undergraduate and postgraduate engineering courses have declined (slight increase in undergraduate commencements during recent years), also exhibiting a highly skewed sex ratio, with 18% of females commencing engineering studies (Kaspura, 2020). In addition to the lack of gender diversity, Australia's heavy reliance on permanent and temporary skilled migration programs to ameliorate such effects, has generated a lack of ethnic diversity (ibid). Countries which contribute the highest number of engineering graduates per year include China, India, Russia, The United States and Iran (Mackay, 2016).

Barriers to the uptake of school STEM (Science, Technology, Engineering, Mathematics) subjects, which underpin entry into tertiary engineering courses, have been highlighted extensively throughout the literature, with dominating themes such as negative imagery, perception of difficulty, low socioeconomic status, unclear career pathway, uninspiring teaching methods and a lack of encouragement from parents and teachers (Ge & Li, 2017). In the past, literature suggests a highly gendered perception of STEM capabilities between males and females, pointing to potential reasons such as gender stereotypes and stereotype threat, life goal preferences, workplace climate and learning styles (Bible & Hill, 2007; Shih et al., 1999; Spencer et al., 1999; Van Loo & Rydell, 2013). This has negatively influenced female participation in school STEM subjects, a gateway into tertiary engineering courses.

The STEM community is making progress in many areas, such as the implementation of this knowledge towards intervention programs, to improve participation in STEM study and employment. However, a lack of lasting engagement, especially in engineering, remains prevalent within Australia. One factor, absent in the current landscape of work conducted within this area, revolves around individuals' perceptions of engineering specifically.

What are Perceptions?

Given (2008, p. 607) characterises perception as "apprehending reality and experience through the senses, thus enabling discernment of figure, form, language, behaviour, and action." She proposes that perception is analogous to a set of lenses through which an individual views the world. "These lenses evolve from perspectives of location, subjectivity, particularity, history, embodiment, contradiction, and the web of teachings imparted to the individual." (ibid). Often, this interpretation of the world can be substantially different from objective reality and becomes one's truth. Hence "perceptions are extremely powerful and influential in human thought and behaviour" (ibid).

Children's Career Aspirations

Preschool aged children (as early as age 3) can cluster information to develop rudimentary perceptions of categories of work (Lutz & Keil, 2002). This is evident in their early encounters of the question "what do you want to be when you grow up?" Seldom do we hear children specifying an interest in becoming an engineer, let alone a particular engineering discipline. Such career decisions are often determined before children reach middle school, rendering the primary years highly critical in terms of shaping perceptions towards particular subjects and careers (Wyss, Heulskamp & Siebert, 2012). These perceptions do not develop in a psychological vacuum, but are cultivated under the guidance of various contextual factors, such as parental, institutional and societal influences (Wang & Degol, 2017). We next examine children's, parents' and teachers' perceptions of engineers and engineering within the literature.

Perceptions of Engineers and Engineering

The perception of the general public, engineering students and novice engineers is that solitary technical work dominates engineering practice, one of the most deeply embedded misconceptions. There are similar perceptions among children, parents and teachers:

Perceptions about Engineers as Individuals

- Engineers are male, 'geeks' and 'nerds', exhibiting physical traits such as glasses, lab coats or pale skin (Hirsch et al., 2014; Leeker et al., 2017; Rivale et al., 2011).
- Engineers are exceptional at science, technology and mathematics but lack many social skills, particularly in communication, teamwork, organisation and leadership (Bazylak et al., 2016, 2017).

Perception about Engineering as a Profession

- Study in engineering is based solely on facts and is irrelevant to the real world (Fredericks et al., 2004; Mena et al., 2009; Myers, 2010).
- The engineering occupation primarily involves physical labour e.g. working in construction and automotive industries, driving trains, operating machines and computers, carried out by solo males (Capobianco et al., 2011, 2017; Chou & Chen, 2017; Newley et al., 2017; Reeping & Reid, 2014; Symons et al., 2015).
- The engineering occupation is generally associated with electrical, mechanical and civil engineering disciplines (Mena et al., 2009; Trenor et al., 2009).
- The engineering occupation does not provide opportunities to make social impacts (Graziano et al., 2011).
- The engineering workplace climate tolerates a poor work-life balance and workplace discrimination (Calnan & Valiquette, 2010; Settles et al., 2012).

Engineering is not usually perceived as a team activity, which may alienate people from considering it as a career choice. However, research indicates that many engineers estimate the actual time spent on solitary technical work (designing, coding, calculating, modelling) is around 10% of working time, with the rest spent on important social interactions of technical nature required to achieve and operationalise solutions (Trevelyan, 2014).

Research suggests that many young students who possess traits highly desirable in engineering such as creativity, curiosity and strong social skills, often do not know enough about the profession. Similarly, parents and teachers, who are their main sources of information, do not know enough about engineering to provide accurate career guidance. It is to be noted that this literature review about perceptions, which shift quickly, may be outdated. Recent work around children's, parents' and teachers' perceptions of engineers and engineering are very limited, substantiating the need for such a study, described below.

Research Aims, Contributions and Implications

The aim of this study is to investigate children's, parents' and teachers' perceptions about engineers and engineering. The overarching research question that will address this aim is: **How do upper primary children (Years 4-6/Ages 9-12), their parents and their teachers perceive engineers and engineering as a discipline and as an occupation, in an Australian (Victorian) context?** Three tiers of research will be conducted (1. Pilot Study, 2. Main Study, 3. Intervention). This paper reports on the pilot investigation of perceptions. Findings from the main study will inform an intervention, to ascertain whether perceptions can be broadened or influenced.

The outcomes of the research may inform approaches to diversity and attraction of more people who are suited to the job, based on the true representation and perception of what engineers do, rather than false or misleading perceptions, helping both potential students and the profession to have the right people. Trevelyan's (2014) definition of engineering will be used as a reference point: "Expert performance in engineering practice, in its essence,

requires a combination of technical and financial foresight and planning as well as the technical collaboration performances required to convert plans into reality." It is of benefit to both prospective engineering students and the profession to match up students' interests and strengths to a true representation of what engineers do in their daily activities.

This work can be used to improve engineering-focused educational activities including:

- Careful selection and design of outreach activities
- Recommendations into marketing and communications
- Creating a network of university student mentors, who are more informed about perceptions and can work more successfully in their interactions with schools
- Introducing accurate portrayals of engineering into primary school curriculum

Preliminary and Proposed Research

Theoretical Framework

Social Cognitive Theory (SCT) is used extensively throughout many areas of human functioning, for example in motivation, learning, achievement and career choice, and will inform the theoretical lens for this study (Bandura, 1986). SCT posits that personal factors, the social environment and behaviour influence each other (ibid). Parents, teachers, peers and the media, form the social environment, providing examples of behaviour for children to observe and imitate. Coupled with personal factors, such as behavioural capability, attentiveness, motivation, ability to retain and reproduce information, internal/intrinsic reinforcement, personal expectations and self-efficacy, this influences how children acquire and maintain behaviour, in particular, certain perceptions about engineers and engineering.

Methodology/Method

This research follows a 'sequential explanatory mixed method' design, in which a large-scale, cross-sectional study is currently being implemented with upper primary children (chosen due to the gap in literature and their ability to read, write and understand) and their social environment of parents and teachers. This paper reports on the pilot study, which validates survey and interview questions for the main study, from which an intervention will be introduced to ascertain whether perceptions can be changed. Online data collection via self-completion questionnaires (Qualtrics), followed by semi-structured interviews (Zoom), gains a broader view of the research landscape, with both breadth and depth. An established instrument, licensed from the Institution of Engineering and Technology (IET), has been modified to reflect findings from the literature and Australian context. The structure of the questionnaire includes a combination of 7-point Likert scale, open-ended, ranking, multiple and single selection options. Factual material showcasing a variety of engineering careers is displayed mid-survey, with follow up questions to investigate the effect on participants' perceptions of engineering. Participants are recruited from Government, independent and Catholic schools across Victoria, primarily (but not limited to) via a top-down approach, starting from school leadership to teachers, who distribute the questionnaire to parents via email and school newsletters. Participants who wish to participate in a follow-up interview are contacted via an email address voluntarily provided in their questionnaire. Participants complete the questionnaire and interviews separately. Additionally, the potential interplay between children, parents and teachers is studied via linking of surveys and interviews. This research has been approved by Monash University Human Research Ethics Committee (MUHREC, Project ID 27301), Melbourne Archdiocese Catholic Schools (MACS, Project ID 1089) and the Department of Education and Training (DET, Project ID 2021_004390).

Pilot participants comprise of 21 children (approximately equal gender distribution and mostly in Year 4) and 21 parents (71.4% female) from 6 co-educational schools (4 Catholic, 1 Government and 1 Independent) across the Victorian metropolitan regions. Parents education levels are as follows: 52.4% - Bachelor, 23.8% - Master, 14.3% - Doctorate, 4.8% -

TAFE, 4.8% - secondary school). Their primary occupation was in STEM (81% of parents were engineers, had spouses, family members and other connections who were engineers).

Results and Discussion

Children's and Parents' Knowledge about Engineers as Individuals

Whilst negative imagery is still frequently highlighted in the literature, as a cause for the lack of participation in engineering study and employment, as illustrated in Figure 1, no parents and a minority of boys and girls surveyed supported such claims in our sample. Children cited "creative", "problem solver" and "have social skills", as the top 3 attributes of engineers. Similarly, parents mentioned "problem solver", followed by "good at mathematics" and "logical", as key descriptors. This could be the result of sampling bias in a small sample, or it could indicate a difference in the views of the culture. Interestingly, only 33.3% of fathers and mothers supported the notion that engineers "have social skills". This result correlates favourably with the findings of Bazylak et al. (2016, 2017), in which engineers are portrayed to lack many social skills, particularly in communication, teamwork, organisation and leadership. Although these perceptions were mostly unmodified by gender, surprisingly, no girls described engineers as male, despite engineering being a male-dominated industry.

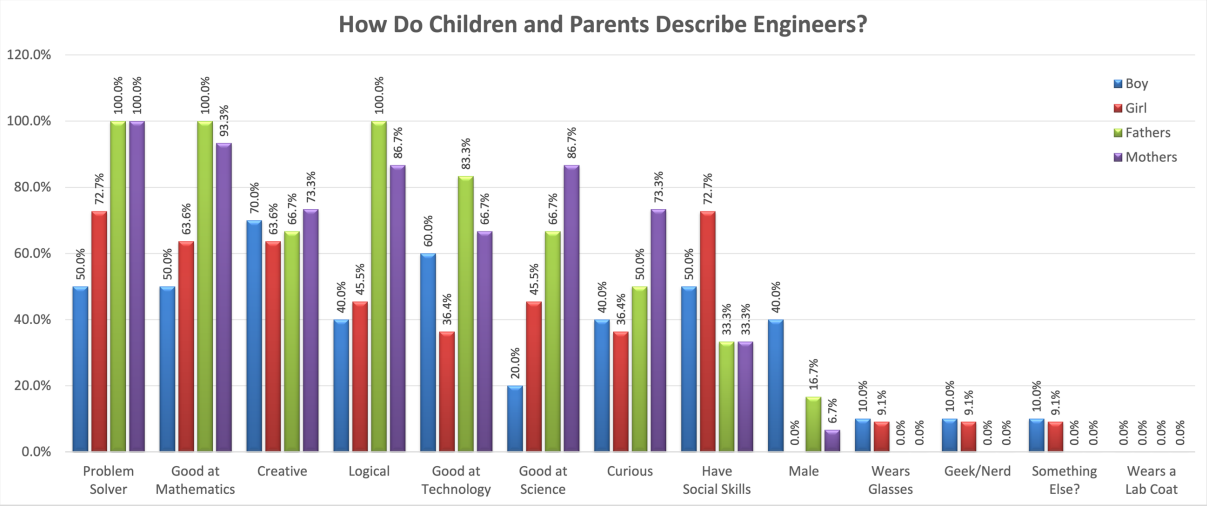

Figure 1: Children's and Parents' Descriptions of Engineers as Individuals

Children's and Parents' Knowledge about Engineering as a Profession

Figure 2 indicates pilot results for children's and parents' understanding about engineering work. Interestingly, children and parents perceived "build/construct things", "design things", "work in groups" and "test things" as the top 4 characteristics of engineering work, with mostly insignificant variations in gender. Unsurprisingly, 30% of boys and 90.9% of girls associated engineering with fixing things, particularly cars and computers, corroborating previous findings in the literature. A greater proportion of parents (66.7% of fathers and 80% of mothers) compared to children (40% of boys and 45.5% of girls) considered engineers to "invent new things". "Drive trains" was the least popular selection, supported by only 9.1% of girls and unexpectedly, 16.7% and 13.3% of fathers and mothers, correspondingly, perhaps due to differences in language as train drivers tend to be referred to 'train drivers' rather than 'engineers' in Australia. Some of these results are contrary to the early literature around diversity in engineering being unapparent, especially by children, 61.9% of children were aware of the more 'traditional' branches of engineering, correlating the disciplines of aerospace, agricultural, civil, chemical, electrical and mechanical as the crux of engineering. Parents also demonstrated a more progressive understanding, familiar with biomedical, environmental, industrial, information technology, marine and mining engineering.

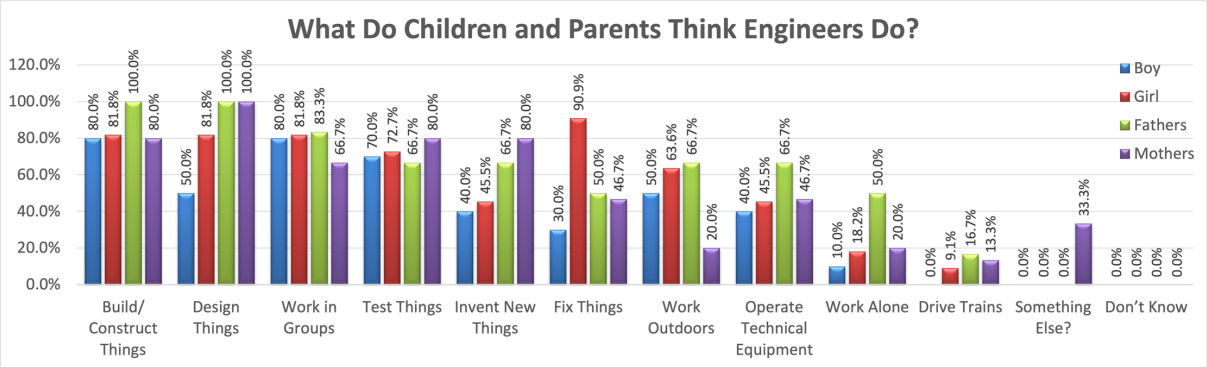

Figure 2: Children's and Parents' Understanding about Engineering as a Profession

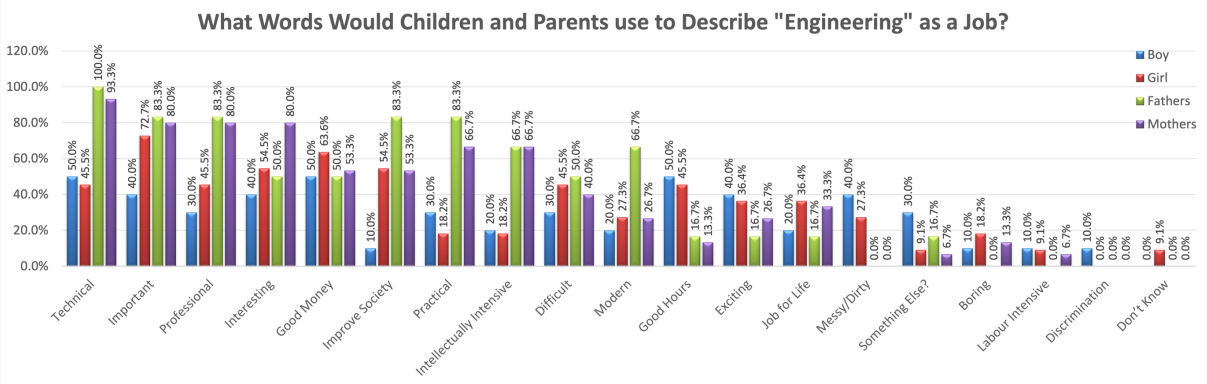

Figure 3: Children's and Parents' Descriptions of Engineering as a Profession

Figure 3 shows children's and parents' descriptions of engineering work, with "important" and "technical" as dominant descriptors. Remarkably, 72.7% of girls regarded engineering to be "important" in comparison with only 40% of boys. Children perceived engineering to generate "good money" to a greater extent than parents, citing this as their top preference, in conjunction with "good hours", "exciting" and "messy/dirty". Conversely, parents embraced more sophisticated views, deeming engineering to be "professional", "practical", "intellectually intensive" and "improve society". These results are in accordance with those of Fredericks et al. (2004), in which participants conveyed engineering to be a practical, highly interesting and financially rewarding career. Notably, mothers believed engineering to be most interesting, with 80% in favour, in comparison with only 50%, 54.5% and 40% of fathers, girls and boys.

Engineering is perceived as a predominately 'thing-oriented' career, involving mastery of technical skills, having no tangible relation to society with unapparent opportunities to make social impacts (Fredericks et al., 2004; Mena et al., 2009; Myers, 2010). Women embrace person-oriented cultures, with an inborn disposition for 'caring' or 'humanities' roles (Bible & Hill, 2007; Johnson et al., 2013; Shih et al., 1999; Spencer et al., 1999; Van Loo & Rydell, 2013). Unexpectedly, more girls than boys considered engineering to "improve society" (54.5% vs. 10%), in contrast with more fathers than mothers (83.3% vs. 53.3%). Engineering being seen as "modern" resonated most with fathers at 66.6%. Surprisingly, 26.7%, 20% and 27.3% of mothers, boys and girls, respectively, viewed engineering as "modern", despite being instrumental in the technological development that has helped shape modern society (Centre for Economics and Business Research, 2016).

Children's Favourite School Subjects

The Australian education system does not introduce engineering at primary and secondary levels. However, science, technologies (design and technologies, digital technologies) and mathematics, which underlie engineering principles, are currently offered. Enjoyment peaked in these subjects, however, with a lower proportion of girls in agreement (figure not shown). Positive and negative descriptors such as "fun to learn", "interesting", "imaginative",

"challenging" and "boring" makes an interesting juxtaposition of children's justifications. Expectedly, most children failed to articulate the importance and relevance of STEM subjects to everyday life, an exception being: *"What I enjoy about all of these subjects are that these are the principal tools and skills that we need to design and create our future and our understanding of how this universe works. Also these are the keys on solving mysteries and using the knowledge of our current understanding to advance human civilisation."* This corroborates findings from the literature, in which complex scientific and mathematical calculations are seen as having no tangible relation to society (Myers, 2010). Enjoyment of STEM subjects by the majority is promising for boosting technical confidence and strengthening children's interest in and positive attitudes towards engineering careers.

Integration of Engineering into Primary School Curriculum

Parents showed great interest in the infusion of engineering into primary school curriculum, with 78.3% in support, articulating an opportunity to introduce children to engineering and its relevance to society from an early age. Barriers around difficulty can be broken down, embedding positive attitudes around STEM subjects in children's psyche, which may be passports to stimulating, diverse and lucrative engineering careers. It *"provides a unique opportunity and taps into a mindset that is currently left lingering or well underdeveloped at the primary school level".* These views differ from parents in Hsu et al. (2011) and Bagiati's (2011) research, in which parents indicated disinterest in integrating engineering into K-12 curriculum, justifying their responses due to the young age of their children and its appropriateness at the tertiary level.

Engineering Intervention Strategies

As indicated in Figure 4, children mentioned "visits to school from real engineers", "more practical activities in school – games, making things etc.", "school trips – to see what engineers really do", "more visits to schools from young engineers" and "open days – to see what happens behind the scenes" as the top 5 ways to support positive perceptions about engineering careers, with a higher proportion of girls in favour.

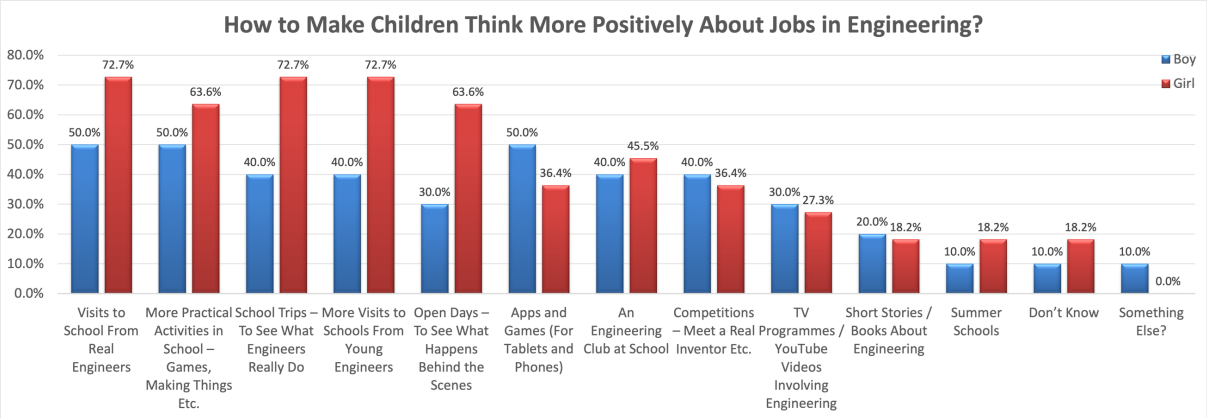

Figure 4: Engineering Intervention Strategies

Results are in accordance with those of parents (figure not shown), who furthermore expressed their advocacy for female engineer role models, as seen via this illustrative quote: *"I strongly advocate more female engineer role models as there are not many in women in core engineering area. There is a decline even further at senior leadership level. Girls have to be encouraged right from a young age to follow a career path in engineering and industry engagement is also essential to show the pathway to an engineering career."* Common among these activities is the infusion of real-world experiences into engineering education, which can encourage richness, showcasing the breadth and creativity within the sector, in addition to its relevance. Real-world experiences, 'elementary engineering' and marketing

material as methods to communicate accurate information about engineering, may be valuable to support children and families to make well-informed career decisions.

Conclusion

Parents have been widely recognised as critical early socialisers of their children's academic interests and a source of occupational knowledge (Jacobs & Harvey, 2005; Strutz, 2012; Wankat, 2007; Zhao & Akiba, 2009). Children have been found to exhibit a greater understanding of their parents' occupations compared to other occupations (Seligman et al., 1991) and the phenomenon of occupational inheritance is evident in engineering - children (particularly girls) with parents or family who are engineers often follow in their footsteps (Mannon & Schreuders, 2007). Our pilot study revealed children and parents having some accurate perceptions of engineers and engineering, which contrasts against findings from the outdated literature. Our findings were similar to those reported by The Institution of Engineering and Technology (2019). *"Since 2015, perceptions of engineering and technology have improved, with both children and parents less likely to describe engineering jobs as 'messy and dirty'. Children in 2019 are more likely to describe engineering as 'modern, professional and interesting', while parents are more likely to say that it 'makes a difference'. It's a move in the right direction, but there is still work to be done."* The proportion of parents and children who supported these views were relatively small and parents from our pilot study demonstrated more accurate perceptions, summarised below:

Table 1: Perceptions of Engineering – IET (Blue) vs. Pilot Study (Red)

Description	Parents	Fathers	Mothers	Boys	Boys	Girls	Girls
Modern	21%	66.7%	26.7%	23%	20%	21%	27.3%
Professional	54%	83.3%	80%	35%	30%	37%	45.5%
Interesting	43%	50%	80%	50%	40%	35%	54.5%
Creative	37%	66.7%	73.3%	43%	70%	38%	63.6%
Messy/Dirty	15%	0%	0%	27%	40%	34%	27.3%

Understandably so, due to their higher education and primary occupation being in STEM. Despite these reasons, data from the pilot study show that misconceptions still exist:

- Engineers lack social skills (33.3% of fathers and 33.3% of mothers)
- Engineers do not invent new things (60% of boys and 54.5% of girls)
- Engineering is not important (60% of boys)
- Engineering does not improve society (46.7% of mothers and 90% of boys)
- Engineering is not modern (73.3% of mothers, 80% of boys and 72.7% of girls)

The main study is currently being administered with children, parents and teachers from more diverse types and demographics of schools to gain more widespread insight into this multifaceted problem. Accompanied by results from semi-structured interviews (which were not available at the time of writing), this research will help to gain a more holistic insight of the perceptions held by these groups, so that we may help devise strategies to reinforce a more representative perception of engineers and engineering.

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