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**Girls' engagement in engineering: Influences, independence and interest**


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# GIRLS' ENGAGEMENT IN ENGINEERING: INFLUENCES, INDEPENDENCE AND INTEREST

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## Abstract

*Increasing diversity in engineering, which is a goal of the profession, education and government, starts with increasing the diversity of those choosing to study the discipline. This paper focuses on girls' engagement in engineering. Data is from a survey of girls attending a university open day and interviews with practising female engineers. The notion of "possible selves" is used to explain patterns in their responses. Both prospective and participant groups indicated that family, friends, teachers and societal messages informed and influenced their view of what engineering involved and who could be an engineer. Practising female engineers identified the impact of school subject choices, 'hands-on' and practical home experiences and the nature of the lecturer and peer support. This paper contributes to discussions of when and how to encourage girls into engineering, offering evidence that a comprehensive approach is needed that includes the community, schools and tertiary institutions as well as the profession.*

## Keywords

Career options; engineering; gender; recruitment

## Introduction

It is generally agreed that many of the challenges and opportunities facing society today will benefit from, or even require, input from STEM (science, technology, engineering and mathematics) professionals. However, the future supply of those with STEM-related skills will likely be insufficient for the many and complex challenges we face. There are also concerns about the limited representative diversity of those choosing these fields, including underrepresentation of women, although this does vary from country to country (European Commission, 2015; Organisation for Economic Co-operation and Development (OECD), 2020; Society of Women Engineers (SWE), 2019; United Nations Educational, Scientific and Cultural Organization (UNESCO), 2017; Wang 2019). In New Zealand in 2015, women represented only 16 percent of Engineering New Zealand's membership (IPENZ, 2015). How to attract women into STEM subjects as a way to increase the number of STEM professionals and also reduce the gender imbalance requires an understanding of what influences how female students self-select into STEM fields (Chise et al., 2020). In this paper we focus on factors that prompt or hamper women from choosing to study engineering. As a step towards understanding the reasons for this, we surveyed the views of girls and women who were interested in or participating in engineering qualifications to ascertain their perceptions of influences on their study choices and their STEM-related (or other) career aspirations.

## Establishing a framework

Researchers have used several frameworks to investigate barriers and enablers to women choosing to study engineering, persisting to complete a qualification and moving into the profession. These studies usually include both individual attributes and the socio-cultural-environmental context (Rüschenpöhler & Markic, 2019; Simpson & Bouhafa, 2020). Internal or personal factors typically include gender, self-efficacy in relation to mathematical ability and whether students have a fixed or growth mindset in relation to this and more widely. Levels of academic preparation and achievement, especially in subjects such as mathematics and physics, play a role (Shi, 2018). External or contextual factors range across parental and teacher influences, peer and media influences, and societal norms and stereotypes about the nature of STEM work and its workers (Rüschenpöhler & Markic, 2019; Sarkar et al., 2014; Thébaud

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& Charles, 2018). In the New Zealand context, Fox-Turnbull et al. (2020), Mozahem et al. (2019) and the IPENZ (2015) report have identified a range of barriers to women's participation similar to those above and include lack of career and subject choice guidance that encourages students to pursue maths and/or engineering pathways while at school, lack of promotion of the profession and society's perception of engineers as being masculine.

While identity is commonly used to describe and explain student STEM choices (Lakin et al., 2020; Simpson & Bouhafa, 2020), in this paper we use Markus and Nurius' (1986) Notions of Possible Selves theory to consider the way these factors might come together. The notion of possible selves relates to an "individual's ideas of what they might become, what they would like to become, and what they are afraid of becoming" (p. 954). Markus and Nurius assert that while individuals are free to create any variety of possible selves, "the pool of possible selves derives from the categories made salient by the individual's particular socio-cultural and historical context, from the models, images, and symbols provided by the media, and by the individual's immediate social experiences" (p. 954). That is, possible selves and the strategies that can be used to attain them are sensitive to contextual cues (Bi & Oyserman, 2015). Notably, the possible selves construct "takes account of a person's expectations and the importance of having a clear pathway towards a long-term destination" (Harrison, 2018, p. 1).

The possible selves framework has been used to understand and expand the possible future science/STEM career horizons of middle, secondary and undergraduate students (e.g., Beier et al., 2012; Packard & Nguyen, 2003; Schlegel et al., 2019). Bennett and Male (2017) employed the notion of possible selves in their investigation of second year engineering students' perceptions of their self-efficacy to become an engineer. Their research suggests that even engineering students may have only a limited understanding of the realities of engineering work, and face challenges in relation to their self-efficacy. Papafilippou and Bentley (2017), in their longitudinal study, used the notion of possible selves to trace how four female and three male UK engineering graduates constructed their career identities during the transition from university to work. Overall, these studies indicate that students are likely to need encouragement and support to consider and explore potential future roles that include engineering. The focus in our study was on secondary students and undergraduate students.

## Research design

We were interested in the views of girls and women interested in and participating in engineering qualifications. To understand if and how they viewed being an engineer as a possible self, we adopted an interpretive approach to the research. We gained ethical approval to conduct two anonymous surveys. One survey was of women participants at the 2017 University of Waikato open days. This event is advertised directly to the general public and schools in the region. Girls attending any 2017 Open Day sessions that included a focus on engineering were invited to complete a survey of eight questions aimed to provide information on their reasons and level of interest in pursuing an engineering qualification, the impact attending the session(s) had on their view of the viability of engineering as a career and the challenges they foresaw in studying and working in a traditionally male-dominated field. Respondents were given approximately 10 minutes to fill in the survey. Of the 47 (23% of all females attending the open days) completing the survey, 42 percent were in Year 13 and 58 percent in Year 12, with 60 percent attending co-educational and 40 percent attending single-sex schools.

The second survey involved recipients of the Edna Waddell national scholarship (https://www.universitiesnz.ac.nz/), which are awarded annually to support women entering a four-year professional engineering programme at a New Zealand university. We used a public database to contact 11 women at two universities who had been recipients between 2010 to 2017. Seven agreed to be interviewed. They were aged between 17 and 25 years and ranged from pre-university entry to postgraduate students and were in a range of engineering programmes (chemical, electrical and mechanical). Interviews, conducted face-to-face and via phone/Skype, covered why the scholars had chosen to study engineering, including family and other influences, and barriers they had faced. Suggestions were sought on how to encourage girls to consider engineering as a career. In what follows, we present findings from the survey of school students and from women in engineering/engineering education.

## Findings and discussion

### *School students' views of engineering*

As expected, when surveying girls/women attending an engineering 'promotion' activity, over 80 percent of the 47 survey respondents were interested in pursuing an engineering career (Figure 1), with nearly half having a high level of interest (6–7 on the 7-point Likert scale).

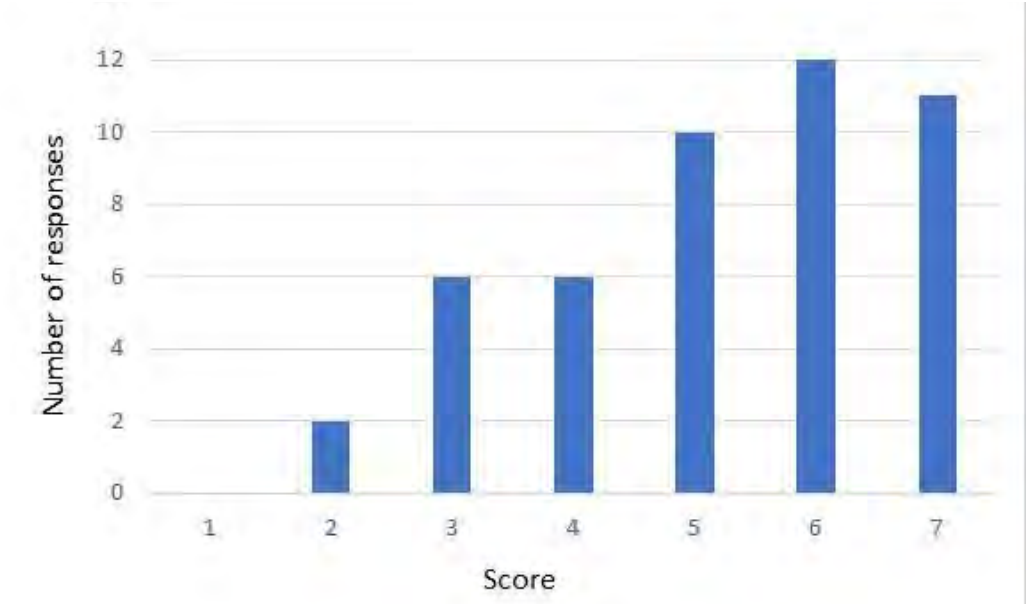


**Figure 1: Current interest in pursuing engineering as a career (7-point scale where 1 = very low and 7 = very high).**

The Year 13 cohort were more certain of deciding on a career in engineering; 60 percent of this cohort indicated a strong interest but only 45 percent of the Year 12 cohort. A higher proportion of the students from single-sex schools (nearly 60% of those surveyed) were strongly interested in engineering as a career than those from coeducational schools (45%), a finding consistent with the New Zealand study by Docherty et al. (2018). This strong interest in engineering as a career had developed in Year 12 students from single-sex schools, where 50 percent were already strongly interested in engineering as a career compared with 40 percent from the same year cohort attending coeducational schools.

Over half (55%) of the participants had sought or received career advice about engineering. People with whom students could be expected to have comparatively close relationships featured father, mother, sibling, family friend, peers (Figure 2). Teachers were also important but interaction with school career advisors was limited, with less than 10 percent of the participants having had any form of engagement about engineering from a careers advisor. Limited input from career advisors has been identified by others (Pugh et al., 2021; Reinhold et al., 2018). There was also a low level of engagement with external engineering organisations and/or the tertiary sector. These findings suggest there is opportunity for the secondary sector to improve student access to quality careers advice and for engineering organisations and the tertiary sector to investigate opportunities for greater interactions.

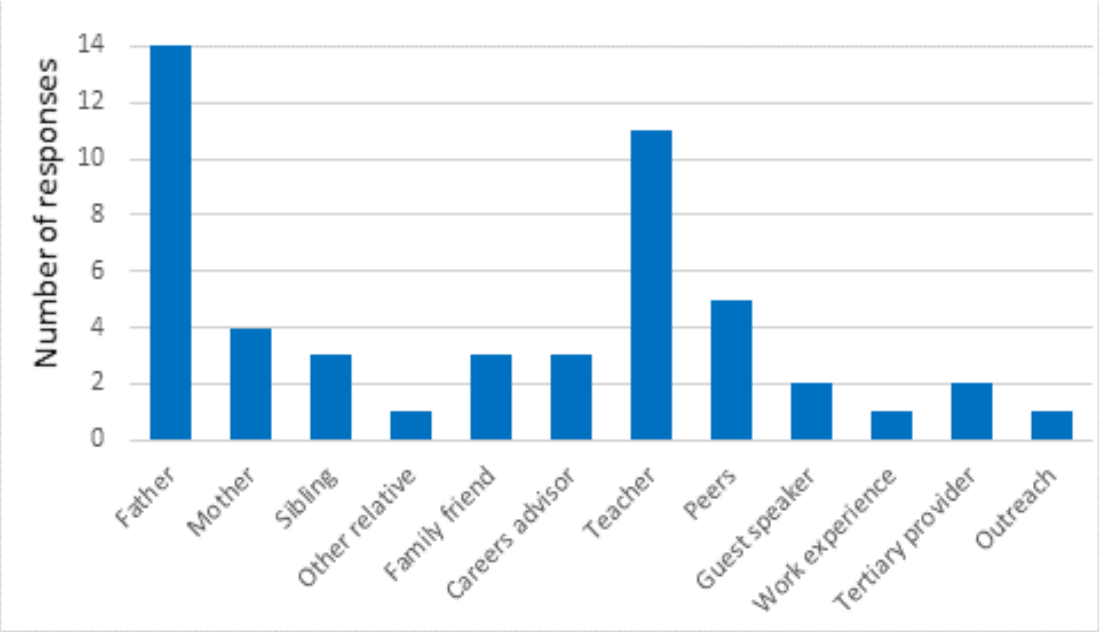


**Figure 2: Sources of advice on an engineering career.**

Engineering education research has emphasised the positive connection between early engineering experiences and quality careers advice, with this being particularly important for women and minority groups (Powell et al., 2012). Over half of the participants in our survey indicated they had engaged in some form of advice about engineering careers before attending the open days, but we did not explore the quality of this advice.

School survey participants had many reasons for considering engineering as a possible career (Figure 3). The major factor (41%) was that they enjoyed or cited a match with a particular subject(s), for example "my ability in maths and physics". The next group of factors was that engineering-related activities are design orientated and enable students to build and create things (17%), and that engineering offered opportunities to problem-solve and engage in interesting, varied and creative work (11%). This focus on opportunities for creative problem solving has been identified by others as supporting women's identification with engineering (Abel-Palmieri, 2014; Lakin et al., 2020). Some participants commented they were encouraged by their parents, "My parents said I would be good at it" or had a family connection with an engineering background (7%). Others credited their teacher with encouraging them to study engineering (6%). Again, research has identified the influence of family members and teachers in shaping orientation to engineering. Factors such as salaries, employability or recruitment activities were acknowledged to a lesser extent. Although the role engineering plays in helping society is often referenced in the literature as a reason women select engineering (Garibay, 2015; Lakin et al., 2020), the respondents did not contribute this as a reason.

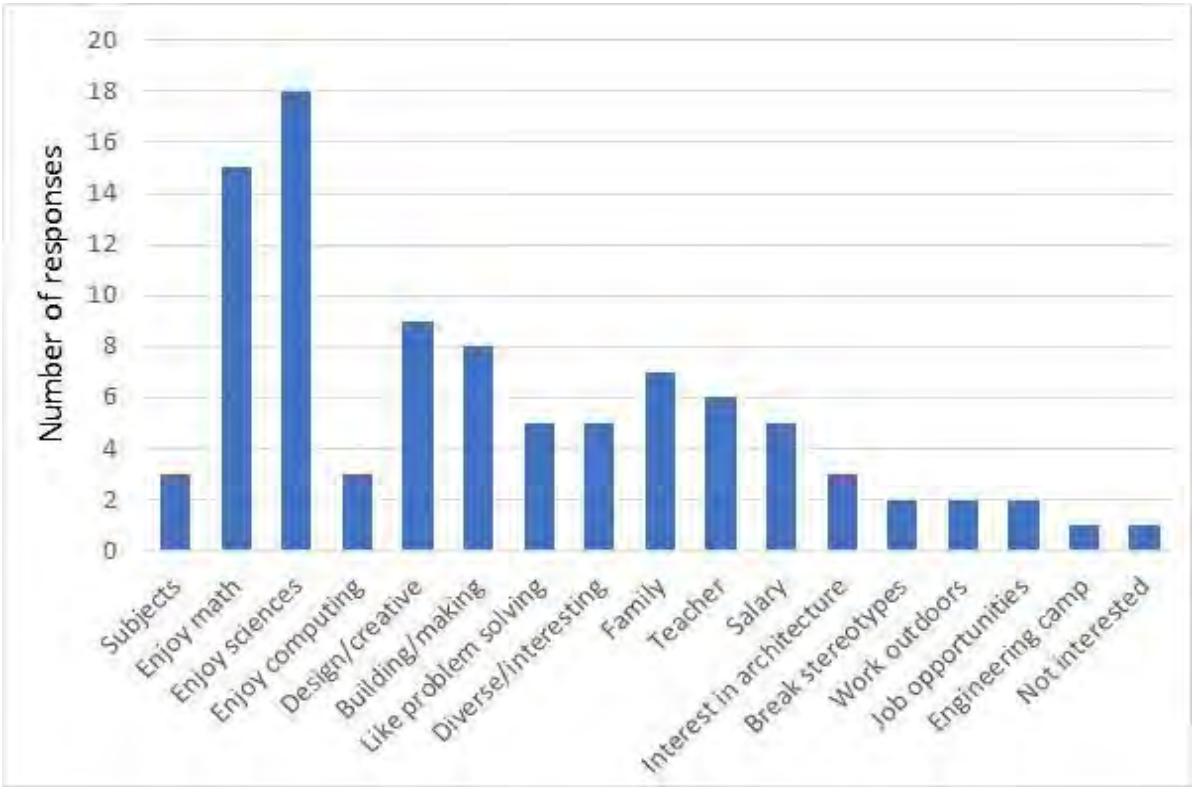


**Figure 3: Reasons for engineering being an interesting career.**

Respondents also gave many reasons why women may find engineering unattractive (Figure 4), with the well-documented problem of societal norms around gender roles and sexism cited around a quarter of respondents (26%). The following comment illustrates this sentiment: "Men don't believe women can do this stuff and therefore put them down or talk to them as if they are stupid." Participants also described engineering as being a "male dominated" job (14%). Eleven percent also felt insufficient information, poor marketing and advocacy were contributing factors. On the other hand, one participant inferred the negative connotations had spurred her decision to enter engineering: "[W]omen tend to not have the confidence to 'stick it to the man', I think otherwise."

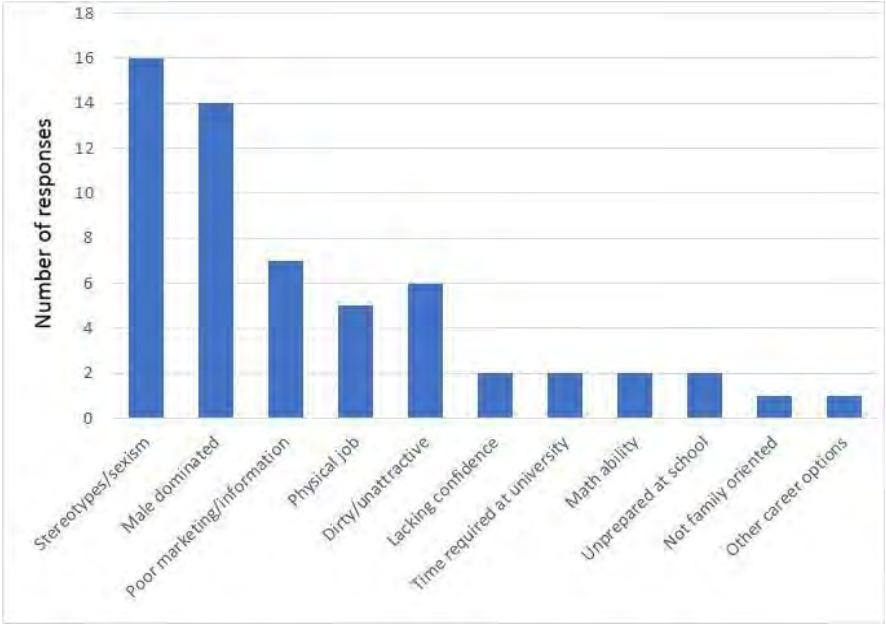


**Figure 4: Reasons engineering is not an attractive career for women.**

The final survey question asked for ideas on how to improve engagement, counteract engineering being viewed as unattractive, and hence recruit women students into engineering. Interestingly, while there is a growing literature attempting to address these issues, this question had the largest number (21%) of nil responses (Figure 5), so interpretation of the results is limited. Suggestions included investing in gender tailored activities (20%), improving communication and marketing (19%) and introducing engineering-type courses into the school curriculum (13%).

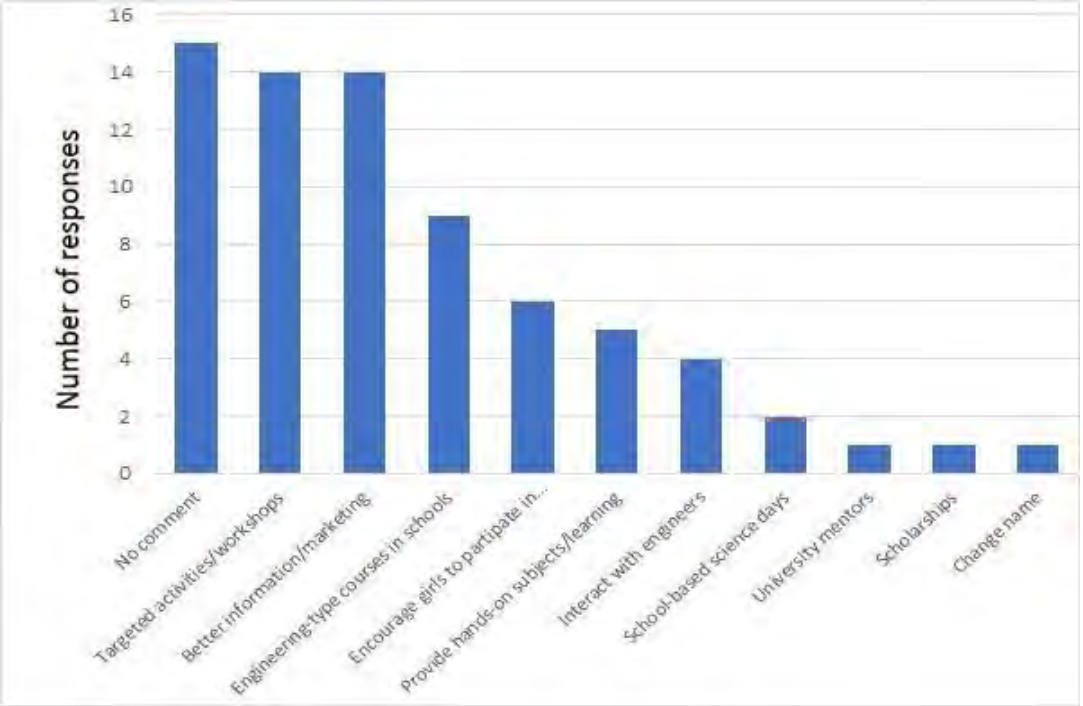


**Figure 5: Activities to encourage girls to consider an engineering career.**

## *Scholarship holder views of engineering*

Responses from the seven scholarship recipients indicated they had all taken STEM-based subjects at school, were confident about their abilities and/or enjoyed these subjects, were academically able and had committed to an engineering programme. One stated, "I've always really enjoyed chemistry, calculus, and physics ... I thought if I enjoyed these, I'm sure to enjoy engineering" (SE1, 2017). All repeatedly asserted engineering allows them to use their problem-solving skills and challenges them to apply theoretical learning, saying, "[I] like logic and being practical" (SE3, 2017), and "All the different things you get to learn and the problems you get to solve" (SE1, 2017). Participants were proud of doing and completing an engineering degree and highly motivated to succeed (Lehr et al., 2014). They reported high levels of self-efficacy and confidence in taking a difficult subject. They considered their career aspirations matched their personal life expectations (Grays, 2013) with one participant explaining, "I've always studied hard and stuff like that, but I guess I have confidence in myself because if I have confidence in myself. I think I can pretty much do anything" (SE1, 2017).

All scholars were attracted to engineering because of the opportunities for creativity, innovation and collaboration, including the possibility of making things work or be better. One stated, "You are working in a team and that you are doing something that is innovative that hasn't been done before" (SE4, 2017), and another said, "I also liked how the field of engineering meant in some way you could give back to the community" (SE6, 2017). Interestingly, the 266 undergraduate respondents in Lakin and colleagues' (2020) study, of whom 75 percent were male, held altruistic professional goals suggesting this aspect and its alignment with student value is worth further investigation. The Edna Waddell scholars considered they were working towards/having a career with status, financial stability and diverse pathways within and beyond engineering because "I felt engineering was or is a respected [sic] and again I felt this would keep doors open" (SE6, 2017), and "I liked [engineering] because it's transferable, it's something that is well recognized, and you can go to lots of different places" (SE5,

2017). Two participants thought engineering would allow a better work-family balance (see also Corbett & Hill, 2015).

All scholars had some form of engineering connection, e.g., parent, siblings, family friend or acquaintance. One said, "[My brother] studied electronic engineering … and also my cousin who is two years older than me, he is studying the same degree I will be studying … so like I've had a lot of support from them" (SE3, 2017). All students considered their parents were supportive of their aspiration to be an engineer, as indicated by one scholar, who commented, "[My parents] took a lot of personal time out to help me with that—that was obviously encouraging" (SE6, 2017). They considered that limited parental support and understanding could be an impediment for other girls because "I think that their parents probably don't know what engineering is about and they think their son or daughter being a doctor would be much better for them" (SE1, 2017). As noted by Lehr et al. (2014), many participants said their fathers played a large role in supporting their degree selection, with one saying, "When I was trying to decide what kind of engineering I wanted to do, [Dad] used his contacts in the business world" (SE6, 2017). Teachers were also cited as being influential, as demonstrated when one participant reflected, "I remember my physics teacher has been amazing" (SE1, 2017).

Consistent with other research (e.g., Sakar et al., 2014), our participants identified limited careers advice as a barrier in their decision-making. For example, one explained, "Engineering wasn't pushed at my school. I was the only one … some of my teachers were surprised I wanted to go into a male dominated career" (SE5, 2017). All scholars had independently researched engineering careers. They reflected that even for them their limited knowledge about engineering and lack of familiarity with the roles of engineers meant ill-defined stereotypes, misconceptions and negative imagery remained influential. This was exemplified by the participant, who stated, "For me, I have still got that perception of computing, software and electrical being male dominated even though I'm in engineering myself. That's probably a stereotypical view of it" (SE6, 2017*)*. Scholars indicated these stereotypes were influential from an early age because "I think when we are brought up as kids, we are sort of socialised differently. It's sort of all these stereotypes like boys fixing things and that and girls are like taking care of other people" (SE7, 2017). This participant also noted that feeling that one does not have the necessary pre-engineering skills can create restrictions but noted this was not only an issue for girls. They elaborated:

> I didn't, you know, fiddle around with electronics in my spare time—I really started off on the back foot. And yeah, guys are like this as well—as not all guys who do engineering do that. So, it's just not a problem with females, but I personally felt that that was my disadvantage and I never really caught up with that. (SE7, 2017)

There was agreement that the breaking down of stereotypes and correction of misconceptions and misrepresentations of engineering needs to occur early. Participants indicated, "I think getting people to talk to … not only high schoolers but you know young high schoolers—introduce this option Year 7 and 8 and not just the final year of school" (SE5, 2017), and "Making engineering specific to class work would be good" (SE6, 2017). Research supports our participants' view that early exposure to STEM experiences is important (Broadley, 2015), increases the likelihood women will pursue STEM-related studies (Hirsh et al., 2017), and that access to careers advisors who are knowledgeable about the breadth of engineering choices is essential (Sakar et al., 2014).

The scholars in our study considered universities could usefully provide resources and professional development workshops to expand understanding of the work of engineers, saying, "I think the tertiary sector needs to see it as a priority and make a commitment that they want to help make this change and come up with an action plan and research this well … but isolating girls wouldn't help" (SE4, 2017). For those involved in the study of engineering they recommended workshops that would help prepare them for difficult encounters and transitions because "trying to learn how to be a female in a male dominated career so making sure you're not seen as passive. It's something I need to get to grips with" (SE6, 2017). They emphasised the value of relationships with groups such as Women in Engineering, Engineering without Borders and internships, and advocated having more explicit linkages of this kind. Grays (2013) suggested that universities need to encourage faculty members to interact with female undergraduates outside the classroom, as this helps improve retention and student engagement. In line with this, one participant made a plea for the university/lecturers to reach out and talk with students (SE4, 2017). Several scholars recognised the value of mentoring and access to role models from a

breadth of engineering fields because "making sure there are role models for them to look up to—who have really cool engineering stuff—there are people like this—there is another type of engineer, not just male builders" (SE2, 2017). Their identified need for mentors echoes recent research showing that effective mentoring programmes can help overcome identified barriers and improve retention, encourage an engineering identity and enhance self-efficacy (Atkins et al., 2020; Broadley, 2015; Wang & Degol, 2013).

## Conclusions

Possible selves theory states that the pool of 'possible selves' available to a person depends on what is made salient by the person's socio-cultural-material context and their social experiences and connections. Across the two surveys conducted, school students and the Enid Waddell scholars (who were at various stages of a career in engineering) identified a range of personal and contextual factors as influences on their interest in and career choices related to engineering. These included societal stereotypes, family support, access to role models (in person and via the media), relevant practical experience and school achievement and academic self-efficacy. In identifying these aspects, participants' comments echo the breadth of contributing factors that have been identified in studies of barriers and enablers to engagement in engineering. They can be understood in terms of the social, intellectual and environmental factors that contribute to and frame the nature and diversity of possible selves the women in our study had access to through their homes and communities, and the various educational and workplace settings they were involved in.

The students and the scholars indicated that their aspirations to be an engineer, their visions of what this might involve and the practical realities of pursuing this identity as a desired possible self were not set or stable. Indeed, research (e.g., Papafilipou & Bentley, 2017) and data on the retention of women and minorities in engineering suggests that aspirations change and that women take advantage of engineering knowledge and skills being transferable. Our analysis indicates that the schooling and tertiary sector and practising engineers could usefully take on a more active role in communicating the value and breadth of engineering work and in supporting those women who chose to pursue engineering as a career. In this way they could shape and/or support perceptions and experiences of being an engineer as something to aspire and value, or at least not seek to avoid.

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