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Initial teacher education (ITE) students' perceptions of typical engineers: assessing potential for bias in the formative career decision years

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Abstract

There is a recognised lack of women participating in engineering and STEM in most western countries. However, it is desirable for engineering cohorts to have a broad diversity. Hence, girls need to be encouraged into all engineering fields, but especially those traditionally dominated by men such as civil, mechanical and software engineering. A number of factors influence students' critical career decisions. In particular, teachers influence their students in a number of different ways, some overt and others subliminal, including influencing students' self-image and belief in capability. Students between the ages of 11–13 years often develop images of themselves that can exclude them from careers in technology related careers such as engineering.

This study conducted structured interviews with 20 initial teacher education students and two of their lecturers. The interviews considered the students experiences in their own career selection, the reasons one may encourage someone to consider engineering, and the participants of engineering and engineering practice. Interpretation of interview transcriptions indicated that most final year teacher-education students held either limited or stereotypical views of engineering. Participants thought of engineers as mainly for men or "country-type" girls who were good at maths and science. Most recognised the practical nature of engineering, some the academic nature. There was little recognition of the social and empathetic characteristics required.

These outcomes imply a gap in understanding that may cause teachers to rely on their gender prejudice, rather than the skills beneficial in the career when providing career advice to potential engineers.

Keywords Engineering education · Teachers' perceptions · Career selection · Qualitative analysis

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Introduction

Background

There are new demands on the engineering sector due to the increasing complexity of modern products. Economic, cultural, sustainability, legal, and environmental considerations must be undertaken when solving modern engineering problems. Hence, collaboration, creativity, analytical thinking, knowledge sharing, and interdisciplinary relationships are critical to retain efficient engineering (Du & Kolmos, 2009). However, engineering tends to be dominated by men in most western countries (Huyer, 2015). Due to the increasing complexity of engineering problems and consumer demands, non-diverse organisations may begin to struggle when up against organisations with greater diversity in their technical divisions (Cadaret et al., 2017; Godwin et al., 2016; Schäfer, 2006). A diverse workforce can identify more opportunities; increase the number of ways to analyse and solve problems; and employ a wider range of intellectual resources to provide a greater range of solutions to a particular problem. (Gutierrez et al., 2017). Furthermore, since engineering is a lucrative career, equity issues arise.

There are a number of influences that negatively affect young peoples' impression of their ability to engage in an engineering career (Dasgupta & Stout, 2014; Hill et al., 2010; Weber, 2012; Weber & Custer, 2005). These issues tend to be social, rather than academic (Hill et al., 2010; Lloyd et al., 2018). Thus, achieving diversity in engineering and professional engineering practice requires understanding of a variety of factors that influence young peoples' perception of engineering, and their potential to become an engineer. While families tend to have the greatest influence on career selection (Kazi & Akhlaq, 2017; Lloyd et al., 2018), academic performance (Kazi & Akhlaq, 2017; Krumboltz et al., 1976; Lloyd et al., 2018), and teachers (Kazi & Akhlaq, 2017; Krumboltz et al., 1976) also play a role. In particular, teachers have been noted to have a significant effect on broad career decisions made during early adolescence (Bandura et al., 2001; Low et al., 2005). Determining the contribution of educator influence offers potential to mitigate the lack of diversity in engineering cohorts. Among potential career selection influences, teachers of early adolescents are unique as specific educational policies could be used manage and inform the encouragement teachers give to their students. Ameliorating the gender and ethnic bias observed in current professional engineering cohorts may enable the upwards social mobility of marginalised groups.

Kazi and Akhlaq (2017) note that students should not be forced into careers they do not want to undertake. However, they also note that students often make career decisions using weak or false information about their options. It is therefore vital that those who influence students' career selection are capable of representing those careers correctly.

This research elucidated the opinions that incumbent primary teachers of 5–13 year olds in New Zealand have towards engineers and engineering. Since women participation in engineering education and practice is sorely lacking in New Zealand (Docherty et al. 2020), particular interest was given to the gender stereotypes that may emerge. The project focused on the professional sector of engineering.

Literature review

The International Engineering Alliance (IEA) is a global organisation that governs the recognition of engineering qualifications, and enforces internationally recognized standards for engineering education and anticipated competence for professional engineering practice (International Engineering Alliance, 2021). The IEA has established the Washington Accord, a global agreement signed between body organisations responsible for accrediting tertiary-level engineering degree programmes. It is mainly focussed on professional academic programmes which establish the practice of engineering (International Engineering Alliance, 2021). The Washington Accord identifies knowledge, skills and dispositions required for qualified engineers and thus offers insight into the reality of engineering.

Engineers are commonly characterised as being analytical thinkers, highly pragmatic, practical, and good with mathematics and science. They also need other work-related skills such as attention to detail, self-discipline, communication, and team working skills (Barell, 2010; Dede, 2010; International Engineering Alliance, 2014; Kay, 2010). To a lesser extent, engineers are also considered to be logical thinkers, creative thinkers, empathetic, and effective communicators (Godwin et al., 2016). While these characteristics form a good basis for engineering practice, modern professional engineer also requires skills in law, documentation for liability mitigation, ethics, ergonomics, client support, written communication skills, and people and project management. Kay (2010) suggests that engineering skills can be subdivided into three categories: Scientific-technological skills, process skills and generic skills. It is likely that people from non- engineering related fields more commonly associate engineering with the first two categories.

Diversity is highly desirable in engineering cohorts. However, engineering is a field that disproportionately employs men, and is thus the culture can be predominantly driven by men (Barnard et al., 2012; Reilly, 2012; Weber, 2012; Weber & Custer, 2005). Non-diverse professions miss out valuable contributions and new ways of approaching problems that a varied workforce brings (Schäfer, 2006). As today's world is increasingly complex, engineering practice must continually change. Multifarious problems involving the economy, culture, sustainability and society are critical considerations when solving engineering problems. Empathy, effective communication, collaboration, creativity, knowledge sharing, and interdisciplinary thinking and practice must be added to 'traditional' engineering knowledge and skills in order to meet the increasing complex nature of today's engineering problems (Du & Kolmos, 2009; Godwin, 2016).

Social skills such as empathy are more commonly associated with women (Hanson & Mullis, 1985) and not commonly associated with engineering (Koppel et al., 2002). Young women with strong scientific and technical capabilities and abilities have exhibited a tendency towards medicine, health or other fields with increased perceived levels of human interaction and social care over engineering or STEM related careers (Gutierrez et al., 2017; Koppel et al., 2002). Women who do select in engineering have exhibited a slight tendency to engineering sub-disciplines perceived to have strong social or environmental elements such as bioengineering or environmental engineering (Docherty et al., 2020). Weber (2012) also found that women did not become engineers, regardless of their abilities in maths and science, possibly basing their decisions on stereotypes.

Stereotype threat occurs when members of a stigmatized group find themselves in a situation where negative stereotypes influence their behaviour because of the risk of being judged in light of those stereotypes (Cadaret et al., 2017). Stereotypical views of engineering are more likely to be associated with the scientific-technological and process aspects of engineering (Du & Kolmos 2006) and are a barrier to women participating in engineering (Cadaret et al., 2017; Cheryan et al., 2015; Dresden et al., 2017).

Spencer et al. (2015) define a stereotype threat as when:

members of a stigmatized group find themselves in a situation where negative stereotypes provide a possible framework for interpreting their behaviour, the risk of being judged in light of those stereotypes can elicit a disruptive state that undermines performance and aspirations in that domain (p. 1).

When a person is confronted by opposition based on stereotypes, they can feel pressure to conform to the expectations provided by the stereotype. Stereotype threat can affect women who identify with the domain of engineering (Cadaret et al., 2017). Seron et al., (2018) state women who study engineering recognize their marginalization and consistent with the theory of tokens (Kanter, 1977), they respond by adopting the norms and expectations of the majority group, reducing their visibility and contributing to the profession's self-perpetuation. Weber (2012) noted that this prejudice was so strong, that girls could choose not to study engineering, even when their grades indicated a strong competence, and aptitude for the profession.

Mitigating these tendencies may be possible if those who influenced young people's career goals had accurate accounts of engineering. Dresden et al. (2017) found that some New Zealand teachers had misconceptions about the computer science field, despite introduction of elements of computational thinking in the Primary school curriculum. They also stress the importance of correcting these misconceptions such that teachers can address their students' misconceptions.

Indirectly, the self-image of children aged 11–13 years can lead to critical decisions about the broad sector of their future careers (Jones et al., 2011; Lamb et al., 2017; Low et al., 2005). At this age, decisions are based on children's perception of their ability in mathematics and science (Ahmed et al., 2019; Godwin et al., 2016; Weber & Custer, 2005). In particular, most students chose to pursue their academic strengths when considering various careers rather than where their personal goals and interests line-up. Through this critical period, teachers influence their students' self-image and thus, career selection (Kazi & Akhlaq, 2017; Krumboltz et al., 1976; Lloyd et al., 2018). In particular, enrolment of women in tertiary engineering has been linked to how engineering was presented to school students (Nguyen, 2000). Furthermore, Weber (2012) noted that technology education activities solely focused on technical and mechanical skills did not generally appeal to girls. Thus, influence has been observed at a course design level as well.

The way teachers talk about various careers has an effect on career selection (Koppel et al., 2002). Emphasising the benefit of engineering and science on the community has been shown to increase selection of STEM careers (Weber & Custer, 2005). Emphasising the positive social and cultural impacts of engineering, may increase the likelihood of girls selecting engineering careers (Mitts & Haynie III, 2010; Weber & Custer, 2005).

Student self-efficacy is an important factor in career selection (Bandura et al., 2001). Godwin et al. (2016) state that the students' identity and self-efficacy are valuable for guiding them to STEM related careers. Students' perceptions of their ability, rather than their actual ability, can stop them considering particular careers (Cadaret et al., 2017; Krumboltz et al., 1976), including STEM related careers (Bandura et al., 2001).

To attract women into engineering, initiatives that systemically encourage girls, protect them from stereotype threat, and provide a nuanced and accurate impression of the broadness of engineering are required. Teachers have a unique access to students and may be a successful conduit for such initiatives (Nguyen, 2000). It is critical that students understand the positive impact they may have on the world if they choose a career in engineering. However, this is only possible if teachers have a precise understanding of engineering themselves.

Methodology

Constructivism is a social reality that assumes beliefs and meanings people create are used to fundamentally shape their reality (Crotty, 2015; Neuman, 2011, Vygotsky, 1978). A constructivist stance enables researchers insight into the realities of participants' views about engineering and engineers, including their stereotypical views, which have come about through their interaction with the world (Crotty 2015). The general overarching hypothesis assumes that primary teacher education students tend to have a view that engineers are overly pragmatic with good technical skills, but lack empathy or strong communication skills. It was further expected that primary teacher education students would have a moderate understanding of engineering practice, and that while they would be aware of the bias in gender participation in STEM, they would not exhibit any personal prejudice in this regard.

The qualitative approach used in this study deployed individual structured interviews with 20 initial teacher education students and two lecturers from two New Zealand universities. The ethics committees of both of the contributing universities granted ethical approval. In line with ethical agreements, the interviewees were recruited via emails sent to eligible lecturers or specific class lists of students in either the final year of a three-year undergraduate degree or graduates undertaking a one-year graduate diploma in teaching. All respondents signed informed consent before recruitment into the study. In line with ethical agreements, the interviewees were recruited via emails sent to eligible lecturers or specific class lists of students in either the final year of a three-year undergraduate degree or graduates undertaking a one-year graduate diploma in teaching. All respondents signed informed consent before recruitment into the study.

Those recruited were given a $50 gift card to recognise their time and contribution. There were 17 women and three men in the student cohort, and both lecturers interviewed were women. This gender ratio is typical in New Zealand primary teacher education cohorts. The students ranged from 20 to 60+years. A lecturer was in the 35–60 age group and the other was in the 60+group. All participants were given a code: M or F for male and female respectively, and an arbitrary number between 1 and 20. The lecturers were denoted FL1 and FL2.

All interviews were undertaken in a private room, with just the interviewee and the interviewer present. The interviewer strictly used the interview script shown in Appendix 1. Across all participants, the interview duration was 30–55min. To assist the study's reliability, the student teachers' perceptions, and interviewees were informed the study was about perceptions of a number of careers, rather than specifically engineering. Initially, the interviews focussed on the interviewee's goals, interests, background, and what led them to their own career decisions. This provided a basis to reflect the interviewee's later responses within the constructivist paradigm. Next, interviewees were asked to describe children who might be suited to a variety of occupations such as: doctor, lawyer, teacher and finally engineer. This then led onto questions specific to engineering and included asking participants to describe the characteristics of engineers and potential engineers, and describe what a cartoon of an engineer might look like. The cartoon question was designed to elucidate opinions from visual/spatial thinkers. Following this, a series of questions were asked about the interviewees' understanding and perceptions of engineering culture and practice. They were also asked for their conjecture on why female, Māori and Pasifika participation in New Zealand engineering education and industry is low. Finally, the interviewees were asked for their age range and gender. Self-reported gender was used. The interviews were audio recorded with a total of 507min of interview data gathered across all participants. Transcribed interviews were analysed, coded, and re-coded using a thematic approach to identify key themes.

Research question

This paper is concerned with a subsection of the responses that specifically considers the perceptions interviewees had about practicing engineers and those that could be encouraged to become engineers. This led to two key questions:

- What characteristics, demographics, and dispositions do interviewees think an engineer is likely to have?
- What are the interviewee's views on the characteristics of a child who they think has the skills and dispositions to be a potential engineer?

Data analysis strategy

As well as achieving triangulation via recruitment at two universities, this research utilised an adapted data analysis triangulation strategy (Creswell & Plano Clark, 2018). Firstly, all authors read all interview transcripts. Then the first author utilised the methodology described in Braun and Clark (2006) to extract themes. They conducted a primary extraction of codes that emerged in the data, with reference to the research questions noted. They clustered the codes into broad themes, and re-read the data to ensure the themes were well represented. They then compiled the key quotes to justify the theme that emerged and wrote their interpretation of the quotes without input from the other investigators. The other researchers were then given the quotes isolated by the first author. The other investigators subsequently made their own independent interpretations of the quotes. While the other investigators were blind to the primary interpretation, they were aware of the theme the quotes were related to. Finally, the investigators met together and all interpretations were revealed. The investigators discussed the congruity of the interpretations and if necessary, adapted the primary interpretation of the quotes to achieve consensus. In cases of inconsistency of interpretation, the authors referred to the primary data to ensure proper context for the discussion. This approach ultimately led to a thorough four-fold interrogation of the relevant data, and ensured precise interpretation of the interviewee responses. This consensus-based approach leverages the sociocultural conflict theory to ascertain improved interpretation of the interviewee responses by airing differences and justifying decisions made (Doise & Mugny, 1984).

Results

Interviewees' perceptions of practicing engineers

Responses related to perceptions of engineers fell into two categories, Appearance (gender, dress and ethnicity) and Personal Characteristics (skills and dispositions).

Gender and Ethnicity

The interviewees were asked to describe a 12-year-old who they would consider would be well-suited for the engineering profession and then what a cartoon engineer might look like (interview questions 2.4 and 3.7, Appendix A). The purpose of this activity was to reveal the participants' ideas about personality traits and physical characteristics of engineers. Interviewees repeatedly declared some specific characteristics of engineers when asked to describe a cartoon of an engineer (Table1). Interviewees consistently described engineers as male (18 of 20 students and both lecturers). Eight described the engineer cartoon as middle aged, and five specifically defined the cartoon should be Caucasian or white. One must note that the interviewees were responding to the 'please describe a cartoon engineer' question, and thus, may have been led to defining their understanding of societies views of engineers, rather than their own, however findings still suggest a strong stereotypical message.

Strong stereotypical views of engineers emerged. For example, M5 described an engineer as a male wearing a hard hat and brown leather boots with tools around him: "not afraid to put in a pair of steel cap boots". However, this image contradicted M5's wife who was actually an engineer "But my wife is 5'3", slim, Korean girl and yet she did [engineering]". The male engineer stereotype is strong even when directly contradicted by a close family member. M5 also had a father and brother who were engineers and thus may have reinforced this stereotype while he was forming his opinion of various careers. By the time he met his wife, his views on engineers may have already become consolidated.

Interviewee F17 had some women friends with a rural background who were training to become engineers and this led her to offer a more general view of engineers as 'country type' girls. F17 said "country girls, always country girls, boarding girls, those are the people [who become engineers]." F8 said, "a female with no makeup on. Yes, the more-sporty type of female, not a feminine type". Taking these thought patterns to their own practice in the classroom, has the potential to lead to subconscious bias against recommending engineering careers to feminine students. Four of the interviewees were embarrassed at their stereotypical views of the engineer cartoon. This embarrassment was exemplified by F3: "Honestly male, which is quite sad because you'd like to think that the image that I had in my young age will necessitate…This is so stereotypical" When asked "why is it sad?" she replied "it's really sad because my youngest sister [redacted name], I try and visualize her in a role like that [engineering], I tried and you still go to what you know, and it's like 'zip' when you asked the question."

Table 1 Summary "Describe a Cartoon of an Engineer"

Descriptors Engineers are explicitly noted as:	Male	Nerdy, Diligent, Intelligent	Casually Dressed	Work Tools & Equipment	Middle Aged	Safety Equipment & clothing	Ethnicity European	Unsocial	Embarrassed about Stereotype
ITE students (N=20)	18	12	10	10	8	7	5	4	4
Lecturers (N=2)	2	0	2	1	0	1	1	0	1

Personality and characteristics

The cartoons described by more than half of the interviewees were as academic, diligent or hard working. Sometimes, the descriptions diverged to include 'nerdy' tendencies. F4's comment described this somewhat typical view of engineers. "Typical engineer: male, glasses, slightly nerdy". Four interviewees specifically noted that the engineers would be weak socially. F13 went so far to say "… and has bizarre social skills". One wonders how this might be drawn!

Prior to specific prompting of question 3.2.2, only one interviewee noted that engineers may need communication skills. After prompting about communication skills required for professional engineering practice, ten interviewees recognised the need for engineers to communicate effectively with stakeholders, fellow engineers, tradesmen, architects, and clients. F2 noted "You've really got to have that communication and that teamwork and cooperation side of things because you need to verbally explain what you are doing, or how you think that this works".

F3 specifically recognised the need for verbal language skills in professional engineering practice:

Good listeners because they need to take the idea of what's going see it and be able to interpret it onto a page…. they're dealing with customers, dealing with a want and to be able to bring that out and also working with others to achieve this, so not only customers but the people that can do it, the builders.

F4 noted that communication skills were needed in concert with core technical and analytical skills.

[Engineers have] to record a lot of results and data and mathematical stuff, and there has to be a lot of communication with for one another, [in a] positive communication process. Also, they have to know how to communicate verbally,

F6 identified written and conflict management skills as necessary for engineers.

[Engineers] would have to have quite a strong writing, because sometimes they would need to write like essays and paragraph, good like in spelling, punctuation and grammar but then you'd need to have good communication skills, probably dealing with conflict and things like that maybe problem solving skills is probably strong in that field.

Even after prompting of question 3.2.2, three interviewees claimed that the demand for communication skills in engineering practice was minimal. F8 stated "I think it's quite just very minimal. They just communicate like this: 'This is the measurement.' I think it's more of like that, more of the calculating side and less of the communication". F9 noted that technical skills were much more important for an engineer than communication skills. However, the examples these interviewees gave to justify their opinions perhaps implied they were referring to a car mechanics rather than professional engineers. "Like mechanics, they would still have to deal with people like insurance companies, maybe police reports, but not so high level thinking".

F15 did not exhibit confidence in their answer, but ultimately noted that engineers did not require social skills.

I don't really know what social… how social engineers are if they work individually or if they work in a group. In my opinion, engineers sort of had their own individual role within the company, so I don't know if they have a lot [of demand for social skills].

The interviewees' family members and personal experiences influenced their perceptions of engineers. Some interviewees with family or friends who were engineers often generalised the characteristics of those they knew to all engineers. For example, F8 notes:

Engineer[s], good at maths, good analytical skills problem solver. I'm thinking of my brother, he's an engineer. So he's not so much of a social person but he can solve those [problems]. He can draft those things that they need for engineering. I think [engineers are] organized also because there's steps in solving their problems.

Characteristics of children who might become engineers

Teachers' conversations with their students impact the way students see themselves and have the potential to influence future career related decisions. Understanding who future teachers envisaged as engineers and the behaviours they associated with engineering offered insight into possible future career related classroom conversations. Three broad skill sets emerged: academic, creative and social.

The interviewees were asked to describe the characteristics of a hypothetical child who would suit engineering. Most interviewees provided expected responses. In particular, academic skills in maths and science were frequently noted (N = 13 and 10, respectively). Most interviewees also described the hypothetical children as diligent, precise, open-minded, intrinsically motived, and passionate about their learning. The description of F4 is a good exemplar of a typical response:

High in math, if I saw a kid who was not just good at it but excited by it and like knew what they were doing and wanted to learn more about it, definitely recommend engineering, a student who is very…. has a certain way of doing things and also being very open minded and I know that you have to be open minded for a lot of things.

Two interviewees captured the methodological nature of engineering. In particular, F6 noted "It would be the ones who are passionate about math who like to do things a certain way, who are very good at following steps". F17 identified diligence as a useful characteristic for potential engineers. "Good at maths, good at sciences and quite passionate, not a slow thinker but I mean someone who thinks things through, got to be hardworking". FL22 provided a specific example of someone she referred to as a potential engineer:

Not that I know an awful lot about engineering but I know some years ago, there was a little boy who was in my new entrant class and I always referred to him as 'my little engineer' because he was very strong with his math, he was very strong with his English, reading and writing I suppose and he was a talent across all subject that I'd thought you've got such a great line-up of talents. I imagined that he'd be a very good engineer.

However, F6 and F9 stated that children who do not succeed academically would be good engineers. F6 held an explicit gender bias: "They're like mainly males, and they didn't really [achieve academic] standards". F9 noted that potential engineers should have creative rather than technical academic tendencies:

I would say very hands on, building. Like those kind of kids, you can see from even like five, six [years] because they're the ones that get into the Lego and they're always creating. If you tell them to stop, they get annoyed. Then they don't really, and I am generalizing, they don't really care about their academics and methods. This is what they are building -the structures.

Ten interviewees described creative, and problem solving hypothetical children. F10 states the importance of creation and logical processes when considering who may be potential engineers:

Once again, when I was back in school, they like to do activities where they're physically building something or they're planning out a process which they have to go through to get to a certain stage. I think those kind of kids that are really kind of hyperactive and enjoy putting things together, [they] would be the type of people that would become engineers.

F4 noted that "a student who [...] has a certain way of doing things and also being very open minded" could be a potential engineer. F15 also emphasised the need for creativity: "I guess they'd be quite inventive and be creating things and trying to find a solution", and F11 recognised problem solving ability as a desirable trait in potential engineers, "They would be interested in math and science, and like problem solving."

F19 noted a nuanced synthesis of technical ability, creativity and critical thinking is important for an engineer. "Technically creative. So someone who's good at building but also has that mathematical mind and can marry them up. Yeah. So just the balance between those two things". Interestingly, these descriptions that placed creativity as a highly desirable trait in children who may become engineers, contrasted with the descriptions of the skills required for engineering practice wherein creativity was seldom mentioned.

Six interviewees noted that potential engineers should be capable of collaboration and maintaining positive relationships with their peers. In particular, F2 said "I think [they would need] cooperation because in engineering there's a lot of group [work] and a lot of team based, ... and you know you have to work with a lot of all people" and M12 stated: "a good engineer has, again, good relationships and is able to understand the clients brief". In contrast, F11 noted that potential engineers are not strong socially in comparison to other professions that consistently require communication in difficult circumstances: "They don't have to be as personable as a teacher or a doctor would have to be. They have to be very persistent, I guess because they're drawn to problems. So, they have to persist at anything".

Some interviewees felt that quiet or reserved children were suited for engineering careers: F4: "Maybe even quiet, like a quiet student, who is lively as well". And "He is not like a people's person, maybe a bit more reserved or quiet". Note the male pronoun.

Overview discussion

The interviewees' views of engineers and engineering aligned with the stereotypical views presented in Godwin et al. (2016), Barnard et al. (2012), and (Reilly, 2012). Engineers were consistently described as analytical thinkers who are good at maths and science. Some interviewees noted that engineers had bad social skills, while most on reflection also noted that they required strong communication skills. However, almost no respondents declared that communication skills were required by engineers prior to prompting.

Perhaps more worryingly, most of the cartoon engineers were described as men. The concern may be partially ameliorated as the act of envisaging a cartoon implies symbolic communication to a wider group. The interviewees may have thus been adhering to stereotypes they recognise in society, but do not necessarily hold themselves. If this is the case, it may ameliorate some of the concern raised by the gender bias of the cartoon as a proxy of biased career encouragement in the classroom. However, when describing hypothetical children suited to engineering, implying or stating gender becomes less defendable. The cases that described young engineers as explicitly male are most likely to bring this prejudice into the classroom. Furthermore, there may have been an observer effect reducing the wider presentation of such prejudices.

Ahmed et al. (2019) and Weber (2012) note diversity is a desirable characteristic in the engineering profession. However, in most western countries the engineering profession is currently only 15–20% women (Dresden et al., 2017; Huyer, 2015). Some interviewees claimed that girls were just 'not –interested' in engineering. M7 said "Maybe females feel like engineering isn't a strong female based profession". However, this sentiment contradicts the research that shows increased interest in engineering among women after a careful, gender-neutral presentation of the profession (Nguyen, 2000). One interviewee (M5) recognised that some womens' aversion from engineering starts at an early age and maybe cultural rather than innate:

Because I've got a daughter and a son and my daughter, and certainly not because we're pushing it, but she loves the dresses and the dolls and the Disney characters and all that kind of stuff. My son is 2 and he'll walk over and grab a car, there might be 20 things and he'll grab a truck or car and make noises. So how are we as parent's kind of encouraging that to continue? Whereas if my son is in the backyard and he'll come over and spin the wheels and I encourage that. Whereas if my daughter comes and says it's dirty and I stay away. So I think there are elements of that happening.

The reference to 'cultural influence' on engineering related career decision-making aligns to the theory of constructivism. The participants' exposure to stereotypical views come about through their interaction with the world, thus shaping their reality, even when it is not based on fact or evidence (Crotty, 2015; Neuman, 2011). Even when women enter engineering, they conform to norms thus decreasing their visibility (Seron, et al., 2018) This study supports this thinking, evidenced through the perspectives of some interviewees who noted only girls with masculine tendencies became engineers. Their reference to 'country', and 'boarding types girls who do not wear make-up' in the New Zealand context can be interpreted to reference people from rural locations who don't mind getting dirty.

The general overarching findings of the study show that primary teacher education students tend to have a view that engineers are overly pragmatic with good technical skills but lack empathy or strong communication skills. It also found that primary teacher education students had moderate understanding of engineering practice, and were aware of the bias in gender participation in STEM. Koppel et al. (2002) suggest that career influence may come from the way in which teachers talk about careers, therefore the way teachers acknowledge and talk about engineering directly and indirectly influences their students' views about engineering.

Gutierrez et al. (2017) claimed that girls with technical capability tend to select careers based on altruistic motivations, and thus prefer medical, or social care roles over engineering. F4 noted a similar sentiment "[Engineering is] very male dominated and […] seen as a male job, just like teaching is seen to be for females because of the nurturing side". However according to Du & Kolmos (2009) and Godwin, (2016) professional engineering practice requires excellent communication, empathy, creativity, knowledge sharing, and interdisciplinary thinking. In particular, many engineering roles are predominantly concerned with generating innovation to improve lives in the community. Hence, as Godwin (2016) suggests, full and precise presentation of engineering is necessary to ensure that technically capable students who have altruistic motivations also have a proper understanding of these aspects of engineering careers. However, when no such presentation is possible, children may be likely to select their career aspirations based on prejudice (Hodkinson, 1995). Unfortunately for engineering, this prejudice will lead to exacerbation of the current gender imbalance as noted by F10 "Males go towards engineering and females go towards teaching".

While a single interviewee stated engineers needed social skills without prompting, several interviewees explicitly stated that engineers did not need social or communication skills. Just a few interviewees recognised that engineers worked in collaboration. No interviewees mentioned the ethical or environmental demands on modern professional engineering practice. Furthermore, no interviewees suggested empathy is a desirable trait for potential engineers. However, modern engineering practice requires a broad skill set covering a variety of social and communications skills that go beyond technical skills (Du & Kolmos, 2009; Schäfer, 2006).

This research used a structured interview format. There was a degree of redundancy in certain interview questions (2.4 and 3.7 vs. 3.6). However, in these cases, overlapping questions asked the participants to engage their imagination or their knowledge, respectively. Thus, we were able to ensure extraction of impressions of both those strong in visualisation and those with tendencies to logical thinking. Two methods were used to achieve strong triangulation in this study. In particular, cohorts of students from two New Zealand universities from different regions were recruited. There were also two lecturers in the data pool. These measures ensured that the outcomes of the study are considered relevant in a New Zealand context, rather than particular to a specific region of New Zealand. Broader extrapolation of the outcomes presented in this study to international regions cannot be established without specific data.

To further strengthen triangulation, an alternative triangulation approach enabled a quick, but highly reliable interpretation of the data. In particular, the first author was able to gather and interpret quotes, a time-intensive process that did not need to be repeated by the other authors. (Although, the other authors did read the full transcripts while analysing other research questions.) Triangulation occurred with the blinded interpretation of the content by the other authors, two of whom were not involved in the data gathering. This interpretation was not as time-intensive as the initial specific analysis of 507min of transcribed interviews. The interpretation of the findings across investigators was then compared and discussed until consensus on each point was revealed. In most cases, the interpretation of all investigators was similar and no changes were needed. In some cases, the primary interpretation was expanded due to contributions of the other authors, and in a few isolated cases, the interpretation was challenged. In these isolated challenge cases, the discussion that occurred enabled a consensus that all authors felt improved on the primary interpretation, and may not have been possible without the blinded element of multiple interpretations. This triangulation process was underpinned by the socio-cognitive conflict theory that notes challenges to a correct opinion, even if false, ultimately increases the precision of the original opinion and increases the certainty of the opinion holder's views (Doise & Mugny, 1984).

Recommendations for education

This research highlighted a number of important factors when considering participation of women in engineering. Student teachers presented some deep-rooted stereotypical views of the types of people who might, and do, go into engineering practice. Currently, the strongest presentation of stereotypical views held by a minority of incumbent teachers interviewed could be extremely deleterious on the career aspirations of vulnerable students. Work should be undertaken to challenge the pervasiveness of stereotypical views and their ability to deter underrepresented groups, including women, from engineering practice. Hence, the engineering sector has a responsibility to showcase engineering in a way that attracts a wider diversity into engineering.

If an intervention for student-teachers is applied, care must be taken to ensure that it meets the appropriate target. The New Zealand E2E (2019) study on girl's attitudes to engineering noted that marketing materials for engineering qualifications used by institutes of technology and polytechnics had poor representation of women. In addition to addressing the issue of low representation, intervention programmes need to emphasise the social and cultural impacts of engineering in order for participants to get a more representative image of what the profession involves. It is critical that the intervention is designed in such a way that teachers and consequently their students engage and understand engineering, because such interventions have proven to affect changes in students' perceptions of careers (Mitts & Haynie III, 2010; Weber & Custer, 2005). Hence, the intervention should meet the culture of the cohort, and attendance should not be voluntary.

Conclusions

There is a persistent and significant lack of diversity in engineering education and professional practice. A number of factors contribute to this imbalance, and the education system seems to contribute a secondary influence after peers and family. However, the messaging and influence provided by teachers to students may be influenced via policy. Thus, the education sector, coupled with better outreach, should prove to be a valuable asset in mitigating the gender imbalance that is ubiquitous with engineering in the western world. In New Zealand the National Administration Guidelines (NAGs) clearly state that appropriate career education and guidance must be provided for students in Years 7 (aged 11 years) and above (MOE 2017). In particular, education providers are required to:

provide appropriate career education and guidance for all students in year 7 and above, with a particular emphasis on specific career guidance for those students who have been identified by the school as being at risk of leaving school unprepared for the transition to the workplace or further education/training (NAG1.g).

It is therefore incumbent of the education sector to ensure teachers are accurately prepared for this responsibility. This study scoped the current perceptions of engineers in a cohort of future teachers and their lecturers. The study found a significant level of prejudice against women in engineering. The interviewees also failed to recognise the breadth of engineering practice and the diversity of skills required by the modern professional engineer. In contrast, most interviewees seemed poised to recommend engineering predominantly to antisocial men, who prefer to build things when playing, and have particular academic skills in mathematics and science. Hence, it is clear that an intervention is required.

Appendix 1—Structured interview script

1. **Introduction**.
1.1. Introduction of researcher and overview of project. We are undertaking a research project investigating teachers' influences on career choice in Children Ages 11–13. Prior research suggests that educators have a very high level of influence on the self-perception of children in this age group. The goal of this project is to determine influences in career choice. This interview should take 30–45min.
1.2. Tell us about where you come from and a little about your background? *(urban/rural background)*
1.3. What occupations do/did your parents or primary caregivers have?
1.4. Consider the person or people in your life who was/were most influential in you deciding to be a teacher.
1.5. What was it about them that encouraged you in this direction?
1.6. Tell me about your professional goals and the part of teaching interests you the most?
2. **Students**.
2.1. In your mind, please imagine the 12-year-old that you would recommend a career in teaching. Describe that person to me by identifying the top 10–20 characteristics they would ideally have and why?
2.2. In your mind, please imagine 12-year-old that you would recommend consider a career in Medicine. Can you describe them to me?
2.3. In your mind, please imagine 12-year-old that you would recommend consider a career in Law. Can you describe them to me?
2.4. In your mind, please imagine the 12-year-old that you would recommend a career in Engineering. Can you describe them to me?
2.5. Literature and anecdotal evidence suggests that female numbers are low in engineering. Why do you think technically minded females tend to pursue non-STEM professions?
2.6. Literature and anecdotal evidence suggests that Māori/Pasifika numbers are low in STEM fields. Why do you think technically minded Māori/Pasifika students tend to pursue non-STEM professions?
2.7. Who do you think has the most influence of children's aged 11–13 career choice.
2.8. What role do teachers play in this decision?
3. **Engineering**.
3.1. What is engineering?
3.2. What do engineers do? Tell us about your understanding of their:
3.2.1. the technical tasks.
3.2.2. communication tasks, writing reports /discussions.
3.2.3. social tasks.
3.3. What is your understanding of 'engineering related careers'?
3.4. Name careers that you think would fit into this category.
3.5. Tell me about any experiences that you have had with engineering related careers.
3.6. What type of people become engineers? Why?

3.7. If you were a cartoonist and asked to draw the "Typical Engineer" what would it look like?
3.8. Explain your understanding of the relationship between technology education and engineering.
3.9. What do you imagine might be the hurdles to a good engineering solution/design?
3.10. What is likely to be the greatest hurdle? Why?
3.11. Did you ever consider a career in STEM? (Science technology engineering mathematics)
3.11.1. If so what put you off the option? Why/When?
4. **Demographic Information**.
4.1. What age range do you fit into.
15–22, 23–35, 35–60, 60+.
4.2. What is your gender?
4.3. Have you had previous career? If so what?

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Data Availability Data is protected under clauses in the ethical agreement. Hence, data cannot be shared beyond the immediate research group.

Code Availability No code contributed to this research.

Declarations

Conflict of interest The authors declare that they have no financial interests related to this research. The authors also hope the gender imbalance in engineering is mitigated. However, care was taken to ensure this desire did not prejudice the results.

Ethical approval Ethics approval was granted by the educational ethics committees of both universities where the research took place. The names of the committees have been withheld to protect the anonymity of the research participants.

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