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Why do students choose to study engineering?: Insights from a large-scale institutional survey

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ABSTRACT

CONTEXT

Improving capability in the science, technology, engineering and mathematics (STEM) disciplines is fundamental to the Australian government's agenda for promoting productivity and innovation (Australian Government, 2017). Increasing participation in university engineering degrees is a key mechanism for achieving this. However, encouraging students to pursue engineering pathways is an ongoing challenge with falling rates of students completing advanced STEM subjects in high school (Barrington & Evans, 2016) and the persistent underrepresentation of minority groups (Australian Government, 2017). Australia's capacity to develop more engineers, and thus address projected skill shortages, requires action across the pipeline. Improved understanding of why students choose to study engineering is valuable in guiding strategies for increasing participation.

PURPOSE

This study investigates factors influencing student decisions to study engineering compared to students studying in other areas. The research question is: "*What factors influence student decisions to choose to study engineering and when do they make them, as compared to other disciplines?"*

APPROACH

Building upon a previous study (Dawes et al., 2015), the first-year domestic cohorts enrolled in STEM degrees as well as selected non-STEM degrees at the Queensland University of Technology were surveyed about their study decisions. In 2022, 19.6% (n=967) of the eligible population responded to the survey. Participants were grouped into (1) engineering, (2) science, technology, or mathematics (STM), and (3) non-STEM related disciplines. Statistical analysis was applied to investigate the relationship between discipline group and specific categorical variables relating to gender, perceived mathematics ability, influencers on degree decision making, and timing of decision to study chosen degree.

OUTCOMES

Engineering students were less likely to be female and have greater perceived mathematics ability compared to both STM and non-STEM students. No statistically significant differences were recorded for the influencers on decision making across the disciplines, but engineering students selected their degree earlier than STM and non-STEM students.

CONCLUSIONS

The differences in degree decision making between engineering and STM students highlights the need for specific strategies to attract students to engineering, rather than promoting STEM as an aggregated field. Separating engineering aspiration from other STEM disciplines is recommended for understanding which factors impact degree selection.

KEYWORDS

STEM, participation, motivations, decision making

Introduction

There is universal agreement that improving capability in the science, technology, engineering and mathematics (STEM) workforce is important for driving economic prosperity, productivity, and innovation (Australian Government, 2017). Increasing participation in university engineering degrees is a key mechanism for achieving this, but there has been limited change to the participation of students selecting engineering as a potential career over the past decade (Australian Council of Engineering Deans, 2020). Encouraging students to pursue engineering pathways is an ongoing challenge with falling rates of students completing advanced STEM subjects in high school (Barrington & Evans, 2016; Kaspura, 2017) and persistent underrepresentation of minority groups including women (Australian Government, 2017). Engineers Australia’s 2017 report found that Australia’s capacity to develop more of its own future engineers is limited by falling participation in grade 12 science and mathematics and the lack of women attracted to engineering (Kaspura, 2017). These trends have been pointed out in numerous other reports in the Australian context, including Australia’s STEM Workforce (Office of the Chief Scientist, 2016), Engineers Make Things Happen (Kaspura, 2017), and Engineering Skills - Supply and Demand (Bell & Briggs, 2022) where shortages of engineering skills are reported across many sectors.

Australia’s capacity to develop more engineers, and thus address projected skill shortages, requires action across the pipeline. This includes increasing the number of school students choosing to study STEM subjects, as well as attracting individuals from diverse backgrounds to participate in the engineering profession (Bell & Briggs, 2022). Most studies focused on career decision making consider STEM as an aggregated field rather than considering the individual disciplines, which can be problematic when developing strategies to increase participation in a selected area like engineering (Naukkarinen & Bairoh, 2020).

This study analyses data from a 2022 survey that investigated factors influencing student decisions to study engineering. This is compared to students studying in other discipline areas to explore the nuances associated with the choice to study engineering. The research question for this study is “*What factors influence student decisions to choose to study engineering and when do they make them, as compared to other disciplines?”*

Background

When developing strategies to increase the quantity of students choosing to study engineering, it is important to ignite enthusiasm across all STEM disciplines and build awareness about how the disciplines translate to careers. Limited knowledge of career pathways, lack of interest, and the perception that STEM subjects are too difficult are some of the most common barriers that dissuade students from considering STEM careers (Center for Social Research, 2009). The STEM engagement process needs to start as early as primary school, given student perceptions of STEM are often set by the time they reach high school (English, 2017; Sullivan et al., 2004). Previous Australian research has shown that most high school students have selected their broad area of study prior to grade 10, but decide on their specific degree during grade 12 (Dawes et al., 2015).

One of the key challenges in attracting students to engineering is that engineering has an identity problem in schools – structurally, personally, and pedagogically (Lyons & Quinn, 2010) – which limits students from developing a strong interest during their school years. Stating that engineering relies on strong foundational knowledge of science and mathematics can reinforce the idea that if teachers attend to science and mathematics, then engineering will look after itself. However, engineering needs to be explicit when it is experienced within the school curriculum. It also needs to be personally relevant and taught using inclusive pedagogies with broad social appeal. To address this, Lyons and Quinn (2010) suggest students are engaged in practices that are a clear representation of what engineers do, such as enabling students to develop and use models, plan and carry out investigations, analyse and interpret data using mathematics and computational thinking, construct explanations and design solutions, engage in arguments using evidence, and evaluate and communicate information. This serves to open the “black box” to support students in understanding what engineering actually is (Naukkarinen & Bairoh, 2020).

Teachers, students, parents, and career advisers form major influencers on students' career decision making (Dawes et al., 2015; Lyons & Quinn, 2010). Building awareness in these influencers of the engineering profession and corresponding career opportunities is necessary to guide the next generation of engineers toward the profession. Promoting STEM subjects at the school level is also essential. However, a lack of direct engineering experience within the curriculum makes the choice of an engineering career more difficult than for other science, technology, and mathematics disciplines (such as biology or chemistry) which offer at least some direct experiences for students in high school (Fleming et al., 2006; Marra et al., 2012).

Females display similar intelligence and aptitude for quantitatively driven university degrees as compared to their male counterparts, yet the self-perception of female students towards their mathematical ability lags, potentially affecting their choice of an engineering degree of study (Correll, 2001). Zander et al. (2020) highlighted that despite having similar grades, girls reported lower mathematics self-efficacy and self-esteem, and were less likely than boys to self-enhance in terms of performance. Wang et al. (2013) revealed that mathematically capable individuals who also had high verbal skills were less likely to pursue STEM careers than those who had high mathematics skills but moderate verbal skills. One notable finding was that the group with both high mathematics and verbal ability included more females than males. The study found that it is not lack of ability that may cause females to pursue non-STEM careers, but rather the greater likelihood that females with high mathematics ability also have high verbal ability, and thus can consider a wider range of occupations than their male peers with high mathematics ability.

When examining STEM participation, research often groups the contributing disciplines together (Naukkarinen & Bairoh, 2020). However, using this aggregated data can be troublesome when developing strategies for increasing participation in a specific STEM discipline. This is because the reasons for selecting a particular discipline can be nuanced. For example, Naukkarinen and Bairoh (2020) found that female Finnish students were unlikely to perceive engineering and technology as viable alternatives to natural science and mathematics when selecting a university degree. Therefore, simply encouraging girls to study STEM may not translate to enrolments in engineering degrees. Comparing students who choose to study STEM versus non-STEM disciplines is also valuable in understanding the differences between these groups. Moè et al. (2021), one of few studies comparing STEM versus non-STEM students, conducted a study on the incremental beliefs of students in three European countries. Incremental beliefs refer to the personal conviction that abilities are not fixed entities, but can be improved with practice, exercise, experience, effort or more learning (Dweck, 2014). Moè et al. (2021) showed significant differences in the incremental beliefs of students studying STEM versus non-STEM degrees, which was theorised to contribute to career decision making. This is supported by Lykkegaard and Ulriksen (2019) who found that students' interests in various disciplines was fluid, with students consistently moving in and out of STEM-focused career trajectories.

Method

Data Collection

This study was undertaken at the Queensland University of Technology, a large metropolitan university in Australia. The university offers degrees in the STEM disciplines of science (including majors of physics, chemistry, earth science, environmental science, and physics), information technology, engineering (including majors of civil, electrical, mechanical, mechatronics, medical, chemical process, and software), and mathematics.

First-year domestic students commencing an undergraduate degree in 2022 were surveyed using the online tool Qualtrics. This survey has been conducted since 2015 but has previously only engaged students in STEM-related fields. In 2022 it was expanded to include business, law, urban development, and design students, thus allowing us to compare the influencing factors of students studying in STEM disciplines against those in selected non-STEM degrees. Therefore, only the 2022 survey results are discussed in this paper. Of the eligible population, 19.6% (n=967) responded to the survey. During the time the survey was open, a COVID-19 wave meant that teaching was shifted online for the beginning of the semester. Additionally, a major flooding event occurred, which caused further disruptions. These events may have impacted the survey's participation rate.

The survey consisted of 39 questions related to the respondent's demographics, academic performance, motivations, aspirations, and views of tertiary education. Question formats were either open-ended, multiple-choice, or five-point Likert scale. The survey took approximately 20 minutes to complete. Students were not required to answer each question. This paper focuses on investigating the relationship between discipline group and specific categorical variables relating to gender, perceived mathematics ability, influencers on degree decision making, and timing of decision to study chosen degree.

Data Analysis

This study seeks to understand influences on student decisions to study engineering as compared to those studying in other disciplines, subsequently expanding on previous research which examined only the STEM cohort (Dawes et al., 2015). Participants were grouped into (1) engineering, (2) science, technology or mathematics (STM), and (3) non-STEM related disciplines. Engineering was separated from STM given conducting research at the aggregate level can be troublesome for specifically assessing engineering aspiration (Naukkarinen & Bairoh, 2020). Where students were enrolled in double degrees with engineering, they were allocated to the engineering group. Where students were studying double degrees that included at least one STM discipline (but not engineering), they were allocated to the STM group. Engineering students comprised 16% of respondents (n = 156), compared to 51% (n = 496) for STM students, and 33% (n = 319) for non-STEM students.

Data were analysed using SPSS Statistics 27. Pearson's Chi-square test (Field, 2017) was used to test associations between the discipline groups and other categorical variables of interest as has been conducted in other similar studies within the sector, with a significance level of 0.05 adopted. (e.g. Naukkarinen and Bairoh (2020); Verdín and Godwin (2015)). The test compares the actual frequencies in each category to what would be expected if distributed by chance. Prior to conducting the analysis, assumptions of independence and expected frequencies were checked and were found not to be violated (Field, 2017). Where statistically significant differences were identified, post hoc testing was used to determine which pairs were different from one another. To protect against Type 1 error, the Bonferroni Adjustment was used (Field, 2017).

Results and Discussion

Results are presented by variable for their relationship with discipline group. This is in the order of gender, perceived mathematics ability, influencers on degree decision making, and timing of decision to study chosen degree.

Relationship between Gender and Discipline Group

Figure 1 shows the breakdown of the survey respondents by gender and discipline grouping. It must be noted that respondents were not required to select a male/female dichotomy within the survey, nor were they required to respond to this question. However, due to the very small sample size associated with responses other than male and female, when examining differences in responses based on gender responses, those not coded as male or female were excluded from the analysis.

A Chi-square test, performed to assess the relationship between gender and discipline grouping, found strong evidence of a relationship ($\chi^2(2, 883) = 53.290$, $p < .001$). Post hoc comparisons revealed that the rate of women choosing engineering (37.8%) was significantly lower than STM (54.2%) and non-STEM (71%), which were statistically similar. This is reflective of the wealth of research around participation in the engineering profession, which consistently documents the underrepresentation of women (Australian Government, 2017; Bell & Briggs, 2022; Naukkarinen & Bairoh, 2020). A recent Engineers Australia report found that over 90% of women in non-engineering fields never consider or only briefly consider pursuing engineering as a career (Engineers Australia, 2022). This also highlights that separating engineering from other STEM disciplines, as suggested by recent research, is important in addressing discipline specific challenges like the gender gap which can be obscured between and within disciplines. Moote et al. (2020) found that collapsing of engineering aspirations within STEM aspirations makes it difficult to assess the extent to which factors may be common or different for engineering compared to STEM.

Naukkarinen and Bairoh (2020) found that female engineering applicants tended to be slightly more open to other career options than their male counterparts. This is supported by Mann and DiPrete (2013) who found that more flexible curricula and the possibility to pursue coursework in other fields of interest enhanced female interest in a discipline and may divert them away from fields of engineering that lack curricular flexibility.

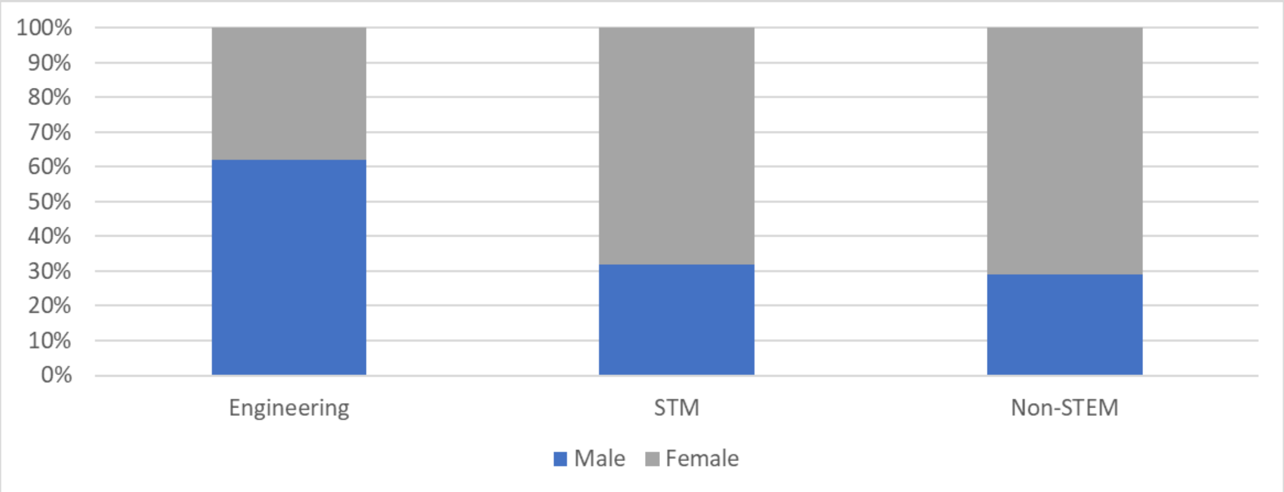

Figure 1 – Gender breakdown by discipline grouping for survey respondents

Relationship between Perceived Mathematics Ability and Discipline Group

Students were asked to respond to the statement "*I am talented at mathematics"* on a five-point Likert scale. The distribution of responses is shown in Figure 2. A Chi-square test of association was used to assess the relationship between perceived mathematics ability (categorised as positive for those selecting the strongly agree or somewhat agree options, and neutral or negative for those selecting the remaining options) and discipline group. This found strong evidence of a relationship between the variables (χ^2(2, 968) = 27.159, p < .001). Post hoc comparisons between discipline groups suggested engineering students were more likely to have positive perceived mathematical ability (with 71% selecting this option) compared to STM (53%) and non-STEM (45%) students respectively. There were no statistically significant differences between the STM and non-STEM groups.

There are many factors contributing to mathematics ability stereotyping including capability-related beliefs, mathematics being challenging, some parents believing boys are more skilled than girls, and mathematics anxiety (Verdín & Godwin, 2015). These negative stereotypes about mathematics might prompt students to engage less in STEM subjects, which in turn leads to preferences for academic degrees and professions with low mathematics or spatial content (Eddy & Brownell, 2016). Wang et al. (2013) concluded that it is likely that individuals with high mathematics and high verbal ability believe in their potential to succeed in either STEM or non-STEM occupations. These individuals may also feel they are in a position to consider how a STEM or a non-STEM occupation will fulfill their life goals and values (Eccles, 2009). This is supported by Dweck (2014) and Eccles (2009) whose research suggests that individuals are more likely to choose a given pathway if they believe in their capacity to succeed in that area. Similarly, Verdín and Godwin (2015) found self-beliefs and background factors related to identity were predictive of choosing to study engineering at university.

Figure 2 – Response to “I am talented at mathematics” by discipline group

Relationship between Influencers and Discipline Group

Students were asked to select who was most influential on their decision to pursue their chosen degree. The distribution of results by discipline group is shown in Figure 3. This shows that across the discipline groups, the majority of students stated that no one influenced their decision making. Parents followed by teachers were identified as being the next most influential across all three discipline groups. A Chi-square test was used to test the relationship between the key influencer and discipline group, revealing no statistically significant differences between groups ($\chi^2(8, 900) = 9.480$, $p = .303$).

Students often hold stereotyping beliefs for occupations, which are frequently informed by media portrayals of particular industries. Additionally, having a good and well-liked teacher can raise school students’ interest and enjoyment of taught subjects, and subsequently increase the likelihood of pursuing a similar area of study at university (Wint, 2022). Supporting this, in the Universities Australia (2012) study, respondents consistently identified teachers with both passion and subject knowledge as important contributors to their career aspirations and choice of university subjects. The study recommended that secondary school students are made aware of the career opportunities at an earlier age, rather than in just grades 11 and 12.

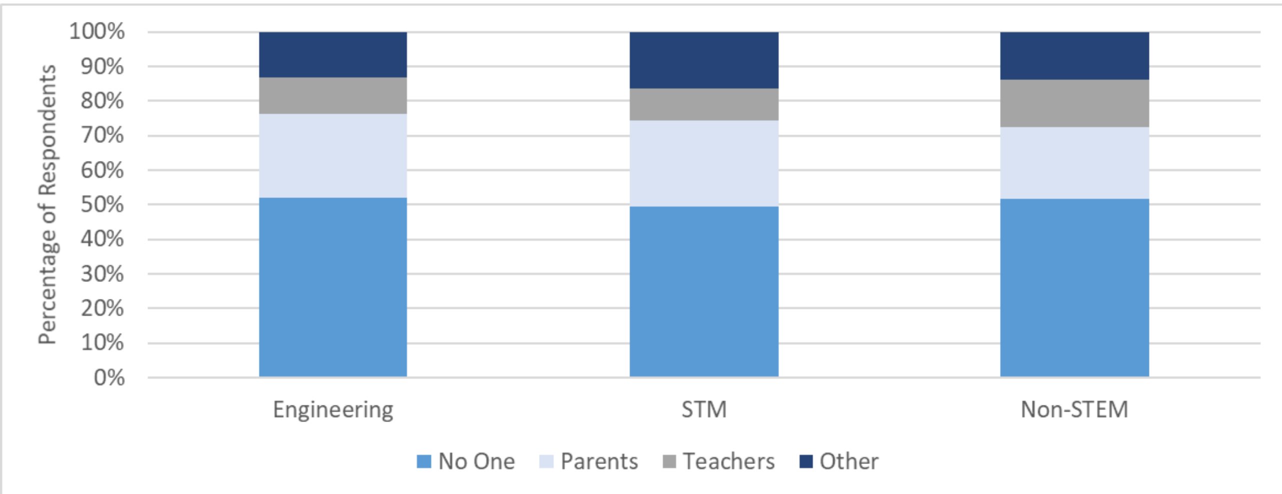

Figure 3 – Key influencer on student decisions to pursue chosen degree by discipline group

The proportion of students selecting no one as their key influencer represents an increase of 9% of students since 2015 (Dawes et al., 2015), potentially due to the COVID pandemic reducing students’ ability to access face-to-face information events with their key influencers. Consequently, students likely increased their reliance on self-sourcing information online to aid their degree selection process. Godwin et al. (2016) described student's beliefs about their performance and competence on their own are not significant predictors of engineering but are mediated by the interest and recognition of others. They also concluded that student identities and agency beliefs are significant predictors of choosing engineering.

Relationship between Timing of Decision and Discipline Group

Students were asked when they decided on their broad area of study, with the distribution of results shown in Figure 4. The Chi-square test of association between timing of decision and discipline group revealed strong support for a relationship between the variables ($x^2(6, 900) = 23.570$, $p <$ .001). Investigating pairwise associations through post hoc testing, it was shown that non-STEM students were less likely to choose their broad area of study in Year 7 or before (9%), compared to engineering (19%) and STM (20%) students who were statistically similar.

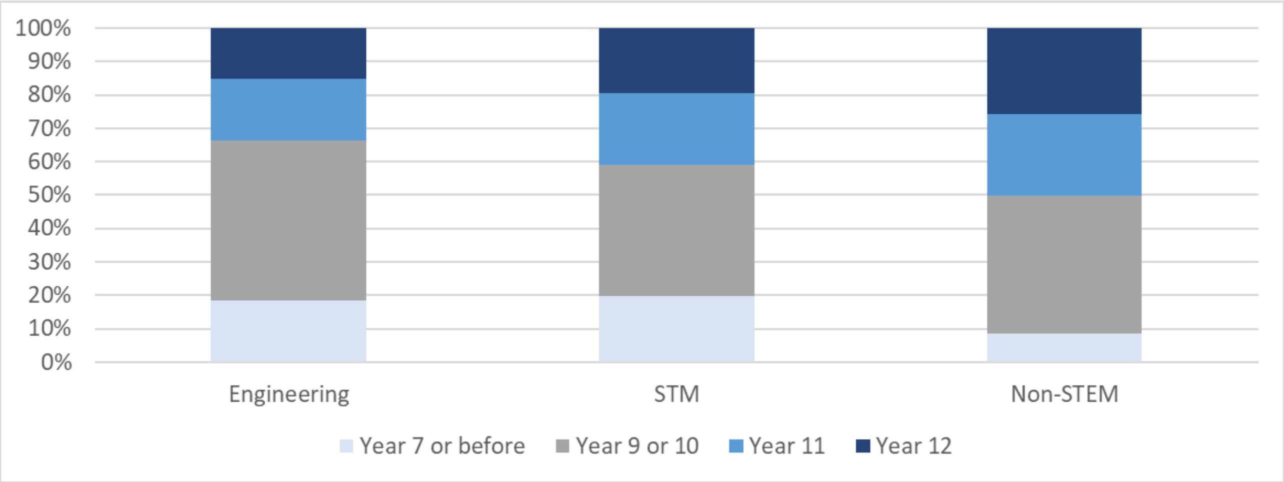

Figure 4 – Timing of decision to select broad area of study by discipline group

The timing of when students selected their degree is of particular interest to the higher education sector as it can determine when recruitment efforts would be most effective. Moote et al. (2020) reported little change in students engineering aspirations between 10 and 16 years and suggested that there is little detectable evidence of the impact of engineering interventions after age 14. This was based on their study of 20,000 grade 6 and grade 11 students from the United Kingdom. The finding is supported by researchers from the University of Newcastle who collected data on career aspirations of 3,500 grade 4, 6, 8 and 10 students, and found that 40% of grade 10 students were tentative or undecided about a particular career (Gore et al., 2015).

Concluding Remarks

Understanding the motivation behind factors that influence student decisions to study engineering is key to designing strategies for widening engagement. We surveyed first-year domestic cohorts enrolled in STEM degrees as well as selected non-STEM degrees at a large Australian university about their study decisions. Participants were grouped into (1) engineering, (2) science, technology, or mathematics (STM), and (3) non-STEM related disciplines for comparison. Clear differences were observed when analysing results by gender, with the rate of women choosing engineering significantly less than the STM and non-STEM groups. Perceived mathematics ability also varied significantly between groups, with engineering students having a greater perceived ability, but there were no statistically significant differences between the STM and non-STEM groups. There was no statistically significant difference between the three groups for key influencers, with parents found to be a larger influencer than teachers. Finally, we found that engineering students selected their field of study earlier than STM and non-STEM groups. The present study highlights the importance of separating out engineering aspirations from STM aspirations to better understand which factors impact degree selection.

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