Diversity and gender enrolment patterns in an undergraduate Engineering program

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INTRODUCTION

Gender diversity, along with other diversities, has recently been a significant issue in Engineering degree programs throughout the world. There are national variations, though and in many countries the number of females undertaking Engineering programs is significantly lower than the number of males and the drivers and reasons behind these trends are poorly understood. In Australia the proportion of females has remained at around 15% in recent years [1]. The University of Sydney, Faculty of Engineering and Information Technologies has made significant progress in improving its gender balance (with over 30% of the commencing engineering undergraduates being female - almost double the Australian national average).

The gender imbalance generally has the potential to skew professional workplace (engineering) cultures; to have narrower perspectives in technology related projects; to not produce effective outcomes from projects; and to result in the Engineering profession being less popular with females.

In reviewing the general trends in our enrolment and student performance data, alluded to above, it is easy to make untested assumptions which can lead to misinterpretation of the nature of the gender difference. This can potentially be addressed by undertaking fine-grained statistical analysis of our data. The aim is to use the resultant insights to drive admissions and curriculum decision making and through this to improve our gender balance and optimise the appropriate support provided to all students. A detailed analysis of a relatively large cohort of students (N=3906) who have been enrolled in our undergraduate Engineering degree

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programs over the last decade has been undertaken, where students' high school subject choices and results are correlated with their subsequent performances in their undergraduate engineering studies.

1 BACKGROUND

Exploration of gender issues in university Engineering programs has been undertaken by numerous researchers in different countries and cultures.

Early work was undertaken with a relatively small sample that showed that neither ethnicity nor gender differences had significantly influenced the success of students. Factors such as vocational interests and low stress levels were major influencing factors [2]. Interestingly, [3] did find that gender had an impact on student performance but it should be noted that this was a relatively small sample of only Chemical Engineering students.

In a much more recent study, an analysis of gender and ethnic enrolment patterns in a relatively large data set of electrical and computer engineering students illustrated a number of trends [4] but explanations of these were not attempted. In another substantial study, student success and attrition were examined through regression analyses where both cognitive and noncognitive variables were considered however gender differences were not found to be material [5].

Gender differences in student experiences and attitudes in a number of science majors, although not specifically engineering, are presented in [6] and it is suggested that significant gender differences in high school students regarding interest in different science majors with physical-related being more popular with males and biological-related being of more interest to females, and furthermore, males appear more interested in the financial rewards in careers while females were more connected with a “helping others” ethos.

Gender differences in grade point averages (GPA) among undergraduate students in biology, the physical sciences, and engineering were studied in [7], and a hypotheses was formed for the gender ecology of science/engineering and the advantages of support programs for women were noted.

An instrument to measure individuals' self-concepts toward engineering design tasks and identified motivation and anxiety were identified by [8]; and [9] identified the roles of gender and persistence in undergraduate computing majors’ are related to various self-efficacies, however, these self-efficacy beliefs did not vary by gender.

These studies, and many others result in a relatively unclear picture of the ways in which gender may be a factor in student performance – though they do suggest that this is at least in part because the relationships are multi-factorial and a hence a simplistic analysis is likely to lead to misleading or erroneous conclusions. We therefore aim to explore our data in a more nuanced fashion.

2 METHODOLOGY

We have collected a large data set containing all students who have been enrolled in an undergraduate Engineering degree program at the University of Sydney between 2006 and 2016 and who completed their secondary school studies in the state of New South Wales.

This includes students who enrolled in either a single Engineering degree program (e.g. a Bachelor of Engineering (Civil Engineering)) or a combined degree program where the student undertook an Engineering degree program concurrently with a different discipline (e.g. a Bachelor of Engineering (Electrical Engineering) / Bachelor of Commerce). The total data set contained N=3906 students as shown in Table 1.

Table 1. Total data set characteristics

Gender	***Single degrees***	***Combined degrees***	***Total***
Male	1717	1341	3058
Female	376	471	847
Unspecified	1	0	1
Total	2094	1812	3906

For each student we recorded the following details:

- gender;
- secondary schooling data:
  - o the overall secondary school ATAR (Australian Tertiary Admission Rank). The ATAR is the ranking most commonly used as the primary basis for admission into University degree programs in NSW. It is calculated by the relevant state-based university admissions centres and is expressed as a percentile score that represents the students position within their overall cohort.
  - o the subjects undertaken and result in each subject.
- university degree data:
  - o enrolled undergraduate degree program (course code; course name);
  - o the list of each University subject/unit of study attempted (unit code; unit name) and the result in each unit.

We also then derived:

- course type: i.e. whether the degree course was a single or a combined degree course.
- university overall results: The students' weighted average mark (WAM) across all attempted units in the degree course, as well as the WAM for all attempted first year units; the WAM for all attempted mathematics units; and the WAM for all technical units related to their Engineering discipline of study.

We then used this data set to assess a range of specific questions related to the relative performance of male and female students.

3 DATA ANALYSIS

3.1 Overall performance comparison

Question 1: How do females perform compared to males?

A reasonable starting point is to compare the overall performance (and standard deviation) of female and male students using their overall course WAM.

Females (N=847) $\overline{WAM}$ $\mu = 64.45$ $\sigma = 12.87$
Males (N=3058) $\overline{WAM}$ $\mu = 63.62$ $\sigma = 13.16$

Applying a 2 sample t-test to test if these means are different, gives a p value of 0.049, indicating that this difference in WAM for males and females is statistically significant at $\alpha=0.05$, and we can therefore conclude that it is likely that females are indeed performing at a higher academic level than males in this particular set of Engineering degree programs. A common, but flawed, extension of this data would be to then conclude that this shows there is no significant academic disadvantage experienced by female students. This is supported by looking at the *output* performance (i.e. WAM) without considering the *input* performance (i.e. the ATAR) of the commencing students. If we look at the mean ATAR of the commencing cohort, then we see the following:

Females (N=847)	$\overline{ATAR}$	μ = 93.70	σ = 4.66
Males (N=3058)	$\overline{ATAR}$	μ = 92.55	σ = 5.18

Again, applying a 2-sample t-test, this time gives $p<0.001$. This shows that the females enrolling in the engineering programs have a higher mean secondary school performance ($\overline{ATAR}$). It would therefore be surprising if they *did not* then have a higher overall performance in their degree program ($\overline{WAM}$). A worthwhile question to explore, though beyond the scope of this paper, is *why* we see this difference in the prior academic performance of males and females. It might be hypothesised that the nature of engineering programs (and their academic culture) is such that only females who are more confident in their academic abilities (relative to males) are choosing to undertake an engineering degree.

Irrespective of the reason for the above disparity in the commencing students, a natural subsequent question is whether this higher level of performance of females in the Engineering degree programs derives solely from this difference in their prior performance. This can be assessed by exploring the $\overline{WAM}$ for sub-cohorts that sit within the same ATAR bands.

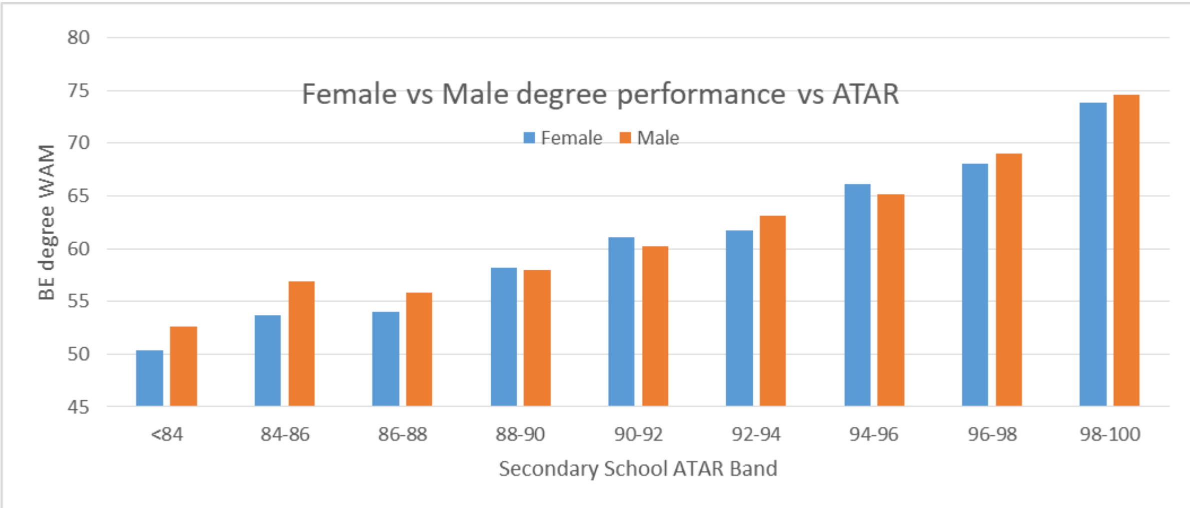

Fig 1. Degree performance by ATAR band.

Figure 1 shows the mean performance of males vs females for students in different high school performance bands. This shows that despite females having an overall degree performance that is better than males, they generally perform worse across most of the ATAR bands shown (six out of nine). This apparent anomaly is an example of Simpson's paradox, resulting from the commencing female students being skewed towards higher secondary school performance than males, and their degree performance therefore being higher than males, but the gap has reduced. This points towards two key avenues of further exploration: (1) Why are a higher proportion of female commencing students coming from higher ATAR students? (2) Once previous performance is factored out, why are female students on average performing slightly less strongly than male students?

3.2 Combined degree vs Single degree programs

It is common in Australian Universities for students to undertake a combined degree program where they complete two different undergraduate degree programs in parallel. Examples include a Bachelor of Engineering in conjunction with Commerce, Law, Science, Arts, Architecture, or Medical Science.

As high school performance increases students become more likely to choose a combined degree – see Table 2. Whilst below an ATAR of 95 this may partially be a consequence of the admission criteria, above 95 there is no difference in the admissions criteria.

Table 2. Proportion of students enrolling in combined degrees.

Type	90-92	92-94	94-96	96-98	98-100	Total
Single	64.29%	54.69%	38.50%	29.67%	27.03%	40.67%
Combined	35.71%	45.31%	61.50%	70.33%	72.97%	59.33%

Q: Is there a difference in the proportion of males compared with females undertaking combined degrees?

Table 3 compares data related to combined degree enrolments and shows that female students have a significant skew towards combined degrees when compared to males (55.4% compared to 43.8%). Given the above observation that higher ATAR females are more likely to choose to study Engineering than lower ATAR females, and higher ATAR students generally choose combined degrees, it is useful to consider the proportions only for high ATAR students. For those with an ATAR above 98, 75.0% of females choose a combined degree, and 72.1% of males – so the skew is much less pronounced than in the total group.

There is a noticeable difference in the choices being made by females and males regarding their second degree. Males are more likely to choose commerce whereas females are more likely to choose Architecture, Arts, and Medical Science. The reasons for this are worth further study.

Table 3. Comparison of combined degree performance

		Single	Combined						Total
Values	Gender		Archit	Arts	Commer	MedSci	ProjMan	Science	
Proportion	Female	44.55%	5.69%	6.99%	12.56%	8.89%	3.67%	17.65%	100.00%
	Male	56.15%	1.96%	3.30%	15.66%	3.83%	3.76%	15.34%	100.00%
ATAR	Female	91.37	97.64	94.63	96.50	95.47	93.56	94.99	93.68
	Male	90.42	97.45	94.10	96.67	95.00	92.71	94.57	92.55
WAM	Female	62.46	66.00	62.84	66.27	66.90	64.60	66.73	64.39
	Male	60.98	68.99	62.70	67.61	66.26	66.25	67.45	63.62
Total Proportion		53.64%	2.77%	4.10%	14.99%	4.92%	3.74%	15.84%	100.00%
Total ATAR		90.59	97.53	94.29	96.64	95.18	92.89	94.67	92.80
Total WAM		61.24	67.66	62.75	67.37	66.51	65.90	67.28	63.79

3.3 Patterns of secondary school subject choice

The data set contained information on students' secondary school subject choices. It is worth considering whether there were gender differences in these choices, and whether this might be correlated to differences in engineering degree choices or performance.

Q: For students in a particular school ATAR band, do males and females make different subject choices?

Table 4 provides a comparison of females and males secondary school subject choices, including a comparison of their resultant overall ATAR band. There are few clear patterns in the data, though it is interesting to note that the level of Mathematics and Science studied was almost identical for males and females, whereas females tended to average a higher level of English and, possibly surprisingly, a lower level of HSIE (Human Society and Its Environment – which includes subjects such as Geography, History and Economics) and other languages.

The reasons for these variations are unclear but one hypothesis worth further exploration is the possibility of self-selection – i.e. only female students who are more focused on core subjects (English, Maths, Sciences) choose Engineering, and those who have wider interests are more likely than their male counterparts to not choose Engineering.

Table 4. Secondary school subject choices for male and female students. *(The values shown are the mean number of subjects taken in the given category. For example, a student who studied English, Extension English, Standard Mathematics, Physics and Chemistry would have a value of 2 for English and Science, and 1 for Mathematics)*.

	Female					Male				
ATAR	**English**	**Maths**	**Science**	**HSIE**	**Langs**	**English**	**Maths**	**Science**	**HSIE**	**Langs**
88-90	1.05	1.72	1.63	1.68	1.25	1.10	1.73	1.76	1.48	1.40
90-92	1.16	1.76	1.72	1.45	1.47	1.09	1.75	1.68	1.50	1.31
92-94	1.19	1.78	1.80	1.29	1.26	1.10	1.83	1.67	1.46	1.29
94-96	1.21	1.88	1.66	1.31	1.11	1.15	1.87	1.74	1.45	1.33
96-98	1.15	1.97	1.76	1.31	1.33	1.14	1.95	1.75	1.36	1.47
98-100	1.32	1.97	1.82	1.25	1.53	1.18	1.98	1.77	1.21	1.68
Total	**1.20**	**1.87**	**1.75**	**1.34**	**1.33**	**1.13**	**1.87**	**1.73**	**1.41**	**1.47**

We can extend the above analysis to consider students once they are enrolled in the engineering degree program.

Q: For students in a given WAM band, do males vs females have different Foundational vs Technical vs Professional subject results?

Table 5 compares the subject choices and how this correlates with the mean WAM for students. No clear pattern is discernible, though it does appear that higher performing male students are more likely to have studied science, whereas this pattern is not true for female students.

Table 5. University results (WAM) and correlation with secondary school subject choices.

	Female					Male				
WAM	**English**	**Maths**	**Science**	**HSIE**	**Langs**	**English**	**Maths**	**Science**	**HSIE**	**Langs**
50-60	1.18	1.79	1.85	1.33	1.28	1.11	1.78	1.72	1.50	1.38
60-70	1.17	1.83	1.71	1.38	1.32	1.10	1.82	1.66	1.42	1.39
70-80	1.20	1.96	1.80	1.23	1.24	1.14	1.92	1.75	1.32	1.48
80-90	1.24	2.00	1.64	1.22	1.64	1.10	1.97	1.86	1.18	1.52

3.4 Progression through the degree program

The above performance measures show variances between male and female students. These results do not however address how this might relate to variation in performance through the degree program, and in particular whether there is a gender influence.

Q: Is the trend in results from year to year different for males and females?

As can be seen in Table 6a, female students' overall performance in the first two years of the program is marginally lower than male students' (Δ=-0.69 in year 1, Δ=-0.42 in year 2). However by years 3 and 4, females are performing better than their male counterparts (Δ=+0.24 in year 3, Δ=+1.11 in year 4). Interestingly, the performance differential is greatest in Mathematics, and lowest in the technical disciplinary subjects.

Table 6b shows the same analysis for the narrower cohort of Engineering students who had an ATAR of 98 or higher in their secondary school studies. This provides an even more interesting pattern. For these students, who achieved comparable secondary school results, the negative disparity in first year (Δ=-4.14) and second year (Δ=-1.19), and the positive disparity in third year (Δ=+1.72) and fourth year (Δ=+4.22) is much more pronounced than the general group. Possible hypotheses for these outcomes include:

- There is a bias in the data insofar as male students in this 98-100 ATAR cohort have benefited from prior advantage, which is progressively dissipated through the degree, allowing the more capable female students to excel.
- The commencing male and female cohorts are equivalent, but the females suffer a disadvantage in the early stages of their engineering studies (e.g. some form of bias inherent in the design or delivery of the program) which is either not present, or which the female students have learnt to manage, later in the degree program.

The current data is insufficient to explore this issue further, but it does point at a critical issue that warrants further exploration.

Table 6. Comparison of results longitudinally through the degree, and in different subsets of subjects (*Note: Engin. refers broad professional or generic Engineering subjects; Discipl. refers to subjects specific to a particular Engineering discipline, such as Civil Engineering).*

(a) All Engineering students

Gender	WAM	Year 1	Year 2	Year 3	Year 4	Maths	Engin.	Discipl.
Female	65.63	60.10	55.76	58.71	60.69	63.50	63.99	63.43
Male	64.16	60.79	56.18	58.47	59.58	61.75	62.80	62.89
Total	**64.46**	**60.65**	**56.09**	**58.51**	**59.77**	**62.11**	**63.04**	**63.00**

(b) Engineering students with an ATAR>96

Gender	WAM	Year 1	Year 2	Year 3	Year 4	Maths	Engin.	Discipl.
Female	75.21	67.55	64.29	68.89	68.07	73.81	70.37	73.81
Male	74.64	71.69	65.48	66.17	63.85	75.17	74.21	73.13
Total	**74.79**	**70.65**	**65.19**	**66.76**	**64.70**	**74.83**	**73.24**	**73.30**

4 CONCLUSIONS

There are a number of key findings that emerge from the above analysis. Firstly, it is clear that gender diversity is a significant issue in Engineering degree programs throughout the world and that gender imbalance can skew professional cultures, lead to less effective outcomes from projects, and result in Engineering being less popular with females.

Existing literature presents mixed findings regarding whether gender is an important influencing factor in student performance. Our detailed statistical analysis of a relatively large cohort of students over the last decade has however provided a number of interesting insights:

1. Females are performing at a higher overall academic level than males in our Engineering degree programs. This result could easily be misinterpreted as suggesting that the females are coping with the program better than their male counterparts, and hence mask the existence of deeper issues.
2. Females enrolling in the Engineering programs have a higher mean secondary school performance than males. Given this observation, when we look just at a cohort with comparable secondary school performance, the females generally are performing worse in the University degree program, suggesting that there may be factors that are being overlooked.
3. Female students' overall performance in the first two years is marginally lower than male students, but in years three and four they are performing above their male counterparts. This suggests either that the factors leading to lower female performance is focused on the earlier years, or that females develop an ability to overcome these factors.
4. Highly performing female high school students are more likely to choose to study engineering than lower performing females, and these higher performing students generally choose combined degrees. Of those who do undertake combined degrees, males are more likely to choose Commerce as a second degree, whereas females are more likely to choose Architecture, Arts, and Medical Science.
5. The level of Mathematics and Science studied at high school was almost identical for males and females, whereas females tended to study higher level English. Higher performing (high school) male students are more likely to have studied Science, whereas this is not the case for female students.
6. Very high performing high school students show a negative disparity in first year and second year, compared with other students, but a positive disparity in third year and fourth year.

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