Studying engineering at university

Who is eligible and who decides to study it?

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Author
Ralf Engler, Senior Research Analyst
Email: ralf.engler@minedu.govt.nz
Telephone: 04-463 7039

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STUDYING ENGINEERING AT UNIVERSITY

Just over 19 per cent of school leavers who meet the university entrance requirement also meet the subject requirements for studying engineering at university—defined as having achieved 18 or more credits in NCEA Level 3 mathematics with calculus and physics—and this equates to an average of about 2,900 students each year over the years 2005 to 2010.

Males are far more likely than females to have achieved these requirements, and Asian students are over-represented in this group. Māori and Pasifika school leavers in particular are less likely to have achieved the engineering pre-requisite.

Not all students who have the pre-requisite subjects go on to study engineering at university. While males are more likely to study engineering, females are more likely to go on to study natural and physical sciences.

The fact that females are less interested in studying mathematics and physics at school reduces the size of the pool of potential candidates that might go on to study engineering. The pool of potential engineering students is further reduced because, even if they have the pre-requisite school subjects to do so, all else being equal, females are significantly less likely to study engineering at university.

For students with the highest levels of interest in science, as indicated by their school subject choices, getting more of them to study engineering at university will necessarily reduce the number studying science, since most of these students study either engineering or science already.

Other research has shown that simply having achieved particular subjects at school will not guarantee success at university-level study, even if those subjects are pre-requisites for the study. Rather, how well a student performs at school is the better indicator of tertiary performance. This is also likely to apply to engineering and science.

Introduction

This paper considers the question “how many students leave school with the pre-requisites that enable them to study engineering?”. In addition, we investigate the likelihood of these students going on to study engineering in their first year of study at university. Finally, we consider the transition of students to science degrees at university, and compare them to the transition to engineering degrees.

There are no consistent pre-requisite subjects that universities require of students wishing to enrol in engineering programmes. Looking at the information universities provide to prospective engineering students, we find that mathematics with calculus and physics are generally defined as pre-requisite school subjects. In some institutions, chemistry is also a pre-requisite subject. The number of credits required to be achieved in these subjects also varies between institutions.

We have found previously that students who achieved mathematics with calculus and physics are also more likely to have achieved chemistry as well (Engler 2010a). For this study, we have used the achievement of 18 or more credits in both National Certificate of Educational Achievement (NCEA) Level 3 mathematics with calculus and physics as a proxy for the pre-requisites students need to have to go on to study engineering. The data shows that this is probably a necessary, but not sufficient criterion, but it is good enough for us to investigate the factors that are associated with studying engineering.

The data

We have used data that links students' school study details with their enrolments in a tertiary institution, if any. We have looked at school leavers in the years 2005 to 2010 inclusive, and who gained NCEA Level 3 and met the university entrance requirement. We considered gender, the decile of the last school the student attended, their ethnicity as recorded while at school, and their level of academic ability, as measured by how well they performed on average across all their level 3 achievement standards.

We have identified students in this population who have gained at least 18 credits in mathematics with calculus *and* physics at NCEA Level 3. These students are deemed to have the pre-requisites that enable them to enrol in an engineering degree in their first year at university.[1]

Some students do not take NCEA subjects, instead sitting tests administered by Cambridge International Examinations or International Baccalaureate. It is not possible to identify every student who does this in our data, but where possible, these students were excluded from the study.

Ethnic groups are reported using single/multiple response categories. For example, European students are those who only indicated European as their ethnic group, not in combination with other groups. Similarly, the Euro/Māori ethnic group contains students who indicated both European *and* Māori as their ethnic groups. In most of the results in this report only single ethnic group categories are shown, as the other groups were too small to enable analysis. Any totals reported contain all ethnic group categories.

Engineering degrees are often quite generic in year one; students might do a wide range of science and mathematics courses, rather than specific engineering courses. For this reason we have used a broad definition of degree level study to identify students studying engineering at university.

Students with the pre-requisites to study engineering

Table 1 shows the demographic breakdown of students who achieved NCEA Level 3 and met the university entrance requirement between the years 2005 and 2010. It compares this breakdown to students who achieved 18 or more credits in both NCEA Level 3 mathematics with calculus and physics. Only the largest groups are shown in the table.

It can be seen that while European females from higher decile schools make up the largest group of students who gained NCEA Level 3 and met the university entrance requirement (23 per cent), it is European males from higher decile schools who form the largest group that achieved mathematics and physics (25 per cent). Generally European and Asian males from mid and higher decile schools are over-represented in the group who achieved mathematics and physics. European females are substantially under-represented in that group.

[1] Some institutions have four-year engineering programmes, which are made up of three years of a bachelors degree and one year of honours. We have used the word 'degree' to refer to all types of tertiary engineering qualifications.

Table 1

Breakdown of New Zealand resident school leavers in 2005 to 2010 who gained NCEA Level 3 and met the university entrance requirement, as a group, and who gained at least 18 credits in both mathematics with calculus and physics at NCEA Level 3, by ethnic group, gender and school decile

			Per cent of students	
Ethnic group	Gender	School decile group	Who achieved maths and physics (n=17,500)	In total who achieved NCEA Level 3 and UE (n=90,940)
European	Male	Deciles 8-10	25%	17%
European	Male	Deciles 4-7	17%	11%
European	Female	Deciles 8-10	11%	23%
Asian	Male	Deciles 8-10	9.4%	3.6%
European	Female	Deciles 4-7	8.0%	18%
Asian	Female	Deciles 8-10	6.2%	4.5%
Asian	Male	Deciles 4-7	5.9%	2.3%

Notes.
Not all demographic categories are shown.
Students counted in the 'achieved maths and physics' category also achieved NCEA Level 3 and met the university entrance requirement.

Table 2 shows the breakdown of students who achieved NCEA Level 3 mathematics with calculus and physics, shown as a percentage of all students who achieved NCEA Level 3 and met the university entrance requirement.

Table 2

Percentage of New Zealand resident school leavers in 2005–2010 with NCEA Level 3 and who met the university entrance requirement, who have gained at least 18 credits in both mathematics with calculus and physics at NCEA Level 3, out of the total number of students who gained NCEA Level 3 and met the university entrance requirement

Students who achieved maths and physics	2005	2006	2007	2008	2009	2010	Average
All students	20.0%	19.9%	19.8%	18.7%	18.7%	18.8%	19.2%
	2,580	2,720	2,790	2,980	3,120	3,310	2,920
Female	11.2%	10.9%	10.8%	10.5%	10.2%	10.5%	10.6%
Male	33.0%	33.1%	32.9%	31.4%	31.6%	31.2%	32.1%
Decile 1-3	19.3%	17.7%	16.6%	13.7%	13.2%	14.4%	15.4%
Decile 4-7	19.5%	19.1%	19.2%	18.4%	19.2%	18.2%	18.9%
Decile 8-10	20.4%	20.8%	20.6%	19.7%	19.1%	20.0%	20.0%
European	17.0%	17.3%	17.3%	16.8%	17.0%	17.1%	17.1%
Māori	9.1%	10.6%	9.4%	7.8%	8.0%	9.8%	9.1%
Pasifika	13.0%	12.2%	9.5%	7.4%	5.6%	7.3%	8.7%
Asian	39.6%	38.5%	37.4%	35.1%	33.8%	34.4%	36.3%
European/Māori	9.4%	12.6%	12.1%	12.9%	13.7%	12.8%	12.6%
Total students	12,910	13,650	14,130	15,930	16,720	17,610	

Notes.
Numbers have been rounded to the nearest ten students, but percentages have been calculated using the unrounded numbers. The data is derived from matching school enrolment and student achievement data, so these totals may not match those derived from the individual data sources.

Across all students, an average of just over 19 per cent achieved these subjects, and this proportion has declined slightly since 2005, although it has remained relatively steady from 2008 to 2010. The actual numbers have increased as the number of students with NCEA Level 3 and university entrance has increased.

What the table shows very clearly is that males are far more likely to have achieved these subjects than females. This phenomenon—where males are more likely to be studying mathematics or science generally—is well documented (see for example Lamb 1997, Miller et al 2006). In our data, about two thirds of students who achieved NCEA Level 3 mathematics and physics are male (data not shown).

There are fewer differences between students from schools with different decile rankings, although there is a small but generally persistent pattern of students from higher decile schools being more likely to have achieved these subjects than students from other schools (Table 2). Overall, 55 per cent of the students with achievement in these subjects come from higher decile schools, with just six percent coming from lower decile schools (data not shown).

Finally, Table 2 shows there are distinct differences between ethnic groups. Asian students are more likely to achieve mathematics with calculus and physics than students from other groups. European students are below average in their likelihood to achieve these subjects, but it is the Māori and Pasifika students who are less likely to achieve these subjects. Overall, most students who achieve these subjects are European (64 per cent), with the next largest group being Asian students (27 per cent) (data not shown).

While the overall proportion of students achieving these two subjects has remained relatively constant over the years 2005 to 2010, two groups, Pasifika students and students from low decile schools, have shown declines. Interestingly, Asian students have also exhibited some decline over these six years, but the level in 2010 is still higher than any other single demographic group.

Studying engineering at university

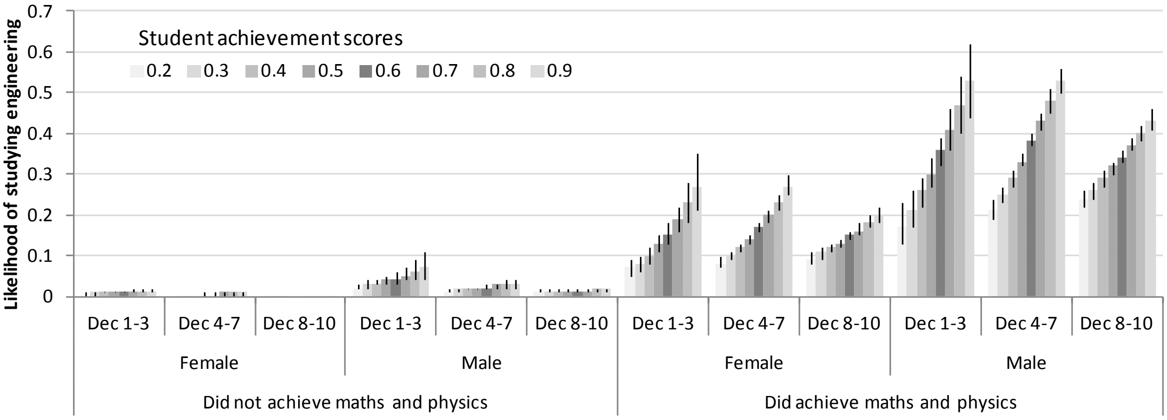
Having the pre-requisites to study engineering does not mean a student will necessarily study engineering after leaving school. These subjects are also taken by people who want to study in health and the sciences generally. This section considers the likelihood that a student will go on to study engineering at university. We consider how this likelihood varies with whether a student has the pre-requisites to do so—using achievement in Level 3 mathematics with calculus and physics at school as a proxy for this— their gender, ethnicity, the decile of the last school they attended, and how well they performed at school. All students have left school, and gained NCEA Level 3 and met the university entrance requirement.

Figure 1 shows the results for students going on to study engineering. [2] It is quite clear that students who did not take mathematics with calculus and physics are quite unlikely to go on to study engineering. It is also obvious that not all students who do take these subjects at school go on to study engineering. In other words, mathematics with calculus and physics are necessary, but not sufficient, indicators of the propensity to study engineering after leaving school.

Figure 1 also shows that even when controlling for school decile and student achievement, females with the pre-requisites to do so are far less likely than males to go on to study engineering.

[2] These results are based on mathematical modelling. Logistic regression was used to model the association between the likelihood of going on to study engineering after leaving school, and the factors gender, the school decile of the last school attended, student achievement, and whether or not the student had gained 18 or more credits in both NCEA Level 3 mathematics with calculus and physics (a proxy for engineering prerequisites). The adjusted R squared for the model was 0.42, and the *C* statistic was 0.909, both diagnostic values indicating the model used had a good fit to the data, and had good predictive power. The final model included two-way interaction terms between the engineering prerequisite subjects and gender, school decile and student achievement, and between student achievement and school decile.

Figure 1
Likelihood of studying an engineering at university, for New Zealand resident school leavers between 2005 and 2010 who gained NCEA Level 3 and met the university entrance requirement, by school decile, gender, pre-requisite subjects and student achievement



Notes.
The bars in the figure represent 90 per cent confidence intervals.
The shaded bars represent levels of student achievement from 0.2 to 0.9.

There is also a strong association with student achievement, with increasing student achievement associated with an increasing likelihood of going on to study engineering. The highest likelihoods occur for students with very high levels of school achievement from low to mid-decile schools. For students with average school achievement (with a score of 0.5), there is no statistical difference in the likelihood of going on to study engineering between school decile categories within the gender/school subject categories. But note, as indicated earlier, over half of the students who have these pre-requisites come from higher decile schools.

There is also a curious pattern seen for students who achieved mathematics and physics from higher decile schools. For these students, increasing school achievement is associated with a smaller increment in the likelihood of going on to do engineering than for similar students from other schools, all else being equal. This means that the highest achieving students from higher decile schools are *less* likely to go on to study engineering than the highest achieving students from other schools. However, the lowest achieving students from higher decile schools are *more* likely to go on to study engineering than similar students from other schools.

We investigated this further and found the effect is essentially due to ethnicity. When we included ethnicity as an additional factor, we found this result was primarily associated with Asian students. For European students the results for students from higher decile schools were much like that for students from mid and lower decile schools, and any differences were not statistically significant. Results for both Māori and Pasifika were also not significantly different. A similar effect was found for Asian students progressing on to tertiary study generally (Strathdee and Engler 2011). In that study, student achievement at school had no association with Asian student's propensity to go on to tertiary study. In other words, Asian students from both lower and higher decile schools were very likely to go on to study at university whatever the level of achievement, once a student had gained NCEA Level 3 and met the university entrance requirement. In our current study, for progression to engineering degrees, this tendency seems to be confined to Asian students from higher decile schools.

The observation that some students with low school achievement are only slightly less likely to go on to study engineering than students with higher school achievement, may signal some problems in terms of tertiary performance. We found achievement at school to be a very strong indicator of first-year performance at university (Engler 2010b), and this applied to all students, including Asian students from higher decile schools. Further work is required to determine whether the desire to study engineering results in some students enrolling who have little chance of succeeding in year one. Of course the likelihood of studying at university is both a function of the desire of the student, and the admission requirements of the particular institution. A study based on our current administrative data cannot distinguish between these two factors.

While achieving particular school subjects may be regarded as pre-requisites for degree-level study, we have shown in previous studies that overall student achievement, rather than achieving a particular subject, is the stronger predictor of university performance (Engler 2010a). That study did not consider performance in engineering because so few students who didn't achieve mathematics and physics go on to study engineering—there is no counterfactual group to compare to. However, it is likely that student achievement is the strongest predictor of performance in engineering as well. We know that it is mostly students who have achieved mathematics and physics at school who go on to study engineering at university (see Figure 1). We also know that engineering students with below average school achievement have a low likelihood of passing most of their first year courses (Engler 2010b, Figure 8, page 22). This indicates quite clearly that having the pre-requisite subjects does not guarantee success. This is not to suggest that students who are not good at mathematics will succeed in engineering; it is that simply achieving 18 or more credits in mathematics at school is no guarantee of success.

Finally, Table 3 gives the proportions of students going on to degrees in a range of fields after leaving school. The data shows that engineering and science are the two main broad areas of study for students who achieved mathematics and physics at school. Students without these subjects go on to degrees in society and culture (mainly law) and management and commerce studies, although a reasonable proportion of students opt for no study in the year after leaving school.

Table 3

Per cent of NZ resident school leavers in post-school activities (study at university or no study) by gender and whether or not the students achieved NCEA Level 3 mathematics with calculus and physics or not, over the years 2005 to 2010

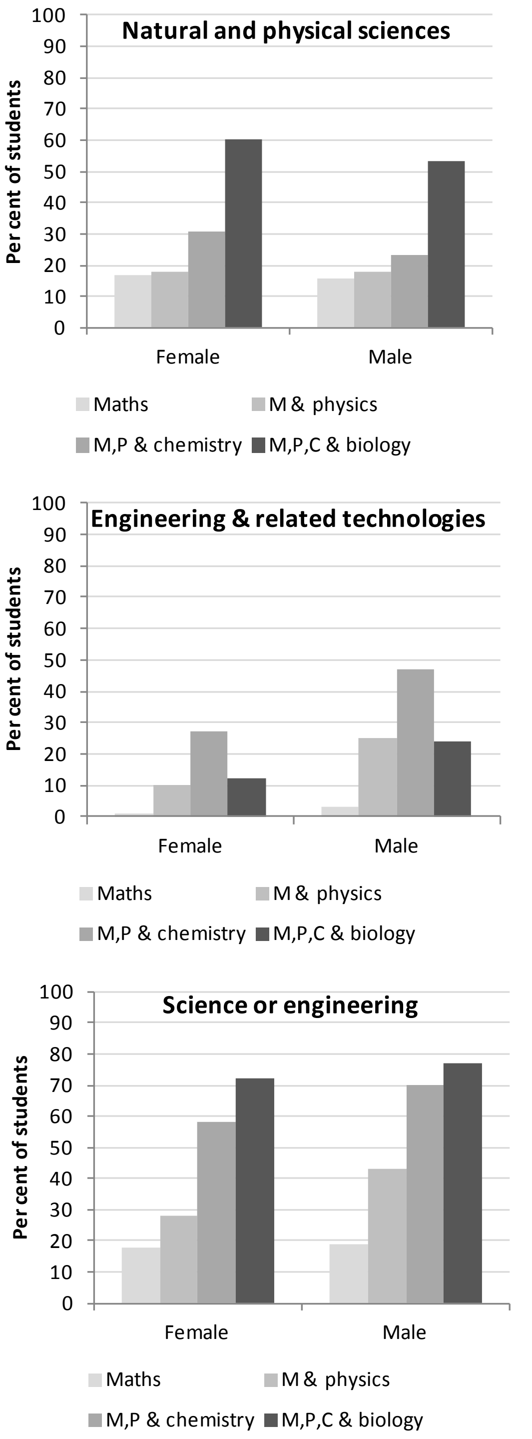
School subjects taken	Gender	Engineering and related technologies	Natural and physical science	Management and commerce	Society and culture	Health	No study
Did achieve mathematics and physics	Male	34%	28%	9%	6%	1%	14%
	Female	16%	41%	7%	9%	5%	12%
Did not achieve mathematics and physics	Male	2%	14%	23%	25%	2%	22%
	Female	0%	14%	13%	29%	5%	21%

Note: not all degree categories are shown.
The category 'no study' refers to the year after the student leaves school; they may go on to study in later years.

Studying science at university

Table 3 indicates that, for students who have the necessary pre-requisite school subjects to study engineering, science was the second most popular choice for males (after engineering), or *the* most popular field of study for females. It is useful therefore to explore the relationship between studying science and engineering.

Figure 2
Per cent of New Zealand resident school leavers between 2005 and 2010 who gained NCEA Level 3 and met the university entrance requirement, who went on to study physical and natural science, engineering or related technologies, or either of these broad fields of study at university, by gender and particular school science subject combinations



See the text for a more precise definition of these subject combinations.

When considering students who go on to study science at university, we have to look at other NCEA Level 3 school science subjects, not just maths and physics. To do this, we have grouped students into those who took mathematics with calculus (but with no other science subject), those who took both maths and physics (and no other science subject, and not maths alone), those who took maths and physics and chemistry (but no other combinations of these subjects), and finally, those who took maths and physics and chemistry and biology (but no other combination of these subjects). Students were included if they gained at least 18 credits in each of these subjects. Note that the category 'maths and physics' is a subset of those having the pre-requisites to study engineering, as defined in the rest of this report, because it excludes those doing any other science subject.[3] The results in this section are therefore not directly comparable with results elsewhere in this report, but they are nevertheless instructive.

Figure 2 shows the results. They indicate the percentage of students who went on to study natural and physical sciences at university (upper panel), engineering and related technologies (middle panel), or degrees in either of these two broad fields of study (lower panel).

The results show that increasing numbers of school science subjects taken in combination is a good proxy for 'interest in science'. The proportion of students going on to study science or engineering at university generally increases as additional science subjects are taken at school. However, it is clear that simply doing one or two science subjects at school is not a sufficient indicator to identify the pool of people who are likely to study engineering or science at university. The results also show that achieving biology, in addition to the other science subjects, is a good marker for 'interest in science', but not a good marker for 'interest in engineering'.

[3] This was done so the categories of subject combinations considered in this section were not overlapping.

Males are more likely to go on to study engineering (Figure 2, middle panel), and only slightly less likely than females to go on to study science (Figure 2, upper panel). But this is not the case for those students, of either gender, who are interested in biology; these students are less likely to go on to study engineering than students who took maths, physics and chemistry together, but are the most likely to go on to study science.

For students who show the highest level of interest in science, indicated by those taking all four of these science subjects at school, over 70 per cent go on to study some type of science or engineering degree at university (Figure 2, lower panel). For this group, 9 and 10 per cent of females and males respectively have not progressed to university. So, apart from improving the rate these students complete their qualifications, there is little opportunity to increase the number of graduates in these fields; most of the students who are very interested in science are already going on to study science or engineering at university. To increase the number of these graduates, focus needs to be directed at increasing the number of students who are interested in science in the early school years, before they have to decide which subjects to take in their NCEA years. These results also suggest that, for those students already quite interested in science, increasing the number of people studying engineering is likely to decrease the number doing science.

Table 4 shows the proportion of students achieving the particular combination of science subjects at school.

Table 4

Per cent of NZ resident school leavers who have taken particular combinations of NCEA Level 3 science subjects, by gender, over the years 2005 to 2010

Subject combination	Gender	2005	2006	2007	2008	2009	2010	Average % (students)
Mathematics with calculus but no other science subject	Female	9%	10%	10%	10%	11%	10%	10% (900)
	Male	11%	12%	11%	12%	12%	12%	12% (700)
Maths and physics, but not maths alone or any other science subject	Female	3%	3%	3%	3%	3%	3%	3% (250)
	Male	12%	11%	11%	12%	11%	11%	12% (690)
Maths, physics and chemistry, but not biology, or any other combinations of these three subjects	Female	3%	3%	3%	3%	3%	3%	3% (280)
	Male	15%	15%	14%	13%	13%	13%	14% (820)
Maths, physics, chemistry, and biology, but not any other combination of these four subjects	Female	5%	5%	5%	5%	5%	5%	5% (430)
	Male	6%	7%	7%	7%	7%	7%	7% (430)

Notes.
Student numbers have been rounded to the nearest 10.

It is clear that the time trends are quite stable for all subject combinations. There is no real change in the proportions taking these combinations of subjects for either gender over the past six years. Whether this is to do with, say, numbers of teachers or classes offered, or a preference for these subjects, is not known.

The table also shows that while females are generally less likely than males to take science subjects at school, they are far less likely to do this for the subject combinations maths and physics, and maths, physics and chemistry. There is far less difference between the genders in those taking mathematics with calculus alone, or taking all four science subjects together. Females make up 56 per cent of students who have taken maths alone, and 50 per cent of students who have taken all four science subjects, over the six years of data. They only make up 25 to 27 per cent of students who have taken the subject combinations of maths and physics, and maths, physics and chemistry. Given that it is those students who take all four subjects who are most likely to go on to study science (Figure 2, upper panel), it would seem that increasing the level of interest in science for both males and females is necessary to improve the numbers of students who will eventually graduate with science degrees.

The scenario to increase the number of engineering graduates is more complex however. For those who are more likely to go on to study engineering—those who take maths and physics and chemistry at school—there is clearly scope to increase the proportion of females taking these subjects at school. But to get more female engineering graduates requires not just that more females take an interest in science, or that more of them choose to go on to study engineering, but that this latter group were not those who were going to go on to study science anyway.

References

Engler, R. (2010a) *Are particular school subjects associated with better performance at university?* Wellington: Ministry of Education.

Engler, R. (2010b) *Academic performance of first-year bachelors students at university*, Wellington: Ministry of Education.

Lamb, S. (1997) *Gender differences in mathematics participation: An Australian perspective*, Educational Studies, 23(1), 105.

Miller, P.H., J.S. Blessing, and S. Schwartz (2006) *Gender differences in high-school student's views about science*, International Journal of Science Education, 28(4): 363–381.

Strathdee, R. and R. Engler (2011) *Who is missing from higher education in New Zealand?* British Educational Research Journal, iFirst Article, 1–18.