

Mum, I want to be an Engineer: Differential access to high ability mathematics standards

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## Abstract

We don't have many Māori or Pacific Engineers and we need them. The University of Auckland's Engineering degree programme is challenging and lists Level 3 Mathematics with Calculus as a compulsory prerequisite for consideration to enter. It has become common practice for secondary schools to stream by ability (for Mathematics) as early as Year 9 and continue this practice through to Year 13, Level 3. This means that placement in the highest ability groups throughout secondary school are necessary to study Level 3 Mathematics with Calculus. Thus, potential applicants for University Engineering programmes are predetermined as early as Year 9.

We present a case study of a high achieving Year 12 Māori secondary school student who wants to be an Engineer. He and his whānau encountered significant resistance by the school to allow him to study the appropriate Level 2 Mathematics prerequisites for Level 3 Mathematics with Calculus. This was despite the student achieving all his Level 1 Mathematics standards (achievement and unit) and having already achieved Level 2 NCEA with merit. The experience of this whānau led us to question whether Māori and Pacific students are given the same access to high ability Mathematics standards as other students. We present data sourced from NZQA and the University of Auckland's Engineering entry data to address this question.

*Key Words: Mathematics, access, opportunity, Māori, Pasifika, Engineering*

## Introduction

Māori and Pasifika are under-represented in the fields of science, mathematics and engineering. This paper looks specifically at the under-representation of Māori and Pasifika as Engineers and presents a plausible reason as to why this is the case, and will remain the case for as long as Māori and Pasifika secondary school students have significantly reduced access to high ability mathematics standards.

The publication *Engineers in the NZ Labour Market* (NZ Dept. Of Labour, 2008) gave the following demographics of NZ Engineers: 87 % male; 4.6 % Māori and 1.6 % Pasifika. These statistics need to be viewed as over-representing the actual presence of Māori and Pasifika in Engineering since the report combines data for Engineers and Architects. Anecdotal evidence given by the Associate Dean (Māori) in the Faculty of Engineering at The University of Auckland, Dr Kepa Morgan, claims that there are three times as many Māori Architects as there are Engineers. Thus, even more sobering figures apply: 1.15 % Māori and if a similar situation exists for Pasifika, 0.4 %.

In the same report, Māori contribute to 11.3 % of the total NZ workforce across all occupations while Pasifika contribute to 4.8 %. Thus there is a significant paucity of Māori and Pasifika professional Engineers. The Department of Labour report goes on to say that performance and choice of subjects at high school are considered to contribute to this under-

representation. This study does not address the performance of Māori and Pasifika students at secondary school but rather the 'choice of subjects at high school' plays a significant role in determining who has the opportunity to study Engineering beyond secondary school.

The Bachelor of Engineering degree with honours (BE(hons)) is academically challenging. At the Universities of Auckland and Canterbury, applicants must have studied Level 3 Mathematics with Calculus, Level 3 Physics and Canterbury requires, Level 3 Chemistry. The University of Auckland candidates can guarantee entry to the BE(hons) if the applicant has a rank score of 240 over 80 NCEA Level 3 credits with 18 Level 3 credits from Mathematics with Calculus and, 18 Level 3 credits from Physics. The rank score is determined by allocating a '4' to every excellence credit; a '3' to every merit credit; and a '2' for every achieve credit. Thus a rank score of 240 implies an average of merit across all 80, Level 3 credits. Not an easy task.

The number of Māori first year Engineering students at The University of Auckland are steadily increasing though this increase is not proportional to the proportion of Māori in Auckland. In 2007, 11 Māori students were accepted in to the BE(hons) programme; 16 in 2008; 28 in 2009. In 2008, we had 437 Māori candidates for Level 3 Mathematics with Calculus throughout the entire country (NZQA website). Of those 437, the achievement standard with the highest Māori pass rate was Trigonometry (90637) with an 80 % pass. If we consider that recruitment for Māori Engineers is required from the pool of Māori students who have passed Trigonometry, the available pool is 350. At the beginning of this year, there were 350 Māori school leavers who may have been eligible to apply for entry to Engineering. Though a huge increase in the Māori first year intake from 16 to 28 this year, these successful Māori students represent only 8 % of the potential pool. With respect to The University of Auckland first year Engineering cohort of 620, Māori contribute only 4.5 %.

### Case Study

A mathematically capable Year 11 Māori student, previously in the school's Year 10 accelerated class, is placed in a mixed ability mathematics stream studying a mixture of Level one achievement and unit standards. The stream that he has been allocated to, studies unit standard algebra (5223) and graphing (5238). Much later that year and after living in another country for all of Term 2, the student tells his parents that he wants to be an Engineer. He is 15 years old. Unbeknown to the student and his parents, he is already on a pathway that excludes him from Engineering as a career option without significant intervention. The student completes his year of mathematics study, sitting 3 external achievement standards at the end of the year gaining an Excellent for 90151 Numeracy, Achieve for 90152 Right angled triangles and a Merit for 90194 Probabilities. He gains 24 mathematics credits (out of a possible 24) and completes that year with Level 1 NCEA with Merit and, Level 2 NCEA with Merit. During terms 3 and 4 of that year, he is commuting for 3 hours a day to get to and from school.

The following year he is transferred to another school to reduce the time spent commuting. He is 16 years old, and still wants to be an Engineer. He and his family know that he must have Level 3 Mathematics with Calculus and Level 3 Physics. They have also scoured the school mathematics curriculum and see that only the students in the highest mathematics stream at Level 2 have any hope of studying Level 3 Mathematics with Calculus. The student and his mother meet with the Deputy Principal and discuss his course for that year. They agree that he must be placed in the highest mathematics stream in order to gain entry to Level 3 Mathematics with Calculus, the following year. His other subjects are selected including Level 2 Physics and the Deputy Principal is asked to confirm before classes start, whether or not the student is in the highest mathematics stream. The family receives confirmation before the start of school.

Six weeks later a progress report is sent home. The parents immediately identify issues regarding the student's mathematics study. He is not in the highest mathematics stream and therefore will not be given the opportunity to study three achievement standards (algebra, graphs and, derivatives and integrals) listed as prerequisites for the study of Level 3 Mathematics with Calculus; he is 'not achieving' but, he is displaying excellent conduct and always does his homework. The parents check with the student regarding him 'not achieving' and find out that he can't understand what his mathematics teacher with English as a second language is saying. They contact the Year 12 Dean and the Deputy Principal about the student being in the wrong stream for his career aspirations and the fact that he cannot understand his teacher. Both the Dean and the Deputy Principal agree that the student needs to be shifted. The mother attends parent-teacher night in that same week to find that the student's current mathematics teacher is indeed difficult to understand and, is not part of the mathematics department but in the school's English Second Language department. This teacher also agrees that due to the student's career aspirations, he needs to shift into the higher stream.

Two weeks later despite agreement from a Deputy Principal, the Year 12 Dean and the current mathematics teacher, the student is still in the lower streamed mathematics class. The parents ring the school several times to find out what the hold up is and it emerges that the Head of the Mathematics Department is taking issue with the student not having studied Level 1 achievement standard algebra (90147) and graphs (90148). The parents try to speak with the HoD Mathematics but are unable to as he is away on a school trip. They do not know this and send the following email:

*Kia ora HoD Maths and Year 12 Dean*

*[Name] is new to your school this year. Previously he attended [School] (Yr 9 to 11). Last year, as a Yr 11 student, [Name] was absent for all of Term 2 as we lived in [other country]. For whatever reasons, he was not registered (by [school]) to sit Algebra (AS external) and instead did Unit Standard Algebra. Despite missing an entire term of school, [Name] achieved all of his Maths standards (~ 27 credits).*

*[Name] is exhibiting an interest in mechanotronics. We are sure that he has the potential to become a mechanotronics engineer. To pursue this interest he will need to study towards an Engineering degree. In order to apply for entry to the University of Auckland's Engineering degree, [Name] must have at the very least (in terms of Maths), exposure to Calculus. He is currently in a Math programme that does not allow him to study Calculus either this year or next year. As failure to have studied L3 Calculus will deem our son ineligible for entry to the Engineering programme, we would like him moved as soon as possible to the more appropriate Maths course, 12[top stream].*

*We also request that we are made aware of the mechanisms of this transfer (i.e. when will the transfer occur and what standards, if any, may be affected).*

*Naku noa*

*[name] and [name]  
(Nga Maatua o [name])*

On his return, the HoD Mathematics sends the following email:

*Hello,*

*Thank you for your email.*

*I have spoken to [Dep Principal] regarding [your son's] current position.*

*The 12(lower level) course is doing the same topics and assessments as 12(top stream) till the mid-year examinations. It would be desirable for [your son] to continue in the 12(lower level) course at present and avoid disruption to his studies as the 2 courses are not synchronised. It would also give [your son] the opportunity to demonstrate, with current evidence of his ability and attitude to doing well. This would enable him to be shifted into a 12(top stream) class, along with several other students in similar positions. If he gains merit passes then there would be no questions about his ability. If less than this, I would want to see his papers to evaluate his progress and understanding. If he is very close to a merit then I would see no real problems to his moving, but if lower than this there would be real concerns, which would need to be clarified.*

*I trust this clarifies the situation.*

*HoD Mathematics*

At this stage, the parents of the student have had 7 separate engagements with the school regarding their son's Year 12 mathematics course. It is week 9 of the term and their son continues to struggle in his mathematics class due mainly to an inability to understand the English spoken by his mathematics teacher. At every engagement other than that with the HoD mathematics, the parents have been assured that their son can study in the mathematics stream that leads to the study of Level 3 Mathematics with Calculus. They are also aware that mathematics is not compulsory at Year 12 and classrooms are not overflowing. The parents struggle to comprehend the gatekeeping exhibited by the HoD. Below is an excerpt of the email the parents sent back to the HoD and copied to the school Principal, the University of Auckland's Associate Deans (Māori) of Engineering, Science, Medicine and Health Sciences and the Pro Vice Chancellor Māori. They have included these stakeholders as they are aware that the University struggles to recruit Māori students into programmes requiring a sound base of the sciences and mathematics. They are also aware that these key people in Universities may likewise not be aware that Māori students may well be actively excluded from the study of science and mathematics at schools, and that their failure to study the appropriate subjects and standards, are not of their own choice.

*Tēnā koe [HOD]*

*Your proposition is not acceptable to us. Our son is not on trial. Our understanding is that [our son] will move to the 12(top stream) class at the beginning of Term 2 before he is further disadvantaged by your department's exclusion criteria and your decision making. We have no confidence in your judgement ... we are qualified to make this assessment.*

*[Our son] has the ability to perform at a level sufficient to complete either a BE(hons) or MBChB. What will prevent him achieving his goals are decisions made (by others) during his secondary education that prevents him learning the appropriate subjects and skillsets. It is obvious that you stream students based on your perception of their ability and that this streaming, significantly pre-determines the outcomes for students. It is to be expected that the top stream, 12(top stream), is taught by the best*

*Mathematics teacher and by insisting that [our son] learn in the lower stream, you are acting in a discriminatory manner. We are concerned that this may not be an isolated event and for this reason, this response has been copied to the Principal and Deputy Principal, Pro Vice Chancellor Māori, Tumuaki of Medical and Health Science, Science and Engineering.*

*If your efforts are driven by a genuine concern for [our son's] achievement and aspirations, we expect that you will have no problem with what we are requiring in terms of his academic curriculum. We also expect that you will provide every opportunity for [our son] to succeed with the same level of resourcing, in terms of teacher expertise, as the student cohort you wish to compare him with.*

*Ngā mātua o [name]*

The next email received by the parents, despite previous agreements by other members of the school's senior management team, was from the Principal. Note that the response below is the full email from the Principal, nothing has been deleted.

*I have complete confidence in my HOD's professional judgement. Therefore he has permission to move whoever he likes after following school procedures and processes.*

At this point, the parents insist on a meeting with the Board of Trustees and make contact with one of the Trustees. The Principal then informs the parents that though they can attend the next Board of Trustees meeting, he will not allocate any time for them to present their issue to the Board. The Principal states that as their concern is a management issue, it has no place being raised with the school Governance team – of which he is a member. The parents concede but insist on an urgent meeting with the Principal and his HoD Mathematics. At this meeting, the parents have prepared a presentation that includes an outline of the three levels of racism: institutionalised, personally mediated, and internalised (Jones, 2000). During this presentation, the HoD interrupts with an outburst claiming that he is not a racist. As the meeting progresses, it becomes clear to the Principal and the parents that the HoD has not seen the student's academic record and has placed him in the lower mathematics class based on his subjective perception of the student's mathematical potential. Finally, the Principal strongly encourages the HoD mathematics to reallocate the student to the Year 12(top stream) mathematics class. This occurs in Term 2.

## NCEA Data Analysis

The case study given above may have been an exception to the rule and plain bad luck for the student and his parents. However with the HoD's admission of not seeing the student's academic record, the parents suspected that their son was discriminated against because of his ethnicity.

This section uses the 2008 National Certificate of Educational Achievement (NCEA) results data for mathematics by ethnicity to answer the question: Do Māori and Pasifika students have less access to high ability mathematics standards?

This analysis confines itself to Level 1 and 2 achievement standards (excludes unit standards) and those achievement standards used as pre-requisites to gain entry to Level 3

Mathematics with Calculus at Year 13. Thus, these standards are the high ability mathematics standards referred to in the title. Percentage access to each pre-requisite achievement standard is calculated for NZ Māori, Pasifika peoples, NZ European and Asian peoples. At Level 1, the pre-requisites for top stream Level 2 are: algebra (90147), graphs (90148) and in some schools, probability (90194). At Level 2, the pre-requisites for entry to Level 3 Mathematics with Calculus are: algebra (90284), non-linear graphs (90285) and, derivatives and integrals (90286). Percentage access is calculated by dividing the number of entries in the achievement standard of interest (e.g. algebra 90147) by the achievement standard with the greatest number of entries. For level one, the achievement standard with the greatest number of entries is 90149, solve problems<sup>1</sup>.

Example:

$$\% \text{ Access}_{(90147)} = (\# \text{ entries in } 90147 \times 100) / \# \text{ entries in } 90149$$

Figures 1 and 2 illustrate the % access to the Level 1 and 2, respectively, pre-requisite achievement standards for studying Level 3 Mathematics with Calculus. These results include all schools offering NCEA and all school decile Levels.

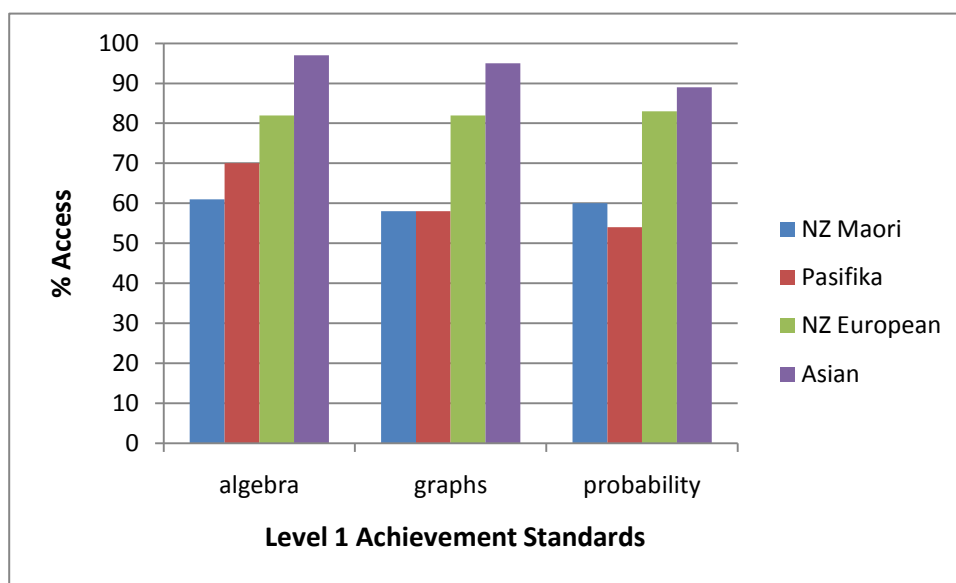


Figure 1. Percentage access to Level 1 mathematics achievement standards by ethnicity.

<sup>1</sup> At level two it is *select a sample and use this to make an inference about a population* (90288) for Māori and Pasifika students, and *stimulate probability situations, and apply the normal distribution* (90289) for NZ European and Asian students.

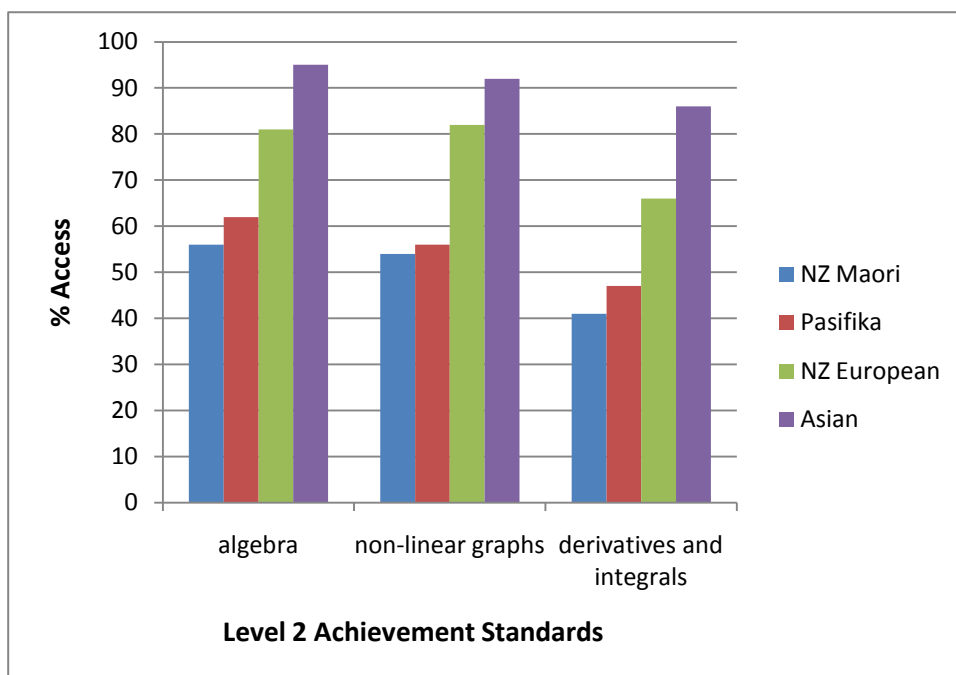


Figure 2. Percentage access to Level 2 mathematics achievement standards by ethnicity.

The charts clearly illustrate that NZ Māori and Pasifika Level 1 and 2 students of mathematics have approximately 20 % less access to high ability mathematics standards than NZ European students and, 30 % less access to high ability mathematics standards than Asian students. Thus, the 2008 NCEA mathematics results data for all schools across all deciles, confirms that NZ Māori and Pasifika students are less likely to be given the opportunity to study the high ability mathematics standards available at NCEA Levels 1 and 2. This in turn means that there is less opportunity for these students to study NCEA Level 3 Mathematics with Calculus – the pre-requisite to study towards the BE (hons) degree at The University of Auckland and Canterbury.

#### Mechanism of Exclusion

In this section, our aim was to determine the mechanism used to exclude students from access to the high ability mathematics standards. This was done by conducting a small cluster study of the mathematics curricula of 4 central Auckland secondary schools (decile range 5 to 8) with their course curricula available on-line. The Māori student in the case study above attended two of these schools.

Secondary schools use various labels for the mechanism that limits student access to high level academic programmes. The following labels were found: tracking, streaming, ability grouping, pathways and finally, banding. Irrespective of the labels, we found the following:

- tracking for mathematics begins in Year 9
- students can prove themselves to be less able e.g by gaining an 'achieve' instead of a 'merit', and move down a 'band' very easily
- it is almost impossible to move up a band once you have been tracked out of the high ability class

- only the most astute parents would be able to know whether or not their child is studying the appropriate standards for their child's chosen career

At Year 9, the schools in this cluster study had at least 2 mathematics ability groups followed by 2 or 3 at Year 10; 3 or 4 at Year 11; 3 or 4 at Year 12 and, 2 or 3 at Year 13. Once a student found themselves in any class other than the highest ability group, it was virtually impossible to work their way back into the top class.

For example, a Year 10 accelerated mathematics student can find himself in the Year 11 Math B class in the following year (perhaps due to not achieving a 'merit' in Year 10 algebra). If this student wants to be an Engineer, the opportunity has been taken away from him since he is now on track to study Level 3 Statistics only. This is because he can only achieve a maximum of 15 achievement standard credits in his Year 11 Math B but requires 16 achievement standard credits to get in to the Year 12 Math A class. Furthermore, his Year 11 Math B class does not study achievement standard algebra or graphs but replaces these with unit standards. This lack of opportunity to study the algebra and graphs achievement standards at Level 1 means that even if the HoD is willing to give him a chance, he is underprepared to study the Level 2 high ability mathematics standards.

A student who is demoted to Year 12 Math B faces the same challenge in that she will not study enough achievement standards to give her the required credits for studying Level 3 Math with Calculus. Moreover, critical achievement standards (algebra, non-linear graphs and, derivatives and integrals) are replaced by unit standards that render the student underprepared to cope with the Level 3 Math with Calculus course.

### Summary

The case study that inspired this investigation illustrated that Māori students can be subjected to ethnic stereotyping (Māori do not excel at mathematics and science) and placed in lower ability mathematics classes without due consideration to their academic record let alone their potential. The advocacy required by the parents in the case study was beyond the ability and resources of most parents. Twelve separate engagements with the school were required before their child was relocated to the high ability class. Those parents were certain that despite the Ministry of Education's Māori Education Strategy (2008), Ka Hikitia recommending productive partnerships between learners, whānau and educators, the last thing their son's school wanted was their engagement.

Disturbingly, a number of parents would not know that their child's career options, with regards to mathematics, can be derailed and significantly limited as early as Year 9. For most students, this is long before they have settled on a career option.

NZ Māori and Pasifika secondary students have considerably less access to the high ability mathematics standards as school processes and procedures provide an effective exclusion mechanism denying Māori and Pasifika students the same level of opportunity as other students.

The Department of Labour report (2008) considered that performance and choice of subjects at high school contributes to the under-representation of Māori and Pasifika peoples as professional Engineers. This study deliberately did not look at performance in Mathematics but chose to focus on access to or, opportunity to achieve the appropriate mathematics



standards required to study Engineering at University. University recruiters for Engineering should be mindful that the paucity of Māori and Pasifika secondary students applying to, and eligible for entry to their programme, is due in some part to the role that secondary schools play in choosing the students' mathematics standards for them. It is not the students selecting the wrong subjects but rather, the students being restricted to lesser (unit) standards within the subject.

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