Engineering Pathways Project
Summary Report
for the
Tertiary Education Commission

Prepared by Professor Dale Carnegie and Craig Watterson on behalf of Victoria University of Wellington and Wellington Institute of Technology (WelTec)

July 2012

Technical Report Resides: http://ecs.victoria.ac.nz/Main/TechnicalReportSeries

Acknowledgements

We would like to thank the following people for their help on this project:

Victoria University of Wellington

Craig Watterson (Project Manager), John Hine, Suzan Hall, Peter Andreae, Will Browne, Howard Lukefahr, Marcus Frean, Kathie Rabel, Karen Davis

ECS Marketing Committee

David Pearce, Chris Hollitt, Ian Welch, Monique Damitio, Amanda Holdaway

ECS Managers, Technicians & Programmers

Mark Davies, Tim Exley, Jason Edwards, Sean Anderson, Christo Muller

Mathematics & Statistics

Peter Donelan, Steven Archer, Megan Clark, Dalice Sim

Physics

Gillian Turner, John Hannah

Central Marketing & Communications

Lindy Wilson, Anna Shanahan, Liz Medford

Awhina

Liz Richardson

Student Learning Support Service

Deborah Laurs

Student Recruitment

Susan Harper, John Dance, Colin Kennedy

Education

Flaviu Hodis

WelTec

Mel Lock, Gail Kirkland, James McKay, Frank Cook

Waikato University CSTER

Mike Forret, John Williams

Waikato University

Janis Swan, Liz Godfrey

Massey University

Jane Goodyer, Stephen Noon

Canterbury University

Paul Gaynor

Base Two Limited

Colin Phillips, Sean McGarry

Contents

List of Tables

List of Figures

Executive Summary

The funding for this project enabled a team from Victoria University of Wellington (VUW) and the Wellington Institute of Technology (WelTec) to investigate barriers to the recruitment and retention of students in the modern areas of engineering, specifically electrical, electronic, computer systems, mechatronics, networks and software in the greater Wellington region. Massey University (Wellington) were invited to participate, but due to issues external to this project, they elected not to. However significant connections were initiated as part of this project with the engineering providers of all New Zealand (NZ) universities and the Metro group of Polytechnics.

In terms of recruitment, the project identified reasons behind the non-responsiveness of today's students to the traditional recruitment techniques. After undertaking extensive market surveys, focus groups, and demographic studies, a strategy was implemented that provided information on engineering careers and training opportunities in the Wellington region. This strategy targeted the students and their influencers, particularly their school careers advisors, teachers and peers. Media employed included the development of a student focussed web site, student centred informational booklets, informational posters for secondary school laboratories and careers advisors offices and the construction and dissemination (nationally) of resources for use in the teaching of electronics, programming and technology in the schools.

Secondary school science and technology teachers were hosted in an evening event by VUW and WelTec, and on-going relationships were developed with many of the participating schools. The results have been a 36% increase in Engineering enrolments at VUW between 2011 and 2012, and nearly a doubling of enrolments in the WelTec BEngTech degree from 2010 to 2012.

The second part of the project identified a number of issues related to the retention in engineering of enrolled students. This study involved independently run focus groups, multiple surveys, literature analysis and discussion at engineering education conferences. We identified several common themes, and others that were institution specific.

One common theme is the need to meet student expectations, and for students to feel that they belong to an engineering community, rather than being some subset of Science. This project enabled the financial support of student engineering clubs and their various initiatives and the provision of a "uniform" that has had a huge uptake, by both students and staff. Poor preparation at secondary schools was a significant theme. Since the NZ Government will not fund foundation level courses at Universities, an Engineering Foundation course was established (funded by this project) at WelTec. The results of this course have been extremely positive – poorly prepared students who enter this course end up performing comparably to students with far better secondary school results in subsequent engineering study.

Early identification of borderline students is critical in order to be able to provide early assistive intervention. It is also valuable, given Tertiary Education Commission's (TEC) recent success-based funding criteria, to identify students who are extremely likely to fail in engineering study and to encourage their enrolment in another degree. Two mechanisms were employed to form a predictor of success in tertiary engineering study. In the first, National Certificate of Educational Achievement (NCEA) student results were obtained from the University of Canterbury, Massey University, Waikato University and Victoria University of Wellington for all first year students entering into one of the modern fields of engineering listed above. Following an in-depth correlation and data mining analysis, a predictor was formed. However the prediction results were not always reliable and so the second mechanism was the creation of a diagnostic test to be administered to students in their first week of engineering study. For the electronics, computer systems and mechatronic students, this diagnostic test in conjunction with NCEA merit and excellence results in Level 3 Mathematics with Calculus and Physics did form a reliable prediction mechanism and has been a key element in the early intervention systems now in place at VUW (detailed below).

The connections this project enabled to be formed between VUW and WelTec have resulted in the drafting of a Memorandum of Understanding (MOU) designed to facilitate the stair-casing of students between our institutions. Certainly VUW can now identify students with a passion for engineering who are highly unlikely to be able to complete a BE due to either academic unpreparedness or a lack of ability at advanced mathematics. Such students can now be transitioned into the BEngTech degree at WelTec. Similarly, high performing diploma or BEngTEch graduates from WelTec who desire further advanced study can be transitioned into high levels of the BE degree. We see this stair-casing arrangement as being extremely beneficial in us being able to provide students with the best advice in terms of what would be their most appropriate programme of study.

This study also initiated a substantial review of VUW's first year engineering programme. One outcome so far has been the major reform of VUW's introductory engineering course ENGR101. It is fair to say that the resulting form of this course (fully informed from the results of this study) is vastly different from its previous incarnation. In order to more fully meet students' expectations of engineering study, VUW is proposing the introduction of a second first year engineering course to be offered in the trimester following ENGR101. The student pass rates (with grade B or above – as required by VUW) rose from 45% in 2010 to 63% with the changes to this course.

Poorly performing students are now tracked at VUW by a software system labelled Big Sister. All assignment data from the engineering, science and mathematics first year courses are input into this programme, allowing staff to see the moment a student begins to fail or otherwise disengage. Motivated by the results of this project, VUW has funded the fractional employment of a pastoral support agent who identifies these at risk students and guides them to appropriate assistance. This is a new appointment in 2012, so the effect on overall retention rates will not be known until November.

However, the number of students now access the help mechanisms has grown from 2 in 2011 to 40 in 2012 – primarily as a result of the personal intervention of our pastoral agent. VUW is actively seeking funding mechanisms to retain this agent and to increase the position to being full-time.

Overall this project has enabled us to form a more complete understanding of the issues relating to recruitment and retention, and facilitated the introduction of a number of initiatives to improve student uptake of engineering and keep them engaged. Initial results indicate a substantial increase in recruitment and are indicating an encouraging increase in retention at first year. The increased connectiveness with other providers of engineering in NZ has also been extremely valuable.

Several journal articles are currently under development detailing the success of the above studies. To date, the results of our recruitment initiatives have been published in:

Carnegie, D.A. and Watterson, C., "Get Those Geeks": An Innovative Recruitment Strategy for a New Engineering Provider. Accepted to the American Society for Engineering Education (ASEE) Annual Conference, San Antonio, Texas, USA. June 10-13, 2012.

Carnegie, D.A., Exley, T., Edwards, J. and Watterson, C., Increasing Engineering Awareness Through Targeted Outreach. *Proceedings of the IEEE Engineering Education Conference (Educon 2011)*, Amman, Jordan, 4 – 6 April, 2011, 128 – 135, ISBN 978-1-61284-641-5.

The prediction findings have been published in:

Carnegie, D.A., Watterson, C., Andreae, P., and Brown, W.N., Prediction of Success in Engineering Study. *Proceedings of the IEEE Engineering Education Conference (Educon 2012)*, Marrakesh, Morocco, 17 – 20 April, 2012, 57 – 65. ISBN: 978-1-4673-1455-8, ISSN: 2165-9559

The retention initiatives have been published in:

Carnegie, D.A., Watterson, C., Browne, W.N., MacKay, J., Lock, M., Williams, J., and Forret, M. Strategies to Improve Engineering Retention. *Proceedings of the IEEE Engineering Education Conference (Educon 2012)*, Marrakesh, Morocco, 17 – 20 April, 2012, 101 – 110. ISBN: 978-1-4673-1455-8, ISSN: 2165-9559

MacKay, J., Lock, M., Carnegie, D., Watterson, C., and Pitawala, S. Inducting Students into the Engineering Community: A Case Study of the Development of a Project Based Engineering Foundation Programme. NZARE Conference, Tauranga, New Zealand, 2011.

Watterson, C., and Carnegie, D.A., Increasing Student Retention and Success: Survey Results and the Success of Initiatives to Create an Engineering Student Community.

Proceedings of the IEEE Engineering Education Conference (Educon 2011), Amman, Jordan, 4 – 6 April, 2011, 191 – 200, ISBN 978-1-61284-641-5

Introduction

The New Zealand Government acknowledges that the country does not produce sufficient numbers of engineering graduates. In response, Victoria University of Wellington (VUW) accepted its first students into a new Bachelor of Engineering degree in 2007. VUW has chosen to specialize in what we will generically label "digital" engineering. Specifically VUW offers Electronics and Computer Systems Engineering (a programme that includes several mechatronics courses), Network Engineering and Software Engineering. This "digital" label is not an accurate one, but will serve in this instance to differentiate these forms of engineering from (say) Civil, Mechanical or Chemical engineering.

VUW is now the primary university provider of engineering in Wellington, New Zealand. It faces challenges in attracting engineering students given the specialized nature of its engineering offering (and poor student understanding of these specializations) and extremely strong competition from New Zealand's two most established engineering universities, The University of Auckland and Canterbury University. Indeed, local secondary school engineering students have many decades of tradition of leaving the city, primarily for Canterbury in order to pursue their studies. This tradition is firmly in the mindset of parents, secondary school teachers and careers advisors. WelTec, while an established provider of engineering certificate and diploma courses primarily aimed at the trades, it is a newcomer in providing a Bachelor of Engineering Technology for the first time in 2010.

Victoria University of Wellington and WelTec were aware of many potential and currently enrolled engineering students who are academically under-prepared, and consequently are either denied entry into an engineering programme, or who once enrolled, do not successfully complete.

In June 2009 VUW and Wellington Institute of Technology (WelTec) began a joint programme of tertiary engineering education research. The Engineering Pathways Project: Digital Engineering (EPP) project was funded by the New Zealand Government's Tertiary Education Commission (TEC) and tasked the two institutions to investigate what barriers exist for successful recruitment and retention of engineering students in the digital and electrical engineering fields. The desired outcomes of this investigation were to increase the successful completion rate of students who wish to pursue an engineering qualification and to make such a qualification accessible to a wider range of students than is currently achieved in the Wellington region. The current project ceased to be funded by TEC on 30 June 2011.

This project and subsequent partnership is non-competitive in that VUW offers a Bachelor of Engineering (BE) (a four year degree awarded with honors), Masters of Engineering (ME) and PhD degrees whilst WelTec offer a two year Diploma and a three year Bachelor of Engineering Technology (BEngTech) degree – both more trade-orientated and hands-on than the various VUW offerings.

WelTec currently offer three majors for their BEngTech degree, Electrical (with a specific specialization in Mechatronics), Civil and Mechanical. The partnership between the institutions concentrates on the overlap of course offerings in the “digital” engineering areas, although there are also overlaps between VUW’s mechatronics offerings and WelTec’s mechanical engineering degree. No attempt was made to partner in the area of Civil engineering since no near equivalent is provided by VUW. When possible, these institutions seek to cooperate in the recruitment areas of increasing student awareness of “digital” engineering and encouraging them to engage in tertiary (university or polytechnic level) engineering study in the Wellington region.

Recent Challenges to the Project

Soon after awarding the TEC funding for our project, the NZ Government decided to restrict entry into NZ Universities and to discourage universities from offering preparation courses. A driver in considering retention issues was the change announced in 2010 that part of the Government funding to tertiary education providers will now be based upon TEC Educational Performance Indicators 2010. These performance indicators are:

- Successful course completion
- Student retention
- Qualification completion
- Student progression

Successful course completion is essentially calculated by dividing the total number of successfully completed (i.e. passed) courses by the total number of course enrolments. Student retention measures an institution’s success in retaining their students through to the completion of their qualifications. This is calculated by considering the fraction of students that either continue with their studies or graduate.

The qualification completion is calculated as being the number of qualifications completed at an institution in a year multiplied by the number of courses that is required of that qualification, and divided by the total number of courses provided. This calculation does not differentiate between students who repeat courses because they have previously failed it and high performing students who take more than the minimum number of courses for their qualification. Student progression is measured by the fraction of students who enroll in a higher qualification within 12 months in New Zealand after graduating. This does not count students who wish to take a gap year or enroll in an institution outside of New Zealand.

There is some unhappiness about these indicators since they discriminate against open entry to professional degrees, such as engineering and medicine that have a high attrition rate. One positive outcome resulting from this new funding criterion is that tertiary education providers are now increasingly concerned about improving retention rates.

As a result of these proposed changes our original project proposal was amended. We also became aware of additional barriers and influencers to student engineering recruitment and retention during the initial scoping work for the project and undertook to develop appropriate responses. This has resulted in several revisions to the original proposal that support and augment the development of a dedicated engineering preparation course at WelTec. No additional TEC funding was required for these extensions.

Specific Challenges of the Current Environment

There is a severe shortage of qualified professional engineers in New Zealand. The New Zealand Institute of Professional Engineers (IPENZ) indicates that, depending upon how the demand is analyzed, New Zealand needs to grow its Dublin Accord accredited Engineering Technicians graduates by up to 178%, its Engineering Technologists (Sydney Accord) graduates by as much as 233% and its full Professional Engineers (Washington Accord) graduates by up to 83%[2]. These figures cover all of the engineering fields, but it would be reasonable to expect that in a growing knowledge economy that the demand for the digital engineers could be even higher than these figures. Conversations between the authors and engineers from some of our major engineering employers state that the inability to recruit sufficient numbers of appropriately trained engineers is, in some instances, the major limitation to their company's growth.

Figure 1 illustrates the poor ranking of New Zealand amongst its OECD trading partners. The OECD average indicates that approximately 13% of all tertiary graduates can be classified as an engineer of some form. New Zealand scores below half of this average at 5.7%.

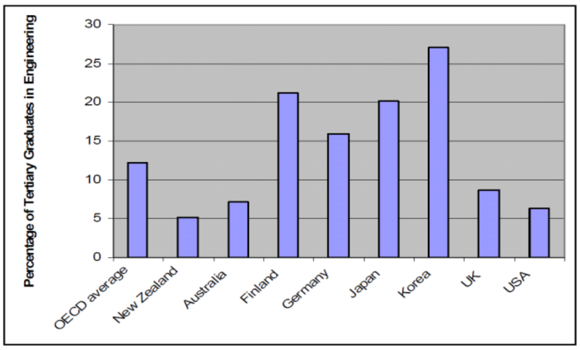


Figure 1. Comparison of per centage of engineering gradudates across 8 OECD countries.

This shortage directly relates to a low uptake of tertiary engineering study by students and high attrition rates in tertiary engineering study, a phenomenon occurring worldwide. The trend of student supply dropping below demand in Science, Technology, Engineering and Mathematics (STEM) has been identified in numerous publications internationally (Carrick Institute, 2008; Unesco, 2010; House of Commons, 2009) and nationally (Earle 2009; IPENZ 2009). The lack of supply has important consequences for the future development of New Zealand's industry and economy, and was the motivation for establishing a new engineering programme at VUW in 2007 and the adoption of the BEngTech by WelTec in 2010.

Research into the problems associated with student performance undertaken in New Zealand have investigated the characteristics of students attitudes both at secondary school and during tertiary study including aspects of transition (Deynzer 2009; Godfrey 1999, 2008; James, Montelle, & Williams 2008; Loader & Dalgety 2008; Madjar et al 2009; Smaill 2007; Ussher 2007; Hipkens & Bolstead 2005; Hipkins et al 2002; 2006; Schagen & Hodgen, 2009), though only few of these directly relate to STEM subjects. These reports echo a common finding in student choice of subjects: 'It is also clear that there is no single way to explain choice patterns. Students have different reasons, in different circumstances, and according to their personal dispositions, interests, future plans, and choice-making experiences' (Hipkens and Bolstead 2005, p.40). However, it is clear from Ussher (2007) that higher academic performance at secondary school increases the likelihood of successful transition to tertiary study, though relating this to the choice of subject remains unclear.

Valuable educational research has been conducted that considers the impact of an institutions culture and the perceptions of students and teaching staff on the learning and teaching experience, and much of this literature is directly relevant to STEM education (Vaughan 2008; Godfrey 2001, 2008, 2009; Cronje & Coll 2008; Coll 2008; Clark, Dodd & Coll 2008; Coll & Eames 2008; Campbell et al 2008; Forret et al 2007; Eames & Stewart 2008). These reports reflect similar thematic findings for improving student performance through teaching and learning. They note that academic success and perception of success directly contributes to subject choice. And likewise, curriculum or perception of its content contributes to the teaching and learning experience and ultimately student academic success at secondary school and at tertiary institutions.

Interestingly, very little research has investigated the existence of a gap in the connection between secondary school teaching and learning, and tertiary teaching and learning from a perspective of curriculum and pedagogy. Yet, most lecturers approached at Victoria University in Mathematics, Physics, Computing and Engineering acknowledge that secondary school students do not appear to be arriving with the necessary skills for successful study at first year tertiary level; a fact borne out in the grade results. Importantly, most lecturers of first year papers at tertiary institutions are unaware of what is being taught at secondary school and the reverse can be said for secondary school teachers who have little knowledge of the subject content that awaits their students in tertiary institutions.

International literature on the problem of poor student performance in engineering, mathematics, and the sciences, particularly physics is considerable. It is clear that there is a worldwide problem in student capability in math and science subjects and that this has major implications for educational providers. The problem for New Zealand tertiary providers is becoming acute as the shortage of New Zealand students for Universities in STEM subjects is increasing and academic performance levels in these subjects is decreasing, though up until now this has been somewhat remedied by the inward immigration of students (Earle, 2009). The literature on tertiary education in the field has focused discussion on attempts to predict performance of potential students through an investigation of pre-tertiary academic performance and diagnostic testing, an understanding of perceptions of student learning environment at tertiary study, aspects of transition, and investigation of innovative teaching methods such as 'Performance Based Teaching' (Boles, 2009).

In the last few years several universities in New Zealand have implemented forms of diagnostic testing for first year mathematics and engineering. This illustrates the current growing awareness by tertiary providers that University Entrance no longer guarantees capability and performance in mathematics, physics and engineering. Diagnostic testing to place students in the correct entry level preparation classes or to decline entry is common in the United States, Europe and Australia. Researchers in the United Kingdom, Adamson and Clifford (2002) acknowledge that student performance at university cannot be reliably predicted from grade performance in secondary school. Solutions for poorly prepared students after diagnostic testing that still gain entry are – placement into a lower level course, and additional mentoring and tutorials. These solutions are costly and have also ignored the larger problem: why are students, who are supposedly prepared through NCEA, poorly prepared?

In 2008, Shulruf et al. gained some insight into the problem when they identified that there was a correlation between grade point average at NCEA and student performance in tertiary study. The report noted that the curriculum structure at secondary school enabled students to seek credit accumulation rather than higher performance in subjects. The implication of this for teaching and learning at secondary school and successful transition to university are critical to future tertiary funding models and have ethical implications on educational commitment to individual students. . There is only a small amount of research (e.g., Yeo & Zadnik, 2004 and Parkinson et al. 2011) into the way attitudes to, and understanding of, science and tertiary level study in science are shaped by their experience of lecturers and learning at the tertiary level. The nature and role of teacher-student and student-student relationships in tertiary learning situations was discussed by Dawes (2004), National Science Foundation (1998), Aufschnaiter (2003), and Welzel et al. (1999). These authors reported findings that students were often heavily influenced by only one or two significant teachers. While studies like Ferreira (2003) and Lovitts (1996) have argued that attrition has less to do with what the students bring into the tertiary institution than with what happens to them once they get there.

One report, Hipkins et al. (2002), 'Curriculum, Learning and Effective Pedagogy: A Literature Review in Science Education' identified a further need for research. This report investigated the following question: 'How does the national and international literature on science education inform our understanding about effective teaching practice/pedagogy on student achievement in science education for the diversity of students in New Zealand?' (p. 2). Through a thorough investigation of studies on student performance, classroom pedagogy and curriculum the report concluded with several key recommendations:

- The effectiveness of current teacher education and support programmes, both at pre-service and in-service levels, is an issue that needs to be urgently addressed.
- Further, resources for teachers should support and enable the teachers to apply the appropriate conceptual frameworks to their science education pedagogy.
- Research is needed into the extent to which secondary teachers have opportunities to learn about the nature of science during their initial tertiary science education
- A clearer alignment of curriculum content with the pedagogies recommended in this review is needed to support change in teachers' pedagogical practice, especially with respect to curriculum "coverage". (Hipkins et al, 2002, p. 241.)

The report suggested that further research questions remained, particularly in understanding the beliefs and perceptions of secondary school teachers and students about the nature and characteristics of science and the purposes of science education, current New Zealand classroom practice and science curriculum and how this is experienced by students and impacts students' perceptions and beliefs about science.

A recent study funded by Ako Aoteoroa: Parkinson et al (2011), 'Engaging Learners effectively in Science, Technology and Engineering: The Pathway from Secondary to University Education' has answered some of these questions. This research undertaken by Massey University in partnership with four secondary schools is currently investigating the learning environment at secondary school and first year university. The key findings of this report clearly indicate the same issues raised in Hipkins (2002) report and recommend 'that more widespread use of best practice pedagogies and provision of relevant contexts would promote student engagement in the sciences at both secondary and tertiary education levels.' The key principles from the study are:

- Teachers and lecturers influence student engagement
- It is not what is taught, but how it is taught
- Science students want to be scientific

- Student engagement is not lost in transition
- Transition from school science to university science is a process
- There are different perceptions between students and lecturers/teachers.

Recommended responses to these findings are, first, to:

- assist lecturers and teachers to develop skills in the 'teacher efficacy' identified in this project
- ensure assessment practices at school and university reward critical thinking rather than reinforce low order learning
- ensure all content is delivered in a context that is immediately relevant to the learner.

Second, it is recommended that universities consider how to use most effectively the learning outcomes achieved by NCEA students in first year university study, by:

- building on the diversity of knowledge that results from the standards-based NCEA high school education
- guaranteeing liaison between universities and schools to ensure school leavers have the content knowledge needed to start their degrees.'

Several of these recommendations are worth repeating in full as they have direct immediate relevance to the problems faced by universities:

- The process of transition

  Key differences between the university and school environments are that at school, one teacher usually teaches all of a subject and has a considerable pastoral oversight of the progress of the student, whereas at university, subjects are usually taught by many lecturers, each of whom has very limited pastoral oversight of an individual student's progress. Ideally, university teaching should place greater emphasis on independent learning and critical thinking than that of school; yet the results of the present study show that this is not necessarily evident during the first year of study at university. Heterogeneity of study at school means that universities cannot accurately predict the knowledge with which a student will enter university study. Early units of study therefore run risks of either (i) teaching to the 'lowest common denominator' or (ii) presenting material that 'goes over the heads' of a significant proportion of students in the class. Either of these situations impairs engagement.

- Key issues facing universities

  Universities need to identify what core content is essential for entry to tertiary study in a given discipline. Universities and schools need to liaise to ensure that this core content is met by the units that school students study. Universities need to determine how best to build on the diversity of knowledge that results from the unit-based NCEA high school education. Universities need to liaise with schools to ensure universities are conversant with the content and process knowledge that students have attained at the end of secondary education, and tailor their entry-level programmes accordingly. Universities should consider how best to promote integration in first-year tertiary study, particularly with respect to determining how the pedagogical advantages of integration between disciplines can best be achieved in institutions that are largely organised into discipline-based ‘silos’.

- Promoting a more active dialogue about key issues

  Underpinning such questions is the need for a more fundamental dialogue about the pedagogical environment in which science education takes place: The pedagogical environment of science education needs to be developed to promote students’ attainment of intellectual independence and high order cognitive and non-cognitive skills, at all levels of their studies. Assessment practices at school and university need to promote engagement, particularly by rewarding critical thinking rather than reinforcing low order learning. Lecturers, and perhaps teachers, need to be assisted to develop skills in the ‘teacher efficacy’ parameters identified by the present research as being critical for students’ engagement. Consideration needs to be given to the structures and systems that are needed to create institutional environments that are favourable for such developments to occur. (Parkinson et al, 2011.)

The gap between learning and teaching for students transitioning between NCEA and tertiary study is getting bigger helped by the fact that the shift to Student Centred Learning, fundamental to the secondary school NCEA system, has received little traction at tertiary institutions in New Zealand. The acknowledgement of a student centred approach internationally is driving the educational methodology from secondary school to tertiary study into a continuous pathway. This is not the case in the New Zealand educational system which clearly has NCEA and tertiary educators delivering two separate forms of student education.

It is clear that there is a perceived gap between NCEA curriculum and student choices and first tertiary year curriculum. In particular, the expectations of all those involved appear to have little connection with what is being studied. The researchers believe that this has direct relevance to new government initiatives for tertiary funding based on managed enrolment and success based funding. It is also the view of the researchers in the EPP project that universities have an ethical imperative to address poor performance results without lowering the standard of instruction.

What is perhaps more worrying is the even poorer performance, in terms of recruitment and retention, of equity groups in engineering study. Digital engineering study at Victoria University and electronic engineering at WelTec attract few women, Maori or Pacific Islanders. This is not an isolated example; nationally there are extremely few members of these groups involved in the fields of digital engineering. A recent report by IPENZ, Minority Groups in Engineering Education, stated:

> "This report details the levels of attainment by gender and ethnicity at Levels 2 and 3 of the National Certificate of Educational Achievement (NCEA) in the subjects (Mathematics with Statistics, Mathematics with Calculus, Physics and Chemistry) that enable prospective students to gain entry to engineering diplomas and degrees at Levels 6, 7, and 8. Maori have low numbers studying these subjects, low levels of attainment and low retention rates in senior secondary school. Pasifika also have low numbers studying these subjects and low levels of attainment but high retention rates in senior secondary school, suggesting that they require more support to select these subjects and achieve credits in them. Women limit their options by their choice of Level 2 and 3 subjects; they are less likely to choose Mathematics with Calculus and Physics that prepare them for entry to engineering qualifications". (IPENZ, Minority Groups in Engineering Education, 2010, p. 4)

This is a bleak acknowledgement that many members of equity groups do not have the required skills to perform at tertiary level. Victoria University of Wellington requires a B average across its first year Part I of the Bachelor of Engineering, a professional requirement of its accreditation; also a difficult task for students with the required NCEA background in mathematics and physics and an almost impossible task for students who do not have the necessary skills. The removal of bridging courses from universities educational domain directly sends these students who may aspire towards engineering into the trades or polytechnic.

The IPENZ report, like other reports examining equity study in STEM suggests that tertiary institutions develop specific recruitment programmes for equity groups a factor which has been taken into account in the development of the EPP project and have been in operation at Victoria University for many years through the nationally recognised Awhina programme and community outreach. Victoria University has for many years acknowledged the role of support networks and has an extremely active student support for equity groups once students have enrolled at the institution (Wilson, 2011). The problem remains; equity students for the most part, do not choose the relevant subjects to undertake or succeed in engineering study, and this must be corrected at the School level. Yet, connections to equity students to STEM and in particular engineering at the primary, intermediate and secondary school levels remains largely out of the prevue of tertiary institutions and certainly beyond the scope of the EPP project.

Since June 2009, not surprisingly our findings have reflected many of those identified above in the current literature of the field. In summary, students choose engineering for a variety of reasons, such as, parental influence, peer influence, career aspirations, and a desire for a seemingly more practical job, to name a few. Students in turn fail for a variety of reasons, such as, problems with social situations, a misconception about what they are studying transitional difficulties and a lack of ability in subject material prior to the beginning of this study. Victoria University has a sixty per cent failure rate for students in Part I of the Bachelor of Engineering and grade analysis reveals that students are entering the Bachelor of Engineering with poor skills in Physics and Mathematics resulting in their inability to obtain the necessary 'B' average in Part I. While WelTec does not have this requirement it faces a similar situation with many students having poor entry skills in required academic subjects.

The project has attempted to provide an increased understanding of the barriers to successful engineering study, in the Wellington Region. A combined approach incorporating a literature review, student surveys, student focus groups, discussions with secondary school careers advisors and teachers, existing engineering educational providers, such as FutureinTech and BrightSparks, liaison with other tertiary engineering providers, and grade analysis has investigated and where possible provided suggestions to address retention and recruitments issues. Our forms of intervention for recruitment include developing a secondary school outreach programme, outreach materials in the form of booklets, a website, circuit boards, educational posters an outreach, engineering study pathways promotion with secondary school contacts. For retention we have supported the creation of an engineering foundation course at WelTec, development of a student culture and where appropriate developed new or modified existing preparatory courses/processes in place at Victoria. In addition, we have identified student preparation needs and entry level requirements for engineering degree programmes, and where gaps in preparatory courses were identified, amendments have been recommended to the existing programmes. Direct intervention has taken the form of introducing mentoring schemes, extra tutorials, online resources and the creation of a Pastoral Care position.

Part I- Retention

VUW Retention Issues

VUW offers three forms of engineering specialization; Electronic and Computer Systems Engineering (ECEN), Network Engineering (NWEN) and Software Engineering (SWEN).

In the first year of engineering study several courses are common to all three specializations, specifically

- COMP102: Introduction to Java programming
- COMP103: Algorithms and data structures
- ENGR101: Engineering technology

From this commonality, the ECEN specialization requires additional physics and mathematics.

- MATH141: Introduction to Calculus
- MATH142: Calculus

- MATH151: Linear algebra
- PHYS114: Physics 1
- PHYS115: Physics 2

SWEN and NWEN do not require this level of calculus or physics. Instead, SWEN requires:

- MATH161: Discrete mathematics
- MATH177: Introduction to statistics or STAT193 Statistics for Natural and Social Sciences
- SWEN102: Introduction to software engineering
- PHYS122: Basic university physics or PHYS 114/115

and NWEN requires:

- MATH151: Linear Algebra
- MATH161: Discrete mathematics
- PHYS122: Basic university physics or PHYS 114/115

One consequence of this first year structure is that in their first year, ECEN students only take one paper that they consider is engineering orientated (ENGR101). The other papers are considered more science-orientated. This situation is not so pronounced for the SWEN student who also has the engineering course SWEN102, but who often also considers the COMP102 and 103 courses as being highly relevant to their engineering studies.

Proposed changes to the Government funding of tertiary education providers means that degrees with a high attrition rate (or even a high proportion of repeated courses) will be financially penalized. This is of significant concern to VUW's Engineering Programme as we currently have a high attrition rate that had been historically accepted on the basis that we were offering a high quality, professional degree where a high attrition rate indicated that only the ably qualified students were graduating.

Any student who meets the general enrolment criteria for admission into VUW is currently permitted to enroll in the BE degree providing they have met the pre-requisites for any required first year mathematics or physics paper. In order to maintain the quality of the graduating students, students must attain a B grade average (65% or above) over their first year engineering subjects in order to be able to progress.

Table I presents the percentage of students whose GPA permitted them to continue engineering study at VUW. As can been seen the percentage who pass in their first year is quite low, but this does include students who perhaps for timetabling reasons could not do all of the required courses in that year. This is reflected in the number of students who pass after two years.

TABLE I. STUDENTS ATTAINING A 'B' OR ABOVE AVERAGE OVER FIRST YEAR REQUIRED COURSES

Year	% Pass after one year	% Pass within two years
2007	22	33
2008	23	41
2009	28	37
2010	30	32
2011	22	N/A

Whilst there is some attrition at later years, this is small in comparison to this first year figure and almost negligible once students begin their third year of VUW engineering study.

These figures do not differentiate between the specializations. ECEN students are particularly affected because of the calculus and physics requirements. In 2009 only 22% of engineering students enrolled in MATH141 attained a B grade or better. In 2010 this figure was not much improved at 24%. Students who performed well at secondary school Mathematics with Calculus can obtain direct entry into MATH142 without first completing MATH141. However, in 2009 only 28% of engineering students gained a B grade or better, though this improved last year with 37% attaining the required minimum mark. For MATH151 2009 provided an encouraging 47% figure, but this plummeted to 27% in 2010 (due to what we believe to be a change in the lecturer).

This calculus dependency is also exhibited in the grades for the ECEN required PHYS115 course where the number of engineering students attaining a B or above grade in 2009 and 2010 were 25% and 23% respectively. The equivalent figures for the PHYS114 course (that had a somewhat lower calculus requirement) were 35% and 25%. SWEN students completely miss these required physics and calculus courses. Equivalent figures for COMP102 are 44% and 50%, for COMP103 46% and 59%, for SWEN102 65% and 75% and for ENGR101, 49% and 57%. There is no doubt that ECEN students are required to do courses in which the B or better grade is harder to achieve and hence suffer a proportionately greater attrition.

In 2011, the results of the BE were even more concerning than in previous years with only 22% succeeding in passing Part I with the required B average in their first attempt. It is anticipated though that the results will increase to 35% total given the number of repeating students in 2012. As discussed later, steps have been taken to wherever possible rectify this trend.

TABLE II. BE STUDENT PASS RATES BY MAJOR AND COURSE - 2011

SWEN	**Total**	**Passed**	**B or better**	**% B or better**
COMP102	44	37	27	61.4%
COMP103	32	22	11	34.4%
MATH151	9	5	2	22.2%
MATH142	1	1	0	0.0%
MATH161	41	28	13	31.7%
MATH177	8	4	4	50.0%
PHYS114	10	6	3	30.0%
PHYS122	23	22	9	39.1%
STAT193	32	23	9	28.1%
SWEN102	32	31	14	43.8%
NWEN	**Total**	**Passed**	**B or better**	**% B or better**
COMP102	31	21	15	48.4%
COMP103	16	12	10	62.5%
MATH151	17	9	5	29.4%
MATH142	1	0	0	0.0%
MATH161	22	17	6	27.3%
MATH177	1	0	0	0.0%
PHYS114	3	3	1	33.3%
PHYS122	19	16	8	42.1%
STAT193	14	10	7	50.0%
SWEN102	8	8	4	50.0%
ECEN	**Total**	**Passed**	**B or better**	**% B or better**
COMP102	37	23	19	51.4%
COMP103	25	20	12	48.0%
MATH151	32	20	15	46.9%
MATH142	24	16	12	50.0%
MATH161	11	9	8	72.7%
MATH177	2	2	0	0.0%
PHYS114	29	19	7	24.1%
PHYS115	16	11	5	31.3%
PHYS122	4	3	1	25.0%
STAT193	1	1	0	0.0%
SWEN102	4	3	2	50.0%

Table II above clearly identifies the difficulty faced by students in the mathematics and physics classes required for the BE and has directly contributed to the establishment of a pastoral care position and the evaluation and ongoing development of changes to the first year mathematics and physics papers.

Analysis of Student Academic Abilities

An extended analysis of student academic preparedness for university study was undertaken. A better awareness of student ability when they first enter the university can help us to direct the student into remedial physics/mathematics classes if required, direct entry them to advanced classes if appropriate and even to inform a policy of restricting entry to only those who have attained a minimum level of ability that would provide them with a reasonable chance of success.

To inform this study, data were obtained from most New Zealand universities that offer a BE degree in these "digital" engineering subjects. This also ensured our data would not exhibit any regional or university bias. These data consist of the final year of secondary school results and the first year course grades for every student who enrolled in digital tertiary engineering study at VUW in 2009, 2010, 2011, and at the University of Canterbury, Massey University and the University of Waikato in 2009. This provided a database of approximately 400 students in the defined digital areas of engineering.

Correlation analyses and a data mining classification system were performed on the data in an attempt to determine whether these secondary school grades could be used as some indicator or predictor of success at first year engineering. Such a prediction system, if successful, could inform the development of a managed entry system so that only students who were likely to pass the first year engineering requirements were admitted into the degree.

In New Zealand most secondary school subjects are assessed under the National Certificate of Educational Achievement (NCEA) criteria. For most science subjects, the grades of "Not Achieved", "Achieved", "Merit" and "Excellence" can be awarded. Prior to 2011, technology type subjects at secondary school were simply graded under a pass/fail system. The NCEA qualification is considered somewhat controversial, but a discussion on this is outside the scope of the project.

The prediction study differentiated ECEN-type students from NWEN/SWEN-type students, the primary difference being the amount of calculus and physics required of the former. Unsurprisingly, good performance (at the merit or excellence level) in secondary school physics and mathematics with calculus produced the strongest predictor of successful performance for an ECEN student in first year tertiary digital engineering. However, the correlation score of this merit/excellence physics/calculus performance with university GPA was only 0.72 which by itself is not sufficient to form an entrance criteria into engineering study.

For the NWEN/SWEN student there are no courses in our secondary school system that teaches students how to program. There are a number that present computer applications and tools, but not algorithms or languages. This accounts for our failure to find a strong correlation with any secondary school subject and a NWEN/SWEN student's GPA. English ability ranked approximately equally with science ability, but the variation between students was significant, with the top correlation score only being 0.513.

In an attempt to improve these correlation scores, we removed students from the data set that had obviously failed to engage at university, that is, those students whose grades were predominately D or E. This did not increase the correlation scores but science subjects displaced English as being the highest rank NWEN/SWEN correlation.

An interesting finding, and a consequence of the unit standard versus achievement standard assessment of Computer Studies (and technology subjects in general), was a negative correlation with university first year GPA. We obviously would be reluctant in the extreme however, to reject students into a Software Engineering course because they had completed a Computer Studies course at secondary school!

A more in-depth analysis of the data was undertaken using data mining software that also considered individual NCEA modules rather than the subject (or groupings of subjects) as a whole. As a first pass, the new VUW Guaranteed Entry Score of 150 was established as being a reasonable level, although a significant number of students were incorrectly classified indicating that an individual assessment of students is still required.

This data mining was able to utilize the "not achieved" NCEA data for VUW students, whereas the national correlation analyses did not have access to this. Again for ECEN students, the importance of calculus and physics at the merit and excellence level was established. Students who only manage an "achieve" level in these subjects are very likely to struggle at the university level. At the least they must be encouraged to take the lower level mathematics and physics subjects and to make full use of the additional assistance provided.

Diagnostic Test

To more fully inform our predictor, an in-house diagnostic test was developed for the ECEN students, with questions primarily orientated to the mathematical solution of real problems. The diagnostic test was developed in conjunction with staff from VUW engineering, physics and math departments. The diagnostic was trialed at Onslow College, Hutt Valley High and Wellington Girls with year 13 NCEA level 3 Math with Calculus and Statistics classes. This test was successful and then trialed with VUW first year engineering students in 2011.

This diagnostic was marked out of 50 and was delivered on a trial voluntary basis so that we could evaluate its efficacy. We were not prepared to offer students course advice this year based on their diagnostic score until this efficacy had been evaluated.

The results of the predictive qualities of this test were very pleasing. ALL students who scored 30 or more in this test passed all of the first trimester engineering courses (ENGR101, MATH141, MATH151 and PHYS114). Second trimester course results are not available at the time of preparation of this draft paper, but will be for the final paper submission. For students who scored between 20 and 29 (inclusive) in the diagnostic, 86% passed ENGR101, but only 43% passed MATH151 and PHYS114. For anomalous reasons none of the students in this score range were enrolled in MATH141, having been directly allowed entry (perhaps erroneously) into MATH142. Of the students who scored less than 20, only 2 (33%) passed ENGR101, none passed MATH141 or PHYS114 and only one passed MATH151.

We contacted all students who scored below 30 in this diagnostic and encouraged them to engage mathematics and physics support services, including the Peer Assisted Student Support (PASS) where students only a year or two senior assist students who are academically struggling especially the PASS. However, *none* of these contacted students chose to take advantage of this. When asked for a reason, the students invariably made a comment such as “their initial poor results in mathematics were due to their laziness and they were confident that they could later catch up”. They were wrong.

As previously mentioned, the diagnostic was only trialed in 2011 to determine its efficacy. Given the very positive results, this test has become compulsory for all first year ECEN students from 2012, and the results are currently being used to provide a very strong encouragement for poor performing students to enroll in a remedial mathematics or physics paper even if it means the degree takes more than the minimum four years. These students are also being contacted by our newly appointed pastoral support person to determine if additional assistance is required.

We have been unable to develop an equivalent diagnostic for the NWEN/SWEN students, primarily because they do not share a common background as the ECEN students do with regards ECEN’s dependence upon secondary school calculus and physics. Most students entering into NWEN/SWEN have not done programming at secondary school and certainly have not had any instruction regarding networking protocols. A literature search has not yielded an indication that any international institution has been able to develop such a diagnostic.

Conclusion – Student Academic Abilities

Whilst the focus of the investigation into grade analysis was primarily on the academic predictors of engineering success, these must be viewed in the context of social, cultural and expectational influencers. It is well known in the literature that students who should perform well at university sometimes do not, and can actually fail abysmally. This cannot be predicted from school results since it can often be the newly found independence at university that alters a student's behavior. Pastoral care is more likely to be able to help identify and resolve such issues before they permanently affect the student's chances of succeeding in engineering.

Whilst the results and conclusions are based on New Zealand secondary school data, these findings have supported and reinforced the common assertion that:

- performance in mathematics and physics at high school (secondary school) is a predictor of engineering success.

Surprisingly computer studies is not predictor of success in computer science based engineering, but this occurs when computer studies is perceived as an inferior subject (in either grades or scholarship opportunities) so is unlikely to attract strong students and hence is almost a negative predictor of success. Improved curricula at high schools and a modification to teachers' attitudes to the subject at high school should reverse this observation.

VUW Student Views

To gauge students' perceptions of their engineering studies at VUW, a survey was conducted of year 1, 3 and 4 students in 2010. The results of this were independently evaluated by trained evaluators external to VUW, specifically from the Centre for Science and Technology Education Research (CSTER) based at the University of Waikato in Hamilton, New Zealand. Additionally this centre conducted four focus group interviews with engineering students. This independent evaluation eliminates any university bias in interpretation and for the focus groups it provides the students with increased freedom to mention negative aspects of their experience.

Surveys 2010

The surveys conducted with VUW year 1, 3 and 4 students in 2010 queried them on a number of issues related to recruitment and retention. As mentioned, these surveys were independently evaluated by the CSTER personnel. Eighty nine first year students completed the survey, 13% of them female. Most were intending to major in Software Engineering (49%), 22% for Electronic and Computer Systems, 15% for Network Engineering, with 14% not decided. Students were asked whether they believed that their expectations of coming to VUW had been met. The options given were:

- Meets all of my expectations.

- Meets most of my expectations.
- Meets some of my expectations.
- Does not meet my expectations.

The responses to this question are presented in Table III. These results are encouraging, and indicate that at least the first Trimester of engineering at VUW is meeting student expectations.

TABLE III. FIRST YEAR STUDENT EXPECTATION RESPONSES

	% responses
All	6.8
Most	78.4
Some	14.8

The students were asked to rate how well prepared they felt they were for university study on a scale of 0 to 9 where 0 indicated ‘not at all prepared’. On average, they rated their preparedness at 5.8 (+ 2.1). The modal response (illustrated in Figure 2) is clearly ‘reasonably well prepared’, but the deviation is broad. Most students were positive about secondary school preparation.

The mean preparedness did not differ by any of the subgroups looked at, that is there did not appear to be any variation in the responses based on ethnicity, gender or being the first in family to attend university. Over half the first year students felt that the most important secondary school subjects required for studying engineering at VUW were Physics and Mathematics, particularly Calculus. The responses are presented in Figure 3, where “Maths” refers to the secondary school course “Mathematics with Statistics”.

The CSTER report states: “It seems clear that students who have difficulties with Physics, Calculus and Maths at secondary school are likely to continue to have difficulties with these subjects at the higher levels of university study, particularly given the foundational role of these subjects within the engineering programme.” This is in agreement with our analyses of secondary school grades presented earlier.

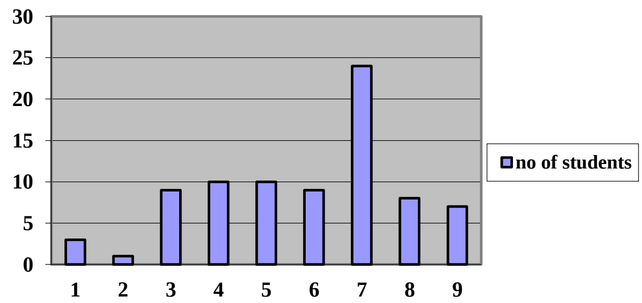


Figure 2. Student response to academic preparedness.

The students were asked to rate their perceived barriers to success in the programme on a scale of 0 to 9 where 0 indicated the factor was not at all a barrier. The listed factors were:

- Lack of ability in academic skills needed for the courses
- Physical or emotional health
- Social activities
- Financial problems
- Living environment
- Homesickness
- Family demands
- Part-time work commitments
- Full-time work commitments
- Community commitments

The students were able to add their own factors if they did not see them in this list. None of the options were rated very highly suggesting that they were not perceived as serious barriers. The highest mean was for Social Activities (at 2.87), followed by Financial Problems (2.82). A reasonable conclusion to draw from this is that there was no systemic barrier experienced by this cohort.

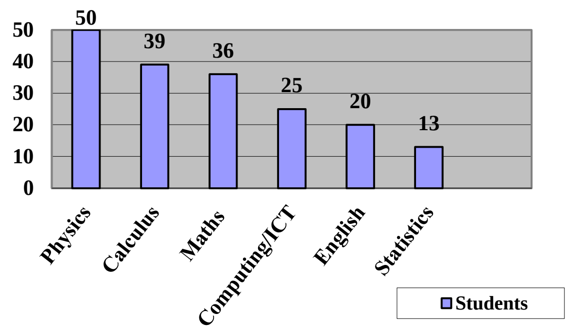


Figure 3. Student ranking of secondary school subjects by perceived importance.

For year 3 students we obtained 16 responses only one of whom was female. Again the students were asked to rate their overall impression of the engineering programme on a scale of 0 to 9, where 9 was the best rating. The programme received an overall mean rating of 6.75 (+ 1.238). The mean rating did not differ by gender, major, or whether or not the student was the first in their family to attend University.

Two students (12.5%) felt the programme met all of their expectations, 7 (43.8%) felt it met most of their expectations, 7 (43.8%) felt it met some of their expectations, and no students felt it met none of their expectations This result indicates that there is a student expectation of engineering study that is not being satisfied during their VUW degree.

The students were asked if they felt they belonged to an engineering community at Victoria. Most (7, 43.8%) were unsure, 6 (37.5%) said yes, and 2 (12.5%) said they did not feel part of an engineering community. This result does indicate that students generally certainly do not strongly relate to belonging to an engineering community at VUW. None of the options related to perceived barriers to success rated very highly suggesting that they were not perceived as significant contributors. The highest mean was for Social Activities (at 3.13), followed by Family Demands (3.00) and Living Environment (2.93).

When queried on which courses they felt were more difficult, PHYS115 was the most commonly identified first year course.

Seventeen fourth year students responded to the survey, two being women. Their overall impression of the engineering programme produced a mean rating of 5.4 (+ 1.7) and did not differ by gender, ethnicity, or whether or not the student was the first in their family to attend University.

However, those in the network major rated the programme statistically significantly lower than the students of the other majors ($F = 4.822$, $p = 0.027$) giving the programme an average rating of 3.67, compared to 6.07 and 6.08 for software and electronics majors respectively.

While none of the students agreed that the programme met all of their expectations, 52.9% said it met most of their expectations, and 35.2% said it met some of their expectations. Two students (11.8%) said the programme met none of their expectations. These proportions did not differ statistically by major. These results are comparable to those of the third year students and indicate some dissatisfaction.

The students were asked if they felt they belonged to an engineering community at Victoria. Ten (58.8%) said yes, 6 (35.3%) were unsure, and 1 (5.9%) said no. Those students who answered yes to this question identified friends they had made during their degree as being the main contributor to a feeling of belonging. Qualitative responses indicated that they did not believe VUW had a strong student engineering culture. First year mathematics, particularly calculus were identified as the first year course they most struggled with. When asked what did they think were the major weaknesses of the first year of the programme, three of the thirteen responses believed there was too much apparently unrelated mathematics in the first year that they did not use later.

Conclusions from Student Survey 2010

The conclusions we take from these Student Surveys is that to improve student satisfaction and hence retention, we need to:

1. Substantially change ENGR101 to give more focus to Engineering work
2. Return student assessments must be returned within two weeks unless there is an extenuating circumstance (for example a major report submitted by a large number of students that requires time-consuming individual feedback).
3. Encourage poorly performing lecturers at the first and second year to seek assistance from the University's Teaching and Learning Development Unit.
4. Work toward developing an increased engineering student culture at first year

Focus Groups

The focus groups were conducted during May 2011. There were two groups of third year students and two groups of first year students. From the former group we wanted to obtain their impressions of what they have experienced at VUW during their engineering enrolment. For the first year groups, we were interested in their impressions of their academic preparedness and whether engineering at VUW had met their expectations. The number of students in each focus group varied between three and five. Two senior academics from CSTER conducted the interviews using a semi-structured protocol to ensure they covered similar areas and both interviewed both year groups.

These focus groups revealed several issues that were relevant to improving our retention. All groups of students expressed significant concern about the late return of assignments which made it difficult to benefit from feedback as they were regularly too late to be of value in the next section of work. Some courses/lecturers were singled out as being particularly bad with months passing before assessment was returned in some of the worse instances.

Students were also dissatisfied with the changing nature of the engineering course requirements. Whilst they understood that some tuning of the programme is required in the establishment phase of the engineering degree, and that "in five years time or so when it's all settled down its going to be really good" – there was a feeling that it has "screwed over a lot of the current students" and makes long term planning very difficult. We are intrigued by this response because should a change in programme occur, our statute permits a student to complete under the old programme or convert to the new one at their choice. Necessarily however, new courses are being created that were not known at the beginning of a students' degree, and some course content is changed when the present form of the course is not meeting our desired learning outcomes. We believed that we had effectively communicated this to the students, and that the impact of these changes was minor. Our degree structure is stabilizing now that we have presented fourth year courses for the third time, but we will be ensuring that any future changes are very clearly communicated.

Students did comment about the very high workload in engineering and that it seems to be higher than many alternative degrees – especially Commerce which also offer a range of computing and programming courses. Weak or struggling students were reported to have abandoned the BE degree in favor of a Commerce one because of the workload issue. We are unlikely to change our workload practices. Engineering by necessity requires substantial laboratory work, it often requires the undertaking of difficult mathematics and physics papers, and project-based assessment that is typical of an engineering degree is certainly more time intensive that comparable assessments in Business or Commerce. A recommendation from the CSTER interviewers is that we conduct exit interviews for all those leaving the BE programme. Whilst we do not always have access to these students (a degree can be exited on approval from the administration office), we will endeavor to do this.

Typically students respond well to lecturers who are engaging and enthusiastic. In the first two years they have experienced a mix of styles, but the third year students report a significantly improved experience at year three when student numbers in the classes have decreased and direct, individual interaction with the lecturers becomes possible.

Third year students generally indicated a degree of loyalty and a sense of connection to VUW based on having spent several years here and the friendships that have developed. However first year students lament the comparative lack of engineering-focused activities, especially when compared to our main competitor – the University of Canterbury – that has been offering engineering for nearly 100 years. Engineering students at Canterbury have become infamous for their alcohol-based culture, which whilst it may be attractive to some first year students, will not be encouraged at VUW. However, this response strongly leads us to consider an increased number and range of engineering-based activities for our students.

Finally mathematics was often mentioned. Students who were poorly prepared at secondary school struggled significantly with the university level mathematics required of the engineering degree. However, the students were often frustrated that in their first year they felt they were doing a science degree rather than an engineering one. This was particularly true of the ECEN students with their heavy emphasis on mathematics and calculus. Further, ECEN students treat the computer science courses as "science" rather than engineering. For these students then, they perceive they are only doing one specific engineering course in their first year, and seven science orientated courses. This leads to resentment and the focus groups anecdotally believe that this has led to a number of first year students abandoning engineering.

Conclusions from Focus Groups

The conclusions we take from these Focus Groups is that to improve student satisfaction and hence retention, we need to:

1. Introduce a second engineering paper for ECEN students
2. Work with the Mathematics Department to provide engineering relevance in the compulsory mathematics courses
3. Clearly and repeatedly communicate any changes to the degree structure
4. Conduct exit interviews to determine if some systemic or fixable issue is leading to a significant number of students exiting the BE degree
5. Work toward developing an increased engineering student culture at first year
6. Provide mentoring and assistance so that lecturers particularly at first and second year level are well prepared, enthusiastic and engaging.

VUW Responses

In response to the focus groups and survey results, whilst we were unable to substantially influence most of the first year courses (as many of the students' core first year courses are not taught by the Faculty of Engineering, such as mathematics and physics-though discussions are underway with these departments), we did alter the core engineering course Engineering 101 - Foundations of Engineering (ENGR101). In line with best educational practice, informed by a recent New Zealand research report, (Parkinson et al 2011), and our survey and focus group findings, significant changes were made to ENGR101.

This involved a change to the teaching and learning practice and emphasized explicit styles of learning rather than simply course content. We know that students arrive into tertiary engineering with a diverse variety of academic knowledge, and importantly, a diverse set of learning styles. Some secondary school preparation in New Zealand has been criticized for encouraging a memorization and regurgitation style of assessment which poorly prepares the student for tertiary study.

The changes to the ENGR101 course were designed to assist in transforming a student's learning style (from consuming to generating knowledge), without creating a prohibitive gap in their learning experience. Woodhead (2009) differentiates between education as 'transforming people' (commonly the modern secondary school approach) and initiation into a body of knowledge' (conventionally the approach at University). The former places the emphasis on the student as a consumer of knowledge, where this knowledge has been modularized and layered, such that they can choose topics that they enjoy at an attainable level. The latter emphasizes complete knowledge of the subject, such that the student may utilize/generate new knowledge. Further, whereas the former emphasizes the middle layers of Bloom's taxonomy, the latter requires all levels. Specifically, the objectives of the ENGR101 redevelopment were:

- To enable students to start taking responsibility for their own learning.
- To show that engineering requires a complete and broad taxonomy of learning.
- To introduce students to relevant and beneficial aspects of engineering as soon as possible.

To enable students to start taking responsibility for their own learning, students first needed to be able to group fundamental related ideas and details together in their memory (as 'Chunks') and then be able to recall the necessary information in order to put it into practice (Awad, 2004). Time management and an attitude of striving to pass assignments at the first attempt were also important skills to foster. The course content was revised to ensure subjects were relevant and digestible; although topics were split up they were related and flowed on from each other naturally. Study skills were integrated into the curriculum in liaison with the University's learning support services. A custom textbook was created containing study advice, which ranged from adapting to university life, time management, report writing, problem-solving techniques, revision guidance and exam practice.

To show that engineering requires a complete and broad taxonomy of learning, subjects were integrated together, such that the students had to learn to decouple their 'chunks' of knowledge into integrated projects, thus learning to apply fundamental engineering knowledge in projects. The main capstone project; that of constructing an autonomous robotic vehicle was a team based active learning exercise. Gaps in knowledge could still exist, but be compensated by other team members and the need for complete knowledge to create a working solution was demonstrated.

Students were encouraged to identify what they knew and compensate for gaps in knowledge. If there was a delay between a student realizing they had a gap in their knowledge and a tutor being available, the student often did not seek out help. This was evidenced by poor attendance at the help desk and peer assisted tutoring system. When questioned, students held the mistaken belief that they could "always catch up" or "could repeat any failed assignment" despite lecturers and senior students explaining to them that this was not the case.

Help was most successful when a tutor or lecturer was immediately available to answer a student's problem as it occurred to them. Thus laboratory sessions with tutors and lecturers being available for up to 15 minutes after the introduction of new material, had a high level of engagement.

To introduce students to practical and relevant aspects of engineering without compromising the academic content or reducing the threshold concepts, laboratories were aligned with teaching and theoretical content was introduced with guidance provided on how it formed the basis of practical engineering systems. Finally, lectures on the benefits of engineering were introduced on topics such as, sustainability and reliability, and Engineers without Borders.

The changes were extremely positively received by the students. There is a corresponding improvement in grade performance and an anecdotal improvement in student satisfaction with the course. Please see Table IV below.

TABLE IV. ENG101 GRADE PERFORMANCE

GRADE	2010-STUDENTS	2011-STUDENTS	2012-STUDENTS
A+	17	5	16
A	10	6	26
A-	6	13	16
B+	6	9	22
B	10	19	17
B-	7	11	8
C+	7	5	12
C	2	6	2
D	9	13	11
E	12	17	23
TOTAL STUDENTS	86	104	153
TOTAL STUDENTS WITH B PASS	39	52	97
% PASS WITH B	45.34%	50%	63.39%

The importance of a second trimester engineering course for ECEN and NWEN students is now also recognized, and this is discussed towards the end of this section.

Another extremely important but embryonic development has been that the results of this study have encouraged our management to actively investigate the first year of the Bachelor of Engineering. A BE Review Committee has convened with the following Terms of Reference:

- Identify appropriate objectives for Part One of the BE.
- Identify any obstacles to achieving these objectives.
- Derive a set of *achievable* objectives for Part One.
- Recommend any changes necessary to achieve those objectives.

As a result of the project this committee has proposed a radical changing of the mathematics offerings at first year. Prior to this study, whilst engineering staff had anecdotal evidence of student dissatisfaction and resulting poor performance in mathematics, it had been difficult to supply the evidence required for substantial changes to be effected. However, as a direct consequence of this investigation, representatives from each of the engineering specializations and the Head of School, are working with mathematics to rationalize MATH 141, 142, 151 and 161 into three engineering relevant courses.

There is no question that mathematics is essential for both Engineering students and Computer Science students, and mathematics must continue to be a component of the first year for both programmes. But it is problematic if the mathematics requirement at first year requires more than 25% (30 points), since this leaves no room for any other options in BE students' first year programme. It is also problematic if the courses required for the different specialisations are very different, since it then becomes very difficult for students to shift between programmes, although many students enter the BE without a clear understanding of what the different specialisations are about and are unable to make a properly informed decision on which courses they should take.

Because of the way the material is currently partitioned, meeting the mathematical needs of the programmes with the current set of MATH and STAT courses is problematic, and the faculty would like to readdress the structure of the first year programme with MSOR to identify a more satisfactory programme.

Ideally, there would be a common 30 points of 1st year mathematics that would meet the needs of all the students. If this is not be possible, it would be highly desirable to have a common 15 points in the first trimester, followed by two alternative 15 point courses for different tracks.

An obvious starting point for this process is for Engineering and Computer Science to identify what mathematics is actually required. Traditionally, this has been expressed as a set of topics in mathematics that are perceived to be essential, usually by identifying all the bits of mathematics that are currently used in higher level Engineering or Computer Science course. However, it is not clear that this is an effective or productive approach, partly because most students forget the details of particular mathematics topics shortly after the exam is over, and partly because there is a very wide range of mathematical topics used across the programme, but no students take courses that require all the topics.

In our view, the real requirement is that our students need to develop a general facility at using mathematics to model and reason about engineering or computing problems, and have sufficient familiarity with an appropriately wide range of basic mathematical tools that they can quickly learn the details of any mathematical topic necessary for a particular course. The focus should be on the process of using mathematics to model and reason about problems and the skills of understanding and manipulating mathematical formalisms used in such models.

Much (though not all) of the content/particular topics that the Engineering and Computer Science courses want to be able to use without explanation are actually high school topics (algebra, logarithms, probability, calculus), but it is clear that high school does not generally give students sufficient facility with these tools. We need courses that will exercise students in the use of these topics.

One issue that Engineering has to work through is the position of calculus for SWEN, NWEN and COMP students. For Electronics and Computer Engineering, especially signal processing, calculus is the most relevant mathematics and students must gain considerable competence at understanding and using calculus for modeling and analysis. On the other hand, most of software engineering, network engineering and Computer Science uses very little calculus; discrete mathematics and probability/statistics is far more relevant. Furthermore, requiring calculus has been perceived as placing a large, and often insurmountable, barrier in the way of COMP, NWEN and SWEN students that would be completely counterproductive to the programmes.

The evidence of engineering student performance in MATH 142 in recent years adds some weight to this argument. However, there are also arguments that any Engineering graduate should have at least some familiarity with calculus in order to be able to communicate effectively with other kinds of engineers. Furthermore, both Artificial Intelligence and Computer Graphics (which are becoming important components of Computer Science at VUW) both use calculus more than other parts of computer science.

Similarly, as alluded to earlier, this study has now produced a wider acceptance of the need for a second trimester engineering course for NWEN and ECEN students. Such a course cannot currently be timetabled for ECEN due to the number of mathematics requirements however, should these mathematics courses be able to be rationalized, there is now a willingness to strongly consider its introduction. The consensus at this stage is that SWEN102 will be deleted and a common second trimester engineering course created that will accommodate all engineering students. The authors' eagerly await the outcome of these deliberations.

While these changes are developed an immediate solution to improve student success in mathematics has been to remedy direct entry into MATH142 for first year students. In response the Faculty of Engineering in association with Mathematics has also agreed to limit direct entry into MATH142 and make MATH141 a compulsory pre-requisite for MATH142. It is hoped that the changes made here will give students the time to develop more mathematical maturity and redress any deficiencies in transition from Secondary School.

Additional requirements for admission to the Bachelor of Engineering for 2013

In 2012, the Bachelor of Engineering had an open entry policy for students who met the Guaranteed Entry Score (GES) imposed by VUW. The VUW admissions page has the following explanation on GES:

The Guaranteed Entry Score (GES) from NCEA is 150 points for all undergraduate degrees, except the Bachelor of Architectural Studies and Bachelor of Building Science which requires a Guaranteed Entry Score of 180. How to calculate your NCEA score:

- Your score will be based on your 80 best credits in University Entrance approved subjects at Level 3 or higher, and weighted by the level of achievement. You can count both achievement standards and unit standards.
- All Level 3 or higher approved subjects can be counted.
- A maximum of 24 credits in each subject may be counted.
- If you have achieved fewer than 80 credits at Level 3 or higher the score will be based on those you have achieved.
- You are advised to take approved subjects and achievement standards wherever possible in your school programme both for entrance purposes and as the best preparation for university study.

Your score will be calculated by awarding points as follows:
Excellence 4 points, Merit 3 points and Achieved 2 points.

As a direct response to our findings the Faculty of Engineering are proposing to increase the entry requirements for the Bachelor of Engineering. Not only will students have to meet the required Guaranteed Entry Score, they will now have to meet the entry requirements for their chosen specialisation.

Table V indicates the NCEA Mathematics/Physics entry requirements for the different BE specialisations, with the equivalent levels required for Cambridge International Examinations (CIE) and International Baccalaureate (IB).

TABLE V. NCEA MATHEMATICS AND PHYSICS ENTRY REQUIREMENTS FOR THE BE SPECIALISATIONS, 2013

Specialisation	**NCEA**	**CIE**	**IB (score 1 – 7 in subject)**
ECEN	16 credits NCEA Mathematics with Calculus 14 Credits Physics	C grade or better A Level Mathematics D grade or better A Level Physics Or A Grade AS Level Physics	HL Mathematics result 4 Or SL Mathematics result 5 HL Physics result 3 Or SL Physics result 4
NWEN/SWEN	16 credits NCEA Maths	C Grade or better A level Mathematics	HL Mathematics result 4 Or SL Mathematics result 5

Note: For CIE: A level is Advanced Level, AS Level is Advanced Subsidiary Level

For IB: HL is Higher Level, SL is Standard Level

Students without the required level of achievement for entry to the BE specialisation of their choice will be encouraged to apply for the Bachelor of Science degree majoring in Computer Science or possibly Electronic & Computer Systems. They may consider transferring into the BE at a later stage. Students will still need to meet the entry requirements for the individual courses, such as Mathematics and Physics.

Develop a sense of Student Community

After investigating our survey findings we decided that the best approach we could make immediately was to develop a supportive engineering culture and community, particularly but not exclusively, for first year engineering students at VUW.

Our solution to the problem lies in developing a sense of student-to-student and student-to-staff communal association through activities outside the classroom where staff and students can mingle. Instead of encouraging students to feel like they were part of the wider institution, we decided to actively support a specific engineering culture and community.

The project members agreed a key factor to achieving a sense of belonging for students was to make engineering staff available to participate in as many activities as possible, while still retaining a student feel to the events. In order to achieve a sense of community, we developed a set of activities to be held throughout the year and to support and extend the events already organized by the student-led Victoria Engineering Club (VEC). Our brief was to encourage participation from students of all years, but also to increase participation by first year students. It was hoped that by increasing inter-year student activities, the stronger sense of belonging exhibited by our third and fourth year students would be shared by second and particularly first year students – those with the highest rate of failure.

Our activities have been developed with the help of the Victoria Engineering Club presidents who facilitated much of the work in helping to get student input into these events. The activities we developed for 2010 are listed below:

- VUW Engineering website
- VUW Engineering Student Facebook site.
- Engineering Pathways Project Website -- GEEK Engineering
- Visit to New Zealand Army base, Trentham, to see the Explosive Ordnance Disposal (EOD) robot
- Formal Friday social event.
- Local area network (LAN) gaming days – held every other month.
- Engineering Student Video Competition
- Pizza, Robots and Prizes night.
- Tour of New Zealand Navy ship HMNZS Canterbury, where students learned about naval engineering practices, specializations and careers in naval engineering.
- Laser Tag gaming night.
- Make your own network cable day, where students learn a little about networking and make a network cable that they get to keep and use in LAN gaming events.
- Tour of Datacom centre in town. Datacom is an industry leading IT solutions and services provider.
- Tour of local printed circuit board (PCB) manufacturing facility.

Staff participation in events was limited to attending the tours, Pizza Robot and Prizes night, where there was a demonstration of robots from around VUW and an informal gathering of students who gathered to see what projects are being worked on around VUW. For most activities staff attended briefly to assist in providing catering for the events. The students reacted extremely positively to being fed and it gave us a chance to see how many people were in attendance and whether there was a good cross-section of students from all years.

The creation of a video competition also received positive student participation. The competition was designed to gain an idea of what the students themselves consider engineering to be and to encourage them to communicate this to others in a video of length 90 seconds or less. The video had to relate to experiences of students in Engineering at VUW. We received a considerable number of entries both from single students and groups from across the whole four years of the degree. Some of the entries received covered existing student projects, a day in the life of an engineering student and experiences in computer labs. The winning entry was a creative exercise in which one of our mobile robots selectively removed non-engineering students from the university's computer hub in order to make room for eager ECEN students.

Formal Friday was an excuse for the whole School of Engineering to dress up in formal clothes, just for fun, and get together to socialize. The evening included playing guitar hero, poker and several other games. Formal Fridays, like the Laser Tag gaming night were excellent student community building events and had a large uptake by the engineering student body.

However, the most popular events by far were the LAN gaming days. The Faculty of Engineering provided space on campus for students to set up and play networked computer games. Student interest in this was considerable and a large cross-section of years attended. This commonality of interest has yet to be fully explored by the Faculty of Engineering but the initial results were excellent and we have tried to continue this each year.

A new initiative has been the provision of a free tee-shirt for all first year engineering students that clearly advertises they are engineers. Senior students are able to obtain a similarly designed sweatshirt. The inspiration is essentially that of sporting teams – supporters wear their team's colors and group identify with each other. We are finding the same result here – the uptake on the wearing of these shirts has been tremendous and is one further step towards students feeling a belonging to an engineering community at VUW.

Evaluation - Surveys End of Year 2010

Responses to the end of year surveys were not as high for fourth year students as those received for the initial survey, though we did receive slightly more third year replies. Poor timing on our part led to us being unable to gain scheduled class time due to exam preparation. That said, the response still offered good results particularly when combined with staff experiences of the activities organized during the year. Overall the student activities had great responses in terms of the number of students attending and in particular with a large student uptake from across all years of the degree.

We asked first, second (though data not included as we have no comparison to trimester one), third and fourth year students several questions on their experience of social events and on what they thought and engineering community was. We received 32 first year student responses, 26 male and six female. Third year student response totalled 17, with 14 male and three female – more than we received in trimester one. The number of fourth year responses, however, was particularly poor, with only four returned surveys. There were no significant differences by any of the subgroups considered.
In question 6 we asked students to explain what they thought Victoria University's engineering community was, and what they thought it should be. The answers we got between years were very positive.

Sample year one student responses:

- VEC to do engineering type things in a social environment. Also projects.
- A bunch of engineers
- Friendly
- A social gathering at comp labs
- It should be bigger
- Should be: More collaborative, i.e. students working together to complete assignments etc, as working in teams is very important for engineers.
- It is good but could be more involving.
- Good for career.
- Pretty interactive and available, not much more to add.
- A community of people who engineer at Victoria University.

Sample year three and four student responses:

- The engineers who communicate with each other.
- 1/ Brilliant, sociable lecturers 2/ Classmates 3/ Those events where we get to wear suits and schmooze.
- Engr environment is good. There is an effort to involve everyone (eg LANs) which makes knowing people better.
- There seems to be small groups of friends in each year and discipline. For me, it is my year group and the course lecturers.
- The engineering community is all about how we can complete work. There is a small amount of external social activities but not enough. I think there should be more regular social activities.
- I think there is a large separation between the ECEN students and the SWEN/NWEN students. We hang out in the lab. It's ok.
- Close knit.
- Good times, very helpful and tight.
- I think it's supportive, but divided into groups depending on majors. It should be more diverse and open.
- I haven't really participated. Too much time spent on study.
- The Engr community is great and student friendly but more industry interaction is needed.

In question 7, we asked students to list what engineering student social activities they participated in to rate their impressions on a scale from zero to 9, where 9 was excellent.

Sample year one student responses:

- LANS, 9. Evenings, 9. Formal Fri, 9.

- VEC LANS 9, Robot Show off Night 9, Formal Friday 9.
- Formal Friday Poker Night – 9
- Meetings 6 Engineering events 6
- Meetings -- 7. Engineering events -- 2. Labs -- 9.
- Engineering Club/Guitar Hero/Pizza Night = 8.
- First engineering club pizza meeting -- 9 -- Free Pizza.
- Pizza evening VEC intro thing = 8

Sample year three and four student responses:

- LAN party. 9, as far as LAN parties go.
- Robots and Pizza night (6)
- LANs, Cable Crimping -- 9
- Trip to the army base weapons simulator -- 8. Naval vessel tour x 2 -- 7. LAN party x 4 -- 8. Learn to make a cable day -- 8. Guitar Hero nights -- 9. Poker nights - 7. Pizza and beer nights -- 8.
- LANs 7. Robots + Pizza 7.
- Poker, 9. Guitar Hero night, 7. LAN, 9. Laser Force, 7.
- Cable Day – 6

For the end of year surveys we asked the students to rate a series of statements relating to their participation in clubs, activities and engineering community, from 0 to 9, where 0 indicated total disagreement and 9, total agreement. Responses to the statement, ‘I actively participate in student activities and clubs’, were excellent for third year students: 52.1 per cent of the students rated it 6 or higher with a mean of 6.53. First year students were still not as active in student activities or clubs compared to trimester one results, with 28.1 per cent giving a score of 6 or higher, with a mean of 4.41. For the third year students, however, 52.6 per cent of the respondents gave scores of 5 or higher, with the single largest group (23.5 per cent) giving scores of 9. The mean score for this question was 6.53.

Student response for the statement, ‘I have made a lot of new friends at Victoria University’ – was positive across all year groups. The majority of the 32 first year students felt they had made some friends, with 53.3 per cent rating 6 or higher. The mean for this was 6.93. Most of the third year students surveyed agreed they had made a lot of friends, with 70.6 per cent rating 6 or higher and a mean score of 7.82. The four fourth year students who responded all rated this factor highly, with ratings of 5, 6, 8 and 9, and a mean of 8.00.

Likewise, all student groups gave high scores for the statement, ‘I feel part of the engineering community at VUW’. Of the first year students surveyed, 64.5 per cent gave a rating of 5 or higher, with the mean for this question of 5.87. Responses by third year students to feeling part of an engineering community were also excellent, with 76.5 of the students surveyed rating it 6 or higher. The mean for this was 7.88. The fourth year students surveyed agreed that they definitely felt part of the engineering community at VUW, with a mean of 8.50.

Despite the low first and fourth year response rates, the third year student response rate was good. The qualitative comments made by all the students were excellent; emphasizing what we were doing in terms of activities and events was having some positive uptake amongst the students. The large numbers of students attending these activities adds to the results, albeit anecdotally, and suggests a developing sense of engineering community. Excepting the third year students, the low rating for the question about student activities and clubs is a little perplexing, given the large number of students attending the student events. However, this could also be due to the numbers of students involved – as hinted at by the low numbers of first and fourth year student responses. For example, where we received higher proportions of responses (17 of the 43 of the third year students) the results were considerably more favourable, with a mean score of 6.53.

Evaluation – Trimester One, First Year Student Surveys 2011 and 2012

Subsequent surveys were been carried out in 2011 and 2012 with first year students. Responses to academic preparedness and barriers to study reflected extremely similar responses to those of 2010. However, there were general improvements in belonging to a sense of community and whether VUW had met student expectations in both 2011 and 2012.

In 2011, 90 first year students completed the survey, 7 Female and 83 male. In response to the question: On a scale of 0 to 9, where 0 = totally disagree and 9 = totally agree, please indicate how much you agree with each of the following statement: I feel part of the engineering community at Victoria University, the Mean was 6.59 with a standard deviation of 2.46, showing an improvement on 2010.

When asked to indicate what first year subject required the biggest jump in ability and knowledge from what you had done at secondary school, most students identified MATH151.

When asked: How do you feel your overall expectations of studying Engineering at Victoria University compare with your experience so far?, 17% (15) students agreed that the programme met all of their expectations, 66% (59) said it met most of their expectations, and 18% (16) said it met some of their expectations. No students said the programme met none of their expectations. These proportions did not differ statistically by major.

In 2012, 143 first year students completed the survey, 14 female and 143 male. On a scale of 0 to 9, where 0 = totally disagree and 9 = totally agree, please indicate how much you agree with each of the following statement: I feel part of the engineering community at Victoria University. The Mean was 8.28 with a standard deviation of 1.41, showing an improvement on 2010 and 2011.

When asked to indicate what first year subject required the biggest jump in ability and knowledge from what you had done at secondary school the students predominantly referred to three papers MATH151, COMP102 and PHYS (no specific paper, and ENGR101. The student comments below are a good indication of the type of comments received for the courses identified:

- MATH151. It's not very similar to calculus and it's MUCH harder.
- COMP102. No previous programming, My computing class at school only really dealt with powerpoints and spreadsheets
- PHYSICS. Big jump in. Sort of different to secondary schools physics
- The Engineering (ENGR) because it is about a bit of programming, maths and everything else i would need to know about the engineering courses

When asked: How do you feel your overall expectations of studying Engineering at Victoria University compare with your experience so far?, 20% (28) students agreed that the programme met all of their expectations, 66% (94) said it met most of their expectations, and 14% (20) said it met some of their expectations. One student, 1%, said the programme met none of their expectations. These proportions did not differ statistically by major.

It is apparent that the continued ongoing support staff have given the Victoria Engineering Club since 2010 and the changes we have been making to first year papers have been having an improvement on a sense of community and satisfying the expectations of engineering students.

Pathways between Institutions

A key aspect of the EPP project has been the strengthening of ties between VUW and WelTec for both staff and students. The challenges of two large institutions working together to promote engineering in the Wellington region and recruit students, while complex, have been for the most part mitigated by the enthusiasm of the projects members. While we are both looking for increased student numbers, our research has made it plain that we are not looking for the same students. The BE and BEngTech have minimal overlap, with each having a relatively narrow focus in terms of ‘digital engineering. WelTec, of course, has several other streams of engineering which sit outside the scope of this project. Yet, where there is overlap there has been cooperation in the forms of raising awareness in the public about digital engineering, and where appropriate engineering in its broadest sense.

To formalise the transfer of students who, for whatever reason, find themselves doing a course that is not the right fit for their needs VUW and WelTec have instigated the process of formally agreeing on a Memorandum of Understanding (MOU) to facilitate this.

Since the initial discussions on this, there have been major changes both in WelTec's operation with the agreement between Whitirea Polytechnic and major government changes to tertiary education. For example, the limitation of funding for students to 200 weeks allowance adds a complication to students adding extra years onto their study by switching tertiary provider.

However, despite these challenges there are still great benefits for VUW and WelTec to work together to enable students to make informed decisions on which engineering qualification to undertake and to implement a credit transfer facility. This cooperation will underpin the values and goals of both VUW and WelTec and will also support existing training and development provided by them.

Currently the MOU is going through its final stages with both senior management teams and will be in place from 2013, enabling students to transfer study credits between institutions.

In addition to the MOU through the Pastoral Care agent at VUW students are beginning to be identified enabling course advice and intervention at a relatively early stage which will assist in student identifying their appropriate course of study. In the recruitment section below there is also a description of the joint awareness campaign and its resources which have been developed to showcase to students both qualifications and study options on an equal footing.

Pastoral Care and Student Support Services

VUW runs an exceptionally successful Te Rōpū *Āwhina* whānau programme designed to assist indigenous Maori and Pacific Island students in Science and Engineering study although it is being opened to include any student facing transitional difficulties (Wilson, 2011). This whanau- (a Maori phrase meaning "family") based approach provides daily interaction with these students, and problems are quickly identified and solutions put in place. It is this model coupled with the TEC projects research that inspired our creation of a pastoral care position.

A variety of non-academic issues including transitioning into tertiary study are well known to contribute towards tertiary success and were identified as contributing barriers to first year engineering students by student surveys and focus groups conducted by the Faculty of Engineering at VUW as part of the Tertiary Education Commission Engineering Pathways Project.

Our research also identified, students often fail to access support, believing that they will catch up. This fact has been attested to by the fact that in 2011 no engineering student attended the Student Learning Support Service (SLSS) Peer Assisted Study Support (PASS) groups set up for difficult math courses. One conclusion is the belief that this behaviour stems from the way many students game play NCEA at Secondary School. The effect of this at University where the workload is increased, often with unfamiliar subject matter, and where there is the new pressure of transition to more self-directed study can severely compromise a student's ability to succeed.

As already discussed to further our understanding of barriers to successful study for engineering students in their first year VUW has continued the accumulation of student performance data and trends. We have worked alongside the VUW Information Technology Services (ITS) team to develop a series of automated reports which contain BE students VUW guaranteed entry score (GES) and NCEA level 3 results and coupled this with our diagnostic test for student math and physics skills.

Examination of an ECEN student's NCEA grades and diagnostic test score is enabling us to identify at risk students at an early stage. Development of an early diagnostic has not been possible for the NWEN/SWEN students. However, for all groups we have been able to identify students who on the surface look like they will have difficulty in achieving the required 'B' average for Part I of the Bachelor of Engineering. These students are categorized into three classifications: 0-Likely to Fail, 1-Likely to need Help and 2-Likely to Pass. This forms the beginning of our analysis for developing a predictor.

While the development of a predictor is in its earliest stages we worked to develop a system that looked at the predictor and student results and coupled them with first year student performance. The programmers at the school of Computer Science and Engineering in association with VUW Te Rōpū Āwhina whānau programme developed a first year student course grade reporting system called 'Big Sister'. Big Sister reports on students grades as they progress through their papers. Ethics approval was granted to the Faculty of Engineering to gather student information and conduct research on it. Currently the Big Sister programme reports on all first year engineering, computer science and physics papers and students are automatically opted in for these papers. For the first year math and statistics papers students opt in through the signing of a release form (this is a MSOR Head of School requirement.) This has been running since March 2012 and acts as a system of early warning of poor university performance.

The data is available as an on-going report, snapshot illustrated in Figure 4 and allows the pastoral care staff member (for Engineering and Computer Science students) and the team at Awhina (for general Science students) the ability to quickly (within two weeks or less of an assignment or tests date) identify poorly performing students. It also allows identification of not only individual students but an analysis of class performance and offers an ability to see problematic assignments.

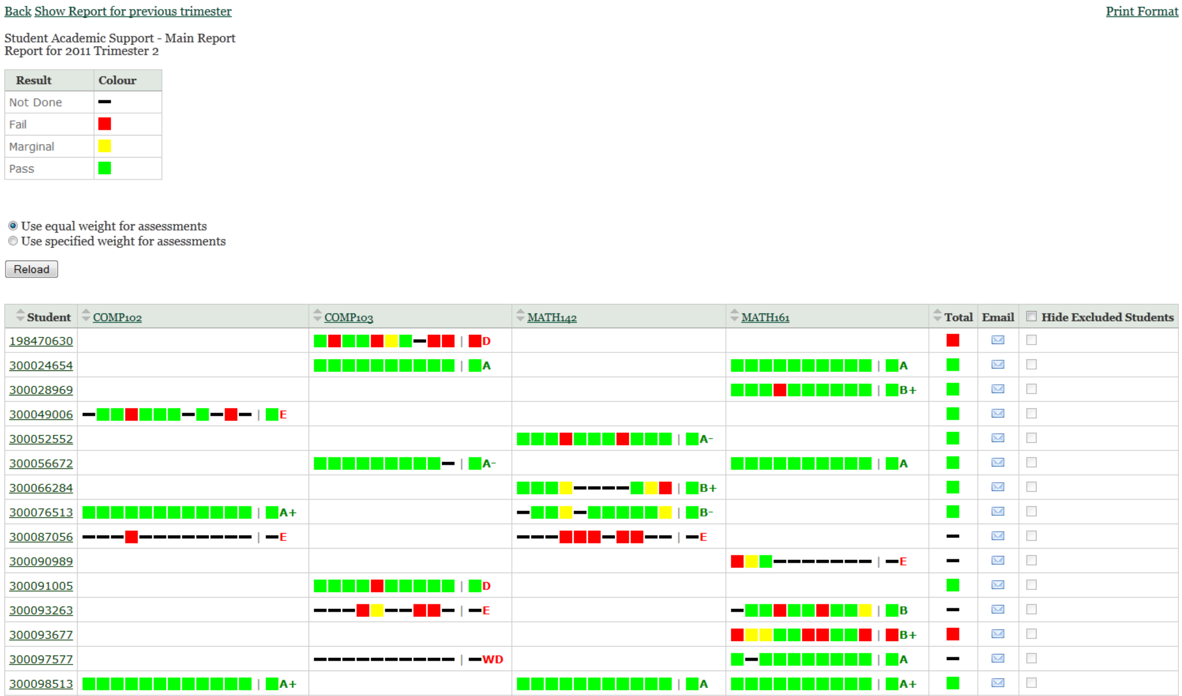


Figure 4. Snapshot of first year student course grade report.

Our pastoral support agent then directly contacts students in difficulty to discuss their progress and gain an understanding of the barriers facing them. If students agree to meet then the pastoral care staff member provides them with ethics forms, interviews them and collects notes. Then advice on accessing the appropriate assistance is provided. Often this involves maintaining informal regular contact with a student to ensure they are accessing the recommended assistance. If non-academic issues are identified the student is encouraged to contact the appropriate support service at VUW.

The aim of this collection is to be able to target individual at risk students with an offer of advice and assistance, and thus help students experiencing difficulty in achieving satisfactory performance in Part I of the BE.

The uptake of students accessing the pastoral care agent has been extremely positive. Over 60 students 39% of the first year student cohort have been to pastoral care with 49 agreeing to release information. Students from other years have also begun to seek help from the pastoral care agent. In addition the information from the interviews has provided excellent information for staff regarding their courses and the faculty regarding student engagement and progress.

To strengthen the help available we increased the efforts to support PASS groups and develop an additional Engineering 101 (ENGR101) tutorial. Two PASS groups operated in trimester one, 2012, one for MATH141 and another for MATH151 as a direct result of referral by the pastoral care staff member. All of these extra initiatives were well attended by engineering students. As mentioned earlier, in comparison, no student from engineering attended a PASS group in 2011. We have also set up a PASS courses for trimester two for MATH142, MATH161 and ECEN220 a difficult second year paper.

The results of the pastoral care are extremely encouraging. In trimester one, 2012, 46 students achieved an A- average and 77 a B average. Last year the same numbers were 21 and 45.

Examples of the type of support offered to students in 2012 include:

Pastoral Care

- The Faculty of Engineering has a dedicated staff member, who is available to discuss any issues you may be having with study and who is able to offer support for you in accessing the correct forms of help. This is suitable for any student in need of some help. Students can drop in anytime or make an appointment.

Engineering 101 course tutors

- There is an Engineering 101 help desk every Thursday. No appointment is required

Engineering 101 Forum

- The Engineering 101 forum is a useful place to raise questions and interact with tutors.

ECS School Office

- School Office is the first option for every day queries and will also know who to direct you to if they cannot help immediately. Suitable for day-to-day queries, rather than academic ones. No appointment is required.

School of Engineering and Computer Science - Staff members

- Designated staff, such as the Senior Tutor, in the school are able to advise women students, Maori and Pacific Nation students, international students and students with disabilities about any specific concerns. Students must make an appointment.

Victoria Engineering Club

- Victoria Engineering Club offers an unstructured, ad hoc and unguaranteed support service.

Awhina

- Students mentors for Maori, Pacific Nation and other students. Suitable for everyone who enjoys guided and group learning. If the freedom of University compares unfavourably with the structure of school/college, then Awhina helps provide mentoring within a supportive framework for learning. Students must make an initial appointment and then can turn up any time.

PASS (Peer Assisted Study Support) groups

- PASS groups are voluntary sessions, led by a fellow student who excelled in the course last year. By promoting 'active learning', PASS Leaders foster a supportive environment where you can meet other students, consolidate subject understanding and develop effective study strategies. Students sign up during the term.

Student Services Group

- Student Services Group Student Academic Support Services offers a wide range of support at Victoria University, from health care to financial assistance in times of need. Suitable for all students in the University rather than specific course queries. Students must make an appointment.
    - Accommodation
    - Career Development and Employment
    - Chaplains
    - Counselling Service
    - Crèche
    - Disability Support Services
    - Financial Support and Advice
    - International Student Support
    - Library
    - Maori Student Support
    - Pacific Student Support
    - Student Health Service
    - Student Learning Support Service
    - Te Pūtahi Atawha- Maori and Pacific Student Success

Student Learning Support Services

- Student Learning Support Services is a great place for learning how to learn and improve the skills associated with the academic study. Transferable skills such as speaking, writing or understanding what needs to go into a laboratory report, can be provided here.
- SLSS sessions for Statistics also run every week. No appointment is required for SLSS sessions: just turn up.

Student Learning Support Services Maths Drop-in Workshops

- These workshops are for students requiring support in any course containing mathematics. Students need to bring examples of problems to work through and run three times a week.

Maths course tutors – School of Mathematics Statistics and Operations Research

- Mathematics have standard tutorials for each course during teaching weeks except for week 1. Good use of the course forums is made for students to ask ad hoc questions. They also run a mathematics helpdesk during teaching weeks except for week 1. Students can drop-in with any maths questions they have.

Stats Drop in Help Desk - School of Mathematics Statistics and Operations Research

- 2 hour Help Sessions run every week during lectures. No appointment is required for these sessions: just turn up any time during the 2 hour period.

Disability Support Services

- Disability Support Services aims to give students with impairments the same opportunity as other students to demonstrate their abilities. Students must make an appointment.

Victoria University of Wellington Students Association

- VUWSA is also available for welfare and representation needs. Students can drop in anytime during the week.

It is hoped that this position will be maintained – pending evaluation from 2013 onwards.

WelTec Response: A Foundation Course in Engineering

Data from WelTec course completion rates from 2006 to 2009 suggest that students in the engineering diplomas are underperforming. This is especially true in mechanical engineering where course completion rates are sometimes below 40 %. An analysis of the 2009 cohort suggests that of the 88 students entering the diploma programme, many came into that programme with low achievement in mathematics and science in particular at college level. This is shown below in table VI.

TABLE VI. NUMBER OF STUDENTS WHO HAVE ACHIEVED AT THESE LEVELS

N=88	NCEA Level 1	NCEA Level 2	NCEA level 3
Mathematics	44	45	16
Science	38	31	18

This tells a story of a substantial drop off in the development of science and mathematics foundations at school level. Additional data collected over these three years by tutors who have taught engineering to this cohort has pointed to identified gaps in knowledge, particularly in calculus, thermodynamics and electrical theory, as well in physics fundamentals. These particular aspects of the school curriculum are necessary for the development of engineering concepts throughout the diploma course.

At the time of this project's inception in 2009 WelTec was preparing to offer the Bachelor of Engineering Technology for the first time in 2010 as part of the Metro Group of Polytechnics. It was perceived that poor fundamentals would create a significant entry and retention barrier to WelTec certificate, diploma and BEng Tech courses. It was decided that a foundation course at WelTec would greatly assist students in overcoming these barriers.

With the changes to the Government restrictions on offering preparation courses imposed on the universities, an engineering preparation course was developed to specifically prepare students for WelTec's Diploma level courses although poorly prepared students considering the BEngTech degree were also encouraged to enroll. A complicating factor was that this course had to cater for mechanical as well as electronic/electrical students.

To develop an active learning classroom environment with improved problem-solving skills we decided to incorporate a 'balance between quantitative problem reasoning and problem solving with qualitative reasoning and conceptual understanding' (Knight, 2004). In the learning design, the Force Concept Inventory and Mechanics Baseline Test were used to identify conceptual difficulties for which a combination of practical and theoretical interventions was administered (Hestenes, 1992). Curriculum features included:

- Content based literacy
- Constructing science knowledge through project based work
- Developing communities of practice

Addressing the content based literacy feature, the development of writing and reading skills within the context of a particular discipline has the combined effect of not only developing the technical aspects of writing that are peculiar to a discipline, but also the advantage of inducting students into a discourse community based on the discipline.

The conceptual development of key ideas in the core content areas is important, however, since this curriculum is more focused on process skills and developing key literacies, a core competency in learning content is for students to learn how to question and interrogate new and also existing ideas in order to construct new knowledge for themselves. In a sense, the content is not important, except that it must be authentic "engineering – focused" content. Project based work is ideal for this situation in that it creates a flexible learning context through which an engineering community of practice as well as different scientific concepts can be developed. In this course, the construction, modification and testing of a steam car (Figure 5) was the project that was undertaken by each of the students in the course. Through this project, physics concepts of energy, thermal interactions and motion were presented. A summary of the topics presented in this course is provided in Table VII. A review of the amount material presented is underway and some changes have been made to the course to address the fact that not all of the topics could be covered in the expected depth given the tight timeframe of the course.

TABLE VII. TOPICS OFFERED IN THE ENGINEERING FOUNDATION COURSE

UNIT	Topic
1	Introduction to Engineering
2	Statics
3	Force and Motion
4	Simple Machines
5	Thermal Interactions
6	Final Project

A total of 24 students were selected and their secondary school results recorded. The module was offered free of charge to students agreeing to participate in the project in the four weeks prior to the start of the first semester. Materials were printed and the module was taught in an intensive four week programme of 6 contact hours per day. Teaching activities included lectures, tutorials, practical work and computer simulations. These were integrated together, so that there was no differentiation between these activities.

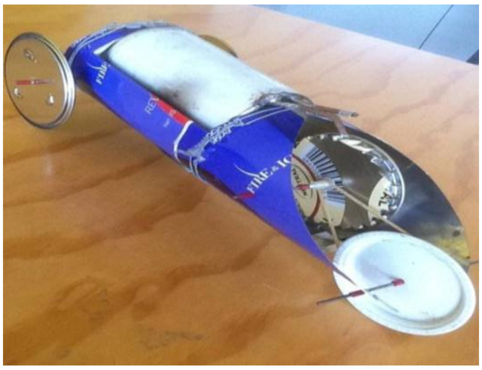


Figure 5. The steam car used as the project application in the foundation course.

Student impressions of the course were favorable. Survey results indicated that most enrolled in order to gain a better understanding of science and technology and to develop skills for the workplace. The most significant perceived barrier to their studies was a lack of ability in required academic skills. The students were happy with the teaching (a rating of 4.5/5) and the course was rated at 4.4/5.

Whilst student impressions are a useful indicator of course success, the objective of this foundation course is to provide students with the academic skills to succeed at mainstream study. A comparison with those students in engineering who did not participate in the foundation course was done by comparing the mean scores between the two groups using a t-test for significance at the 95% level of confidence for groups <30. The foundation students (*n*=16) were compared with the mainstream students (*n*= 36). This was for the pre and post force concept inventory (FCI) tests that give an indication of conceptual understanding of the physics subject matter that was taught.

The first comparison of the means shows that there was no difference statistically between the two groups on the pre-test [$t(50) = 0.72$, $p < 0.05$]; however, it appears that those students who had gone through the foundation course responded better to instruction than did those who had not, as there was a significant difference between the two groups on the post-test, with the foundation students outperforming the mainstream students [$t\ (50) = 2.41$, $p < 0.05$]. Given that the foundation students were initially selected from an academically weaker population of applicants and that the focus of the course was on developing core skills in physics as well as an identity as an engineer, this is a positive outcome.

To further evaluate the effectiveness of the foundation course, a comparison of the overall first year grades was undertaken between those students who participated in the foundation course and students who were directly admitted into the diploma programme (mainstream students). Recall that students were selected to enter this foundation programme on the basis of school grades being too poor to permit being admitted into a Diploma course. The normal expectation would be that in the absence of any intervention, these students would perform poorly. The mean score for these foundation students over their first year diploma courses was 59.7%, compared with 54.6% for mainstream students. Whilst this result is not significant at the 5% level [$t(65) = 0.96$, $p<0.05$] it does clearly indicate that these students have benefited from enrolment in the foundation programme.

We believe that this foundation course has succeeded in meeting its objectives. Critically WelTec are sufficiently satisfied with the results of this course that they have undertaken to resource it and continue to offer it. Whilst this course cannot be credited as a component of VUW's BE degree, we are considering advising marginal students to enroll in this course subject to additional places in the course being available.

Retention Conclusion

New Zealand is well below the OECD average in terms of the number (and relative percentage) of engineering graduates it produces. An approximate doubling of engineering able graduates is required. Whilst there are recruitment issues relevant to this, this paper has explored barriers to successful retention of these students and mechanisms to remove or mitigate the effect of these barriers.

Enrolments in the Engineering BE at Victoria University of Wellington suffer an attrition rate that is no longer acceptable under the revised Government funding models. Identified contributors to this high attrition rate are poor academic preparedness, the degree not meeting the students' expectations and high workloads.

Universities in New Zealand are being discouraged from providing foundation courses; however, no such restriction is imposed on the polytechnics. Consequently a foundation engineering course was constructed and hosted at WelTec. The results of this have been extremely encouraging, with students who normally would not have been able to enter the polytechnic at all on the basis of poor secondary school grades, performing comparatively to mainstream students at the completion of this foundation course.

Student surveys and focus groups undertaken at VUW have emphasized the importance of meeting student expectations, both in terms of material that is presented in courses and in terms of belonging to an identifiable group. In response we have dramatically altered the content of our core engineering paper at first year. The emphasis is strongly on design and build, with the students constructing a robot based on an Arduino processor that then competes in an Olympic series of events.

Simply directing students to access academic assistance has not been successful. Modeling on the "Awhina" programme, we have employed a pastoral care person with responsibilities to identify students who are performing poorly at an early stage, to engage with this student to determine if there are any underlying non-academic issues, to guide this student to accessing academic assistance, and then to continually monitor, in a supportive manner, their use of this assistance.

Since VUW's engineering degree is relatively new and quite small, students have indicated a disappointment that they have not encountered the strong engineering student culture that is present at the more established institutions. In response we have actively supported the creation of a student engineering club, have sponsored events, organized visits, and provided a giveaway tee-shirt and sweatshirt so that students can see that they are part of a wider engineering community. Whilst this might at first seem trite, the adoption of this "uniform" has been very enthusiastic and widespread.

VUW is also engaging in a major review of its first year mathematics offerings to Engineering. The Mathematics Department has signaled its willingness to make these courses more engineering relevant and to consider the rationalizing of the first year offerings. This would also make possible the introduction of a dedicated second trimester engineering course. The physics department has also been extremely cooperative in developing changes to PHYS122 that reflect more of an engineering related curriculum. In 2013 these changes should be in effect.

These modifications to VUW's engineering programme are newly established and require on-going development. However, we expect that the installation of a pastoral care agent providing early and continued intervention for at risk students will significantly improve our retention of the averagely performing student.

Part II - Recruitment

Overview

Recent New Zealand research by the IPENZ identified a number of issues that contribute to student recruitment in tertiary engineering. They determined that the three main factors that contribute to a student's decision of secondary school subject choice are their interest in the subject, their academic ability and the perceived career opportunities. However, additional significant influencers in this subject selection decision include the opinions of their peers, parents, teachers and careers advisors[4].

These findings are very important given that engineering is not specifically covered in our secondary school curricula. Students are able to participate in science (physics, chemistry, biology) and technology (materials, computer applications, etc.) classes, but are generally unaware of how engineering is a distinct discipline. So given that one of the primary motivations of students is subject interest, the absence of engineering options at secondary school level significantly impacts on the number who choose to pursue tertiary level engineering. Interestingly 86% of the secondary school science teachers we surveyed did NOT believe that students are sufficiently aware of engineering or applied science careers in New Zealand.

To compound this, our research (based on focus groups and student and teacher surveys), also found that many of the students' influencers, specifically their secondary school teachers and careers advisors are themselves often unaware of engineering as a distinct discipline and especially the variety of new careers that engineers are now entering into. Many still think that engineering is only about building bridges and tall sky-scrapers.

With a lack of knowledge of engineering options, engineering capable students often abandon the enabling subjects of calculus and physics as they struggle to see the relevance of these courses in their future studies. IPENZ have recognized that intervention is necessary to improve this situation. Their published opinion is that students need to be targeted at secondary school and that, "While some students may go to university and only later decide on a career, tertiary education is too late to foster interest in engineering; career choice needs to be made before leaving school, and indeed before subject choices are irrevocably decided" (Schagen, 2009, pp. 34-35). Additionally, it is well known that it is more difficult to up-skill in mathematics later in life especially if the foundation skills were not obtained during secondary school.

To address some of these issues the New Zealand Government in association with IPENZ created an organization called Futureintech. Futureintech uses student ambassadors and graduates to promote an awareness of science and engineering in schools across the country for all age groups. They have an active campaign but are non-institutionally specific in their approach and as such cannot be directly involved in promoting any institution in a given area. They are also more oriented towards the traditional areas of engineering rather than our offerings in the “digital” area. One of the goals of the project was to avoid replicating the excellent work done by Futureintech.

In addition, VUW and WelTec face several more specific challenges in attracting students. In New Zealand terms, VUW is an old University (established in 1897) and has a significant reputation as being a quality provider of law, government studies and commerce degrees. Whilst the successes of its science schools have been numerous and substantial, it has been difficult to alter the perception of students, teachers and parents who continue to view VUW as a conservative institution that still focuses on the business, legal and politics arenas.

As mentioned earlier, WelTec is a traditional provider of engineering trade qualifications with established certificate and diploma programmes. However, WelTec is new to the field of providing a BEngTech and suffers from the same competition as VUW by established providers and has an additional barrier in that its degree qualifications suffer the perception that they are not as good as those from a university.

In order to address the findings of this research and to avoid repeating or replicating the work of Futureintech, we developed solutions that focus on being both discipline instructional and institutionally promotional. Thus, the recruitment strategy targeted two student groups; those who wish to pursue engineering and are considering the institution best suited to their interests; and those students who are engineering capable but are ignorant of engineering opportunities. An important part of the strategy was the need to ensure that both WelTec and VUW were seen as equal degree providers, with the only difference being the subjects taught.

The following section details a case study of the traditional marketing approach undertaken in 2010 at VUW that resulted in an average success rate. Subsequent sections detail the innovative approach undertaken in 2011 as part of the TEC EPP project that appears to have contributed to a substantial enrolment increase at VUW and WelTec.

2010 Marketing Case Study

At the beginning of our 2011 academic year (March), a survey of first year VUW engineering students was undertaken to determine what factors influenced their decision to enroll in engineering at VUW. A similar survey was not undertaken at WelTec in 2010, during the first year of the BEngTech as it was felt that many of the subsequent 20 WelTec students were already known to the staff from the certificate and diploma courses.

The survey had a return rate of 88 respondents out of a total of 105 surveyed first year students. One question from this survey asked the students to "Please advise us how you found out about Engineering at Victoria University". The students were allowed to enter as many options as were relevant. The survey results are presented in Table VIII. The "other" category allowed students to enter any options not explicitly listed. Responses to this field included ex-girlfriends, an "IT guy at work", the Ministry of High Education in Saudi Arabia, and School/University Career Exhibition.

Some explanation of these fields is required to place them in an appropriate context. The television advertising was very limited. At the time New Zealand had six easily available free-to-air television channels (although more are available with an appropriate digital decoder). One channel was targeted specifically for younger viewers, from approximate ages of 13 through to 25. VUW as an institution chose to advertise there and profiled four areas in separate advertisements, engineering being one of them. Budget restrictions meant that frequency of play was low compared to many other television marketed products.

TABLE VIII. SUMMARY OF STUDENT RESPONSES IN 2011 TO ADVISING ON HOW THEY FOUND OUT ABOUT VUW'S ENGINEERING DEGREE

Activity Description	Number of students selecting this option	Percentage of students selecting this option
Attending Open Day	47	53
Friends	46	52
School Careers Advisors	33	37
Website	27	30
Parents	22	25
Secondary School Teachers	23	26
School Visits by Eng. Staff	19	21
Attending Eng. Outreach Activity	9	10
Publicity Posters	6	7
Engineering Facebook Page	4	4
Television Advertising	5	6
Eng. Sponsorship of Events	2	2
Newspaper Advertisements	2	2
Sponsored Television Interview	1	1
In-Game Advertising	1	1
Other	14	16

VUW Central Marketing also paid for two interviews by a popular television presenter. These interviews each featured a selected fourth year VUW Engineering student who profiled their project and discussed the innovative and modern engineering degree at VUW. These interviews were only aired once, but can be viewed at http://www.engineering.geek.nz/cool-stuff/cool-videos.

Engineering also sponsored "Armageddon" which is a form of sci-fi, comic and gaming convention that attracts a considerable number of students in our target range. Information on Armageddon can be found at http://armageddonexpo.com/nz/. This sponsorship allowed us to insert promotional material into the give-away bags. We provided a one page advertorial for VUW Engineering and an entry form to enter into a competition to win a Mac laptop simply by registering at our website.

Our most innovative marketing feature was to insert a dedicated advertisement into the most popular on-line games available through "Massive" The advert featured the VUW logo, and the caption "Don't just play it. Create it". We were charged by the number of 10 second cumulative views of the advertisement and consequently we believed that this would be a cost effective method of directly targeting our prime audience.

A final point of interest, is that for students who only ticked a single information source box, that box was most likely to be one of; Friends, Open-Day, or Website. No student was prepared to enroll based solely on their parents' advice, but a substantial number did seem make their decision based only on their friends' opinions. Similarly a large number of students claim to have found out about our engineering offering solely through attending our open-day (normally arriving as part of a secondary school coordinated group), or else via our website.

We knew that the sponsorship of Armageddon had gone poorly due to a very low number of responses to our 'win a computer competition' and so we were not surprised at the low number of responses in the survey. The In-Game advertising results produced unexpectedly poor results. Our expectation was that this would be a very targeted and cost effective strategy. As a result of these responses, we have discontinued both these forms of marketing.

Newspaper advertisements are targeted primarily at the students' influencers, particularly the parents. We are not surprised at the very low student response rate to this category but have continued it since parental advice is still a significant contributor.

Students entering our outreach programme were also surveyed and asked "if they previously knew about engineering at VUW then where did they get that information from?". Our expectation was that the results of this survey would be different to those presented in Table VIII since these students have not yet decided to engage in tertiary engineering. Out of 82 surveyed students 54 answered this question. The highest response, at 35% was for school teachers being their information source. This is not surprising since they were at VUW as part of a school trip. The next highest responses were careers advisors 28%, web site 24%, parents 17%, television 17% and friends 15%. Interestingly 4% indicated radio even though we do not do any radio advertising!

The overall effect of our 2010 marketing was a rise of 6% in our first year engineering enrolment numbers. This was a disappointing result for a growing program and new initiatives were required. Our solutions were to:

- better understand the target student culture and be innovative in our marketing towards them
- increase and refine our outreach activities
- more fully engage secondary school teachers and careers advisors

The solutions developed for improving recruitment are presented in the following sections.

Understanding "The Geek"

A demographic study of students at VUW and WelTec was undertaken that spanned both genders, a variety of socio-economic backgrounds and several ethnicities. This study indicated that students with an interest in, and ability to perform in these "digital" areas of engineering, strongly identified with being "geeks" (Phillips, 2010 unpublished). Rather than this being a negative connotation, the target secondary school students enthusiastically embraced this label.

To our best knowledge, this geek culture had not before been used as a significant marketing campaign. However, as detailed in the previous sections, even with innovative interpretations of traditional marketing approaches (such as the in-game advertorials) we were not making an impression on our target demographic. Given that we are new providers of engineering degrees and had to break decades of an established practice of engineering students moving out of region, we decided to embark on a somewhat radical departure from the traditional tertiary recruitment strategies.

Print and online material was subsequently developed to relate with this identified culture – a major departure from the traditional university and polytechnic marketing campaigns. A new website was developed, and a dedicated "geek-hero" advertorial booklet was developed.

The "geek-hero" publication was considered controversial when presented to the marketing department at VUW, but was enthusiastically accepted by the university's student recruitment team. Conversely, WelTec's Engineering team, through the work of Mel Lock completely embraced the idea. To partially illustrate the geek concept, the front and rear cover of this publication is illustrated below.

Internally the first page of the publication explains how engineers can change people's lives – a concept our research has shown to be of particular interest to female students. The differences between study at a university and a polytechnic are detailed and reinforced by a series of relevant student profiles and projects. The theme is a fun, geek-orientated style. The geek concept is further promoted with identifiers such as "DigiGeek", "GeekGirl", "Hands-On Geek" describing particular students. These students are interviewed and asked about their school experiences, what engineering at university (or polytechnic) is like, what projects they are doing, what they do for fun and any advice they might have for new students. A sample of this is provided in Figure 6.

Figure 6. Covers of Geek Engineering promotional booklet.

Note also in Figure 7 below, the students are wearing an identically designed engineering tee-shirt. The caption, next to a retro-looking robot, states “Think it, Plan it, Build it”. Developed primarily for retention purposes to assist in the development of an engineering identity for VUW and WelTec students, these shirts are also distributed as part of our regional efforts to increase engineering awareness. As an aside, the adoption of these shirts (which includes a hooded sweatshirt option) by both staff and students has been very enthusiastic. It is common to see both staff and students wearing them, perhaps in an analogous manner to a sports uniform.

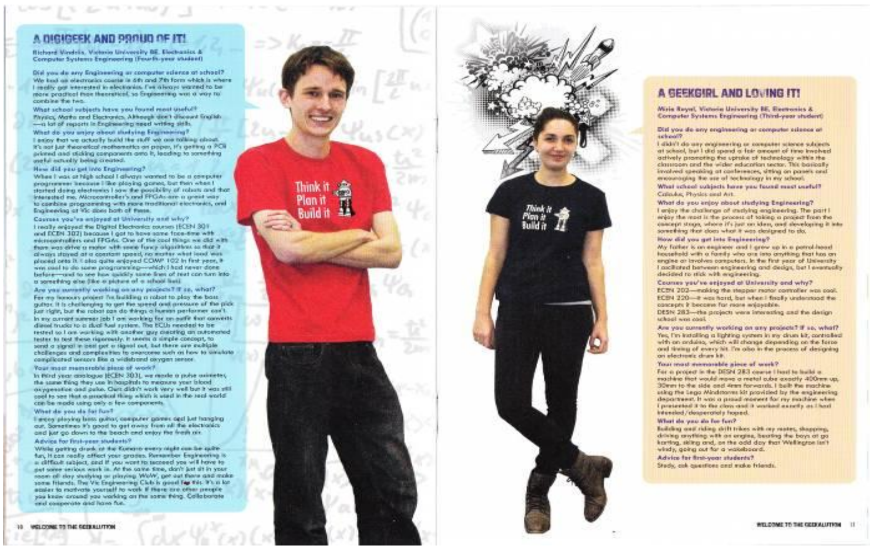


Figure 7. Inner pages of the Geek booklet profiling two students.

Our initial printing of 2500 booklets was exhausted within a few months – substantially faster than the formal university prospectus. Anecdotal evidence from the students, teachers and careers advisors has been overwhelmingly in favor of this novel approach. We have subsequently reprinted 4000 copies and a large number of these have been sent out to schools in the upper South Island and lower North Island.

As well as the printed booklet, a new website was developed in a similar "geek-orientated" style. This is available at www.engineering.geek.nz, and like the geek hero booklet, primarily represents "digital" engineering at a regional rather than at an institutional level. The landing page is intended to initially engage students and then facilitate their accessing of relevant information. Topics include regional providers of tertiary engineering study (primarily VUW and WelTec), cool features of digital engineering, career advice, interviews with students and the profiling of interesting projects. For secondary school students and teachers, there is a page delivering advice and suggestions on the operation of the Arduino outreach boards and a 'Scratch' programming page with the trial programs that can operate on these boards. A sample page from this geek-oriented web site is illustrated in Figure 8. The left image is of a page where the user can click and run a video of a variety of student projects, and the right image is of a resource page to support the use of Scratch.

Figure 8. Sample pages from the geek-orientated promotional website.

Informational Posters

As discussed previously, our recruitment strategy targets two student groups; those who wish to pursue engineering and are considering the institution best suited to their interests; and those students who are engineering capable but are ignorant of engineering opportunities.

To influence the first group, one of our key strategies is to train secondary school students to associate the term "engineering" with VUW and WelTec (and not the Universities of Auckland or Canterbury). This is important as whilst outreach and school visits can attract students into the engineering domain, we need to attract them to our institutions rather than losing them to these more established providers. It is also a difficult challenge given that Auckland and Canterbury offer the full range of engineering subjects and so their student intake, numbers of graduates and industry involvement are an order of magnitude greater than VUW and WelTec's.

One mechanism to begin this association of VUW and WelTec with engineering as engineering degree providers has been to create, a series of seven promotional posters to be inserted inside secondary school science and technology laboratories, mathematics class rooms and careers advisors' offices. These posters need to be informative and professional in appearance so that teachers will want to host them, but they must also strongly identify WelTec and VUW with an area of "digital" engineering.

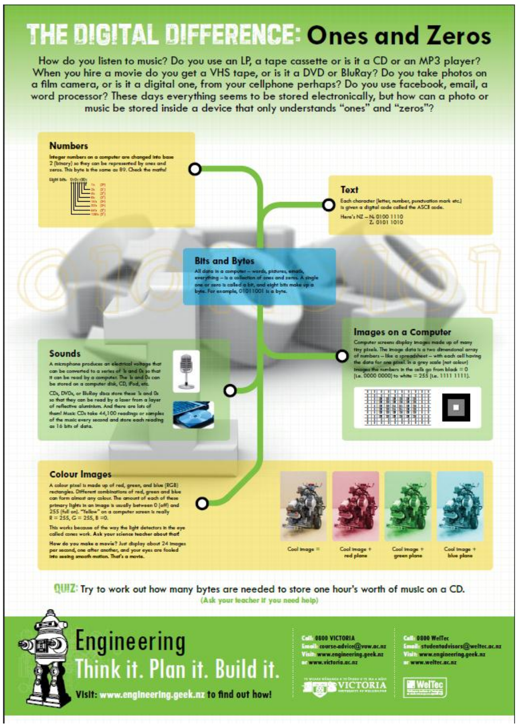
In the absence of dedicated engineering laboratories, we targeted physics and computer science labs since there are many overlaps between our digital engineering specializations and these two secondary school curricula. Specifically we designed posters to cover:

- Ohm's law: Current, voltage, power and series and parallel resistive circuits
- Battle of the Currents: The advantages of AC versus DC, the battle between Tesla and Edison, step-up and step-down transformers
- Conductors and Superconductors: Transmission power loss, metallic conductivities, superconductors and applications
- Building Blocks: Resistors, capacitors, diodes, transistors

For computer laboratories there are posters covering:

- The Amazing Self Healing Internet: How the internet works, its history and the development of "hot-potato routing"
- Facebook: How Facebook works, databases and caching
- Digital Difference: Digital data storage, binary numbers, digital music and image representation

Figure 9 illustrates examples of these posters (selected for this publication because they resolve reasonably well when miniaturized). The rest can be viewed at: http://www.engineering.geek.nz/help/help-for-teachers.



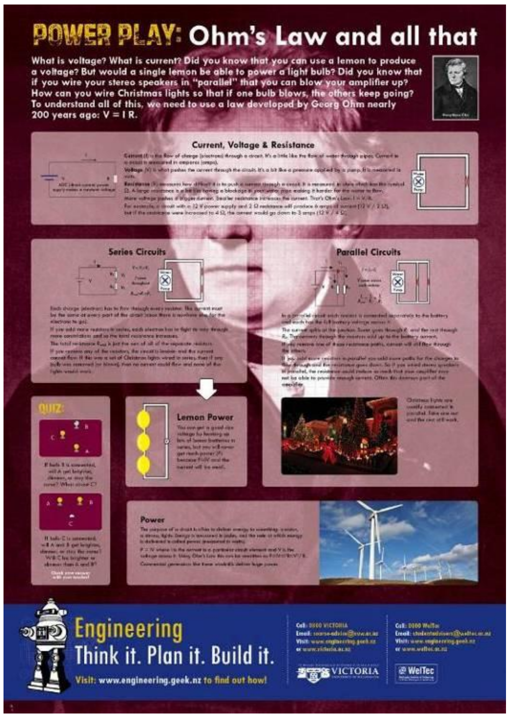


Figure 9. The "Digital Difference" and the "Ohm's Law" informational posters.

Note that both the posters presented in Figure 9, and indeed all of our informational posters, have the same form of engineering caption and contact information at the bottom. They also all include an introduction that is intended to be relevant to the student, and a related quiz question that the students may have to ask their teachers about.

We have also created a special non-informative but visually striking poster for the careers advisors. Whereas the posters inserted in laboratories and classrooms can be text and information rich since the students will see them every day and have the time to read the content, the purpose of this poster is to immediately grab the student's attention and then to associate VUW and WelTec with modern engineering. Our solution is illustrated in Figure 10.

The uptake on these posters has been extremely pleasing and we have had a 36% increase in BE enrolment numbers in 2012. Schools have been requesting additional copies to post in their labs – to the extent that we have distributed double the number we originally anticipated. Given this success, in

2012 we sent out posters to over two hundred secondary schools. The response to these again was excellent with many school requesting additional posters and ‘Geek’ booklets.

Figure 10. Poster for careers advisors office.

Careers Advisors and Teacher Day

Secondary school teachers and careers advisors generally do not having a good understanding of the nature of digital engineering. Secondary school teachers also often lacked training and experience in electronics or programming and busy careers advisors often find it hard to keep up to date with changing technology education. Subsequently we planned a dedicated careers-advisor/teacher-only outreach session on the 6th of June 2011.

The event was hosted at VUW with WelTec in attendance, 59 Secondary School teachers and Careers Advisors attended. The authors spoke to them about the purpose of the outreach activities and in particular about the prevalent ignorance of digital engineering amongst the students. This was of course, a covert attempt to inform the Careers Advisors themselves so that they could then take the information back to the schools. In addition we demonstrated students work and engaged them in the construction of one of these boards with a supporting PowerPoint presentation showing how this technology is used in modern careers. We also used this opportunity to deliver circuit boards, posters and booklets to the attendees and took requests for more of these. We had exceptionally positive feedback during this event.

Secondary School Outreach

When we holistically consider secondary school students, we find that many capable students rule themselves out of engineering eligibility due to the abandonment of the enabling mathematics and physics subjects in their senior years of secondary school study. We find that this is often due to their ignorance about where these subjects can lead to as a future career combined with the perception that these subjects are inherently difficult.

Even for students who do pursue mathematics and the physical sciences throughout their secondary school studies, our research has uncovered a disturbing level of ignorance into their understanding of our defined fields of digital engineering. Capable students who could thrive at tertiary engineering study are instead being lost to medicine and “technology” subjects such as information technology or business information systems. This ignorance of digital engineering and its potential careers is not restricted just to the students; indeed it seems to stem from a lack of knowledge from their parents, their secondary school teachers and even their secondary school careers advisors.

In a coordinated effort between VUW and WelTec we have begun an aggressive outreach campaign designed to redress this situation. The targets are secondary school students and the influencers of these students, specifically the careers advisors and their science and technology teachers. Our goal is to increase awareness of digital engineering, engage the students in a related hands-on activity with the end goal being an increase in the willingness of these students to engage in tertiary engineering study.

One result of the adoption of the NCEA framework is that the students’ secondary school work is far more prescribed than it was under the scheme which existed prior to NCEA adoption in 2002. This has implications for the development of outreach since for the senior students very little time is available for extra-curricular activities and the teachers often struggle to cover the required material within the teaching year.

It is important to note that New Zealand has no specific identifiable engineering content in its secondary school curricula. Science is presented in its broadest form from years 9 – 11, with specialization possible in the final two senior years. There is also a weak Technology syllabus, which is currently being overhauled, hopefully in time for delivery in 2011. Currently electronic technology is assessed similarly to food and materials technology with assessment (for example) taking the form of 90613 “Develop a conceptual design to address a client issue”, or 90792 “Develop a proposal for a production process for a client”. Computing and programming offerings have no standardization at all and the availability and quality of these vary tremendously from school to school.

The consequence of this is that the students certainly are not aware of how engineering differs from science. When pushed for an answer, we would get comments from students identifying engineering as being that discipline which is useful if you are building bridges or tall buildings. As an aside, another indicator here was that every student could identify a famous scientist, but not one of them could identify a famous engineer. This ignorance of engineering is perhaps not surprising since interviews the authors have conducted with secondary school teachers and careers advisors indicate that these influencers are themselves not clear on how engineering is differentiated from science and often struggle to identify those careers available to the digital engineering graduate.

Outreach Specification

Our priorities for the outreach activities were first focussed on addressing this ignorance of the digital engineering disciplines, focussing first on the junior and senior secondary school students and then extending to consider the science and technology teachers and careers advisors. Research and common sense dictate that a “one-shot” offering is seldom adequate to change perceptions, and so our outreach had to have some lasting effect.

Another consideration is that the number of secondary schools in our catchment region renders it impractical to visit every site individually and hence the decision was made to host the outreach in our laboratory facilities. Since this involves a disruption to school routine we had to make it worthwhile for the teachers to take the time (often a half day) to bring their class to visit us. Particularly for teachers involved in instructing senior students this could only be achieved if our outreach assisted in the delivery of a relevant NCEA module. Finally we had to provide something that would help the students have a positive attitude regarding visiting us.

It is worthwhile summarising these considerations. The activity should:

1. Inform the students and their influencers about engineering as it relates to the areas we have defined as digital engineering.
2. Work within the senior syllabus to assist the teacher in the delivery of an NCEA module.
3. Provide the students with a hands-on activity that would be fun and engaging.
4. Provide the students with some lasting impression, rather than something that is enjoyable but quickly forgotten.
5. Teach the students something about an aspect of digital engineering
6. Illustrate engineering concepts, not just the science
7. Announce the prevalence of digital engineering in our everyday world, and that their activity is the first part on a journey towards participating in this.
8. Motivate the students to consider digital engineering for tertiary study.

9. Offer opportunities to extend the project through work with teachers at school and/or individual work.
10. Emphasises the creative nature of engineering by having students create something of their own.

The Project has made it possible for us to individually provide each student with an electronic system on a printed circuit board that they construct during the outreach activity, debug if necessary and then take home with them. Prior experiences by the authors attest to the effectiveness of this technique in engaging the students in a challenging activity that introduces new concepts and skills. Furthermore since the students get to retain these units, there is a permanent reminder of their activity. Finally, if we can design a system that is flexible or expandable, then the teacher can engage in further activities with the students back in the classroom. We are currently looking into a way to make the production of the boards sustainable as teacher education packs with accompanying NCEA resources for 2013.

The knowledge base and skills of the juniors and seniors are significantly different. This coupled with the requirement to work within the NCEA curricula for the senior students mean that two versions of this board have been constructed. These are presented in detail in the following sections.

Outreach Presentation

Depending on class schedule, each class commits to spending a minimum of 90 minutes and a maximum of 120 minutes engaging in our outreach activity. The timing can be flexible since if a class completes early then we can take them on a tour of our robotics laboratories and show them some mobile robots in action. This further reinforces the outreach by providing a physical demonstration of digital engineering research.

We can comfortably cater for 20 students per session but have occasionally had to host 24. The session is coordinated by an experienced academic staff member who guides the activities and explains the background concepts and relevance of the activity. This academic is supported by at least one member of our technical staff and depending upon class size, two or three engineering under-graduates. These under-graduates (often third year students) are important as the high school students typically relate far better to advisors of a similar age to their own.

The decision was made to centre both circuits around a microcontroller board that the students would partially construct and would retain after the activity. Furthermore, for the teachers, resources would be made available so that they could engage in additional post outreach activities in the classroom with these students using these boards. This would be a cost neutral activity for the schools – an important consideration as school budgets come under increasing pressure.

An initial market analysis suggested that the uptake of the junior outreach would be in excess of 300 students per year, and perhaps half that number of senior students. The cost of the units was then of significant importance and hence the decision was made to employ a variant of the cost-effective PIC microcontroller family for both boards.

It is critical that the students engage in some individual circuit construction. This gives them some sense of "ownership" of their board – it's not something that was just given to them, they had to work to make it function. The amount of circuit construction undertaken by the students can be varied, more if the desired emphasis is on electronic hardware, less if more time is desired to cover the software features or the final application.

During the outreach engagement, we often make use of a PowerPoint presentation augmented by clickers. This ensures that even during the theory section of the outreach, the students are actively engaged, and all are answering the example questions posed. The presentations are different for the juniors and seniors, but possess some common characteristics:

- The use of clickers to engage the students – with copious quantities of chocolate fish awarded for correct answers
- An explanation of bits/bytes and binary number representation
- An explanation of the structure of the board and the components the students must insert and solder
- Examples of good and poor soldering practice
- An explanation of the structure of the program embedded within the circuit's microcontroller.
- Continual reference to digital engineering in the world around us, digital engineering as a career and hence as a study option.

Evaluation - Outreach

Between 2010 and the end of 2011 we gave away over 771 circuit boards. Table IX below details the schools and organisations whose classrooms and students received the boards.

TABLE IX. 2010 AND 2011 SECONDARY SCHOOL OUTREACH WITH CIRCUIT BOARDS LIST.

2010 – Secondary School Outreach with Circuit Boards	
Number of circuit boards given away	**School or organisation**
6	Samuel Marsden Collegiate
5	Tawa College
	Wellington Girls - No record of numbers
10	St Catherines
14	HIBS
	Newlands - No record of numbers
20	HIBS
	Chanel College - No record of numbers
2011 – Secondary School Outreach with Circuit Boards	
110	ETITO-Brightsparks
15	St Peters College
30	Kapiti College
25	Samual Marsden Collegiate School
40	Heretaunga College
60	Taita College
44	Queen Margaret College
45	Tawa College
46	Onslow College
40	Wellington College
30	Kapiti College
20	Wellington East Girls College
6	Ponatahi Christian School
5	Home School Network
14	Wellington Girls' College
20	Chanel College
22	Rongotai College
50	Newlands College
20	Naenae College
4	Columba College-Dunedin
6	Reporoa College
5	Upper Hutt College
4	Whangarei Girls High
20	Freyberg High School
35	St Patrick's College Silverstream
771	**Total 2010 & 2011**

Surveys conducted of participants yield an overwhelmingly positive response. These results indicate not only an enthusiasm for the activity, but an appreciation of their newly increased awareness of “digital” engineering and an increased willingness to consider pursuing this as a tertiary study option.

At the time of preparation of this document several outreach activities are still on-going, and so the results presented in this section are only of the surveys collected to date. However, we have no reason to believe that future survey results will be significantly different from those we have already collated, and the summary below represents the responses of 142 students of mixed gender who participated in the outreach activity.

In response to our criteria that the activity be fun, we asked each student how much they enjoyed the programme {a lot, some, little, very little, not at all}. Over the 142 students, 72% per cent of the students responded that they enjoyed it "a lot", 26 % enjoyed it "some". Only 2 % enjoyed it "a little". The seniors were slightly more enthusiastic than the juniors, perhaps because the seniors were those who had already selected to study in the physical sciences/mathematics and were therefore likely to be more amenable to these activities. Indicatively, 88% of seniors registered that they had enjoyed the programme "a lot".

We consider these results (for both groups) to be an exceptional success. However, activities can be fun without the students learning anything, so we asked them if they felt whether they had learned much during the programme. Overall 69% responded that they had learned "a lot", 23% "some". Again seniors were more positive, 77% responding that they had learned "a lot". This outcome is not surprising since for the seniors we were strongly endeavouring to augment their NCEA Physics modules. No student believed that they had learned nothing during this exercise.

The critical success determination however, is whether this activity has increased their interest in this form of engineering and whether they are now more or less likely to consider this for tertiary study. 30% indicated that their interest has increased "a lot" (35% for seniors), 49% "some" (52% seniors), and 16% "a little". There were a mere two responses for the "not at all category" that were obtained from the junior surveys. As to an increased willingness to consider tertiary study in engineering, 12% have a "significantly increased interest" (18% for seniors), 57% have a "somewhat increased interest" (65% for seniors) and 24% remain unchanged in their interest (which importantly could indicate that they were already strongly interested in pursuing engineering study).

The students were invited to make additional comments. They were generally extremely positive and relevant extracts (other than it was cool, interesting etc.) include:

"Making the games was really fun"

"The outreach programme was very interesting. One of the best lessons I've ever had. Stay awesome."

"It was fun and very hands on"

"I really like computer engineering and I'm thinking about doing it in the future"

I definitely want to look more into engineering and different sciences I may enjoy. It gave me an idea how different things can change your mind"

"The staff were great and I learned heaps. I never thought about computer engineering until I came on this course"

There is very little doubt that we have completely succeeded in engaging the students and we are imparting knowledge whilst giving them an enjoyable activity. Of course we are not able to cater for every student type; we have to strike a balance between providing an exercise appropriate for the complete novice, whilst not boring those who already have had some exposure to electronics. There was only one negative qualitative comment:

"Just really boring, and I knew most of it"

Out of 142 students who have completed the surveys, we are prepared to accept a mere 1 or 2 per cent who feel that nothing new was presented. After all, these students who are already very experienced in electronics and are most likely already considering this as a career are not the target of this outreach activity. Of more concern were some comments concerning the programming:

"Fun, the programming language is hard to use"

"It was great! Just a bit more time in the programming section"

"Needed more time programming"

Whilst these comments were certainly in the minority, it does raise issues with the difficulty in instructing novices in programming using C. We will discuss this further towards the end of this paper.

The accompanying teachers were also surveyed. All believed that the students had learned "a lot" (our highest score category). All believed the student had enjoyed the programme "a lot". Furthermore they all believed that our programme both supported and extended the school curriculum most registering the highest category score: "a lot". In response to querying them about whether they thought that the students would be more or less likely to have an interest in engineering because of this programme, the responses varied between our two highest categories "much more likely" and "more likely".

When asked how likely it is that the students will now work with a teacher in the school to follow up or extend this work, the answers varied from "very likely" through to our mid-range option "maybe". This obviously reflects the interest and enthusiasm of the teacher and indicates that perhaps we have more work to do in this area, especially in simplifying the programming requirements which anecdotally several teachers appeared to struggle with.

Nearly all the teachers rated that they would either "yes strongly" recommend our programme to other teachers or "yes" they would recommend. None were negative. All would now recommend to students that they consider engineering study at tertiary level. For the final question, most teachers did indicate that they did not believe that students were sufficiently aware of engineering or even science related careers.

We are delighted with these very positive results. However we are not yet finished. One shortcoming of our work is the difficulty some students (and teachers) have getting to understand C. Even though we abstract away most of the difficult content, several students did struggle. Our on-going work is considering the incorporation of Scratch and related applications into these boards. We are working on a design based around an Arduino board, interfaced to a PC running Scratch. The novice can immerse themselves in the graphical Scratch environment and successfully programme several simple applications such as turning on an LED in response to a signal from an LDR (light dependent resistor). The more advanced student could then break into the accompanying C code and take more direct control of the microcontroller.

This has the additional advantage that we could tailor the outreach activity depending upon the student cohort, more of a focus on hardware for those more inclined towards electronics, or more software orientated if that is the students' preference.

Recruitment Conclusion

Our primary challenges in recruiting include an absence of engineering curricula amongst our secondary schools (and hence a general student ignorance concerning engineering), a history of a poor uptake of university/polytechnic engineering study, and that engineering interested students have a long history of going to one of the two traditional engineering providers that are out of region.

WelTec and VUW lack the resources to increase our recruitment through traditional means of comprehensive television, radio and newsprint advertising. Attempts at this form of traditional advertising – even with some innovative approaches in 2010, proved to be largely ineffective at VUW. We have therefore had to seek cost-effective and even more innovative alternatives supported by the TEC funding.

We have exceptionally positive results from our outreach surveys, the disbursement of nearly double the number of geek booklets compared to the traditional university material, the repeated requests from schools for additional posters, an encouraging number of hits on our website and an increase in enrolment numbers.

In 2011, VUW has had a marked increase in enrolments compared to the previous trend; a factor we believe relates directly to the initiatives created from the project. See Table X below for details of enrolment figures. It can be seen that before our initiatives our enrolment increases were relatively static. However since our initiatives in 2011 there has been a 36% increase in enrolments in 2012.

TABLE X. ENROLMENT STATISTICS FOR VUW BE

Year of enrolment in BE	Number of students enrolled
2007	107
2008	92
2009	110
2010	115
2011	112
2012	152

It is difficult for us to explicitly argue that the project has had a direct improvement on recruitment at WelTec, since we have no data available to measure this (WelTec did not conduct surveys questioning how students learnt about its engineering degree), we certainly believe that the increase in their enrolments is in part attributable to the projects joint efforts.

Supported with the TEC projects awareness campaign in 2011, WelTec also promoted to a wider geographical area from mid north island to Wellington which consisted of the following activities: Lunch presentation to Career Advisors, Info packs send to secondary schools, mail drop, secondary school newsletter, email to industry, newspaper print, online advertising with industry publications, social media advertising, industry publication newsletter and was discussed in the section below.

WelTec’s enrolment numbers have been increasing steadily from, 20 in 2010 to 37 in 2011 and 52 in 2012, as illustrated below in Table XI.

TABLE XI. ENROLMENT STATISTICS FOR WELTEC BENGTECH

Year of enrolment in BEngTech	Number of students enrolled
2010	20
2011	37
2012	52

Student surveys indicate the importance of teachers, careers advisors, friends, web site, open days and outreach activities. However, to engage the students, their teachers and careers advisors we have:

- Created an engaging, informative and flexible outreach programme that now concentrates on senior secondary school students
- Created a series of informative posters for display in secondary school laboratories, offices and classrooms

- Identified the "geek" subculture of our target students and created a booklet, clothing and web pages that embrace this concept.
- Reinforced the outreach events with a student orientated web site that additionally contains useful material for teachers who wish to extend these activities in the classroom.

At VUW in trimester one, 2012, we conducted a survey of first year engineering students in an attempt to ascertain how they found out that VUW had an Engineering degree. Table XII below shows the results of a survey of 142 first year students – *please note the students were able to select more than one answer*. The results reinforce the role of friends, teachers, careers advisors and parents and electronic media such as the Faculties website. These areas are all the targets of our developments, through the EPP and clearly show we are targeting the right approach.

TABLE XII. SUMMARY OF 2012 STUDENT RESPONSES TO HOW 'THEY' FOUND OUT ABOUT ENGINEERING AT VUW.

Activity Description Answer	Number of times option selected	Percentage of total selection
Parent/s	29	21%
Friend/s	69	49%
New Students	10	7%
Future Students	5	4%
Secondary School Teacher/s	27	19%
Secondary School Careers Advisor/s	47	33%
Television advertising	12	9%
Armageddon sci-fi, comic and gaming expo	1	1%
Posters	12	9%
Newspaper advertising	5	4%
Facebook	17	12%
Brendon or Dayna's television interview (seen on Youtube or C4)	1	1%
Victoria University outreach event with circuit boards	10	7%
Programming Challenge for girls	0	0%
Open day at Victoria University	74	52%
School visit by Victoria Engineering staff member	31	22%
Geek Engineering Website	6	4%
Victoria University School of Engineering and Computer Science website	45	32%
In game advertising - can you also tell us what game you saw us in by writing it in the box below:	4	3%
Other means. If you heard about Engineering at victoria by some other means can you please write what that was in the box below:	20	14%

Answers to Other Means:

- Empires and Allies (FaceBook game)
- Previous students
- Family- not parents
- Tech Hui
- Tech Hui
- Opening evening held at the Plymouth Hotel
- Sort of tumbled upon it in 2012 course outlines
- Careers advisor external to school
- To be honest I just always assumed it was offered here, and I'd already decided on VUW
- Fiona Beals- Student advocate for VUWSA- is friend and strongly recommend engineering at VUW
- The Victorious Magazine
- VUW courses booklet
- The non-engineering course planning guy who visited schools
- GOOGLING IT!!!
- Polytechnic tutor
- Just researching computer science courses that did programming. VUW website
- Tech Hui
- I was introduced to engineering through Massey Wellington VEX and MARS programs where their engineering faculty shut down. I chose victoria. For the most part I'm doing engineering this year to try it out . At this point I can't tell if I am capable of doing this course because I haven't applied myself to it fully yet
- Tech Hui
- Careers expo at school

Of course recruitment is still an ongoing effort and perhaps the greatest success of the project has been the realization that as engineering education providers we have a duty to do all we can to assist prospective and current students in achieving their goals.

Final Report Conclusion

At the beginning of this study, there was only anecdotal evidence of a wide range of barriers to the successful recruitment and retention of engineering students within the New Zealand context. Certainly the bulk of the literature published treated engineering in its entirety and hence mixed issues related to traditional engineering fields such as civil or structural with the modern engineering fields such as electronics, networking and software. Certainly student knowledge and expectations of these modern engineering fields is significantly different to the traditional engineering subjects. No studies had formed a reliable predictor of likely success in tertiary engineering study and no studies focused on the issues involved in the provision of engineering in the Greater Wellington region.

This project has made break-through advances in understanding the unique expectations of students with a desire to engage in modern engineering study. Following surveys, focus groups and demographic studies, a greater understanding of students' knowledge and perceptions of modern engineering were formed, and the creation of a marketing initiative focused on these perceptions helped increase engineering enrolments at VUW by 36% and at WelTec by 41% between 2011 and 2012. The marketing initiative also placed importance on improving relations with secondary school teachers and careers advisors. A substantial outreach programme was initiated, and considerable resources to aid in the teaching of the new technology curriculum were distributed to schools. Whilst the emphasis was on the schools in the Wellington area, these teaching resources were distributed throughout the country, and we endeavoured to supply most secondary schools in New Zealand with informational posters for display in their laboratories.

A predictor of likely success in engineering study was created using data from the University of Canterbury, Massey University, Waikato University at VUW, which in conjunction with a diagnostic test is instrumental in being able to advise VUW whether a student is likely to be able to succeed in engineering study, and if so, whether assistive intervention is likely to be required. The connections this study has enabled to be formed with these other providers of engineering has been extremely valuable.

Retention issues have been addressed by the formation of a foundation course in engineering at WelTec and a complete review of the first year engineering programme at VUW. The foundation course has been extremely successful, taking marginal students to the level where they are now performing equivalently in WelTec's courses to students who have a far greater level of preparedness as indicated by their secondary school results. The review at VUW has resulted in a complete alteration to the core first year engineering paper and the proposal to introduce a second one in the following trimester. Initial results indicate the first year pass rate (B or above – as required by the BE at VUW) has increased from 45% to 63%. Part of this rise is also attributable to the fractional appointment of a pastoral care agent, funded by VUW as a result of the findings of this study. Using the Big Sister software tracking system, our Pastoral Agent actively engages with borderline students, directing them to appropriate, individually orientated assistance. An MOU is in circulation at Senior Management Levels to facilitate the stair-casing of students between VUW and WelTec so that the best provision of engineering study can be offered to a student depending on their passion and ability.

Without the funding from this project, none of these initiatives would have been undertaken. Our greater understanding of students' abilities and expectations have led to an unprecedented increase in recruitment and retention. There is still significant work to be done in this area, especially in increasing connections with secondary school teachers, understanding and correcting for the mismatch between NCEA Level 3 mathematics and first year university mathematics courses, increasing the pastoral support, up-skilling teachers in the new technology and computer science curricula, the development of hardware and teaching resources that can be provided to schools, increasing student and careers advisors' awareness of modern engineering careers and developing a mechanism for the exchange of best practice ideas and research findings between New Zealand's tertiary engineering providers. The authors are actively seeking funding to pursue these goals, so far without success.

Readers of this report at TEC are very welcome to provide us with feedback on any of these discussions and we would certainly appreciate ideas or suggestions on how to secure additional funding to continue the momentum of success this project has produced.

Key Sources

Much of the information contained in the report above has been presented and published in the sources immediately below:

To date, the results of our recruitment initiatives have been published in:

Carnegie, D.A. and Watterson, C., “Get Those Geeks”: An Innovative Recruitment Strategy for a New Engineering Provider. Accepted to the American Society for Engineering Education (ASEE) Annual Conference, San Antonio, Texas, USA. June 10-13, 2012.

Carnegie, D.A., Exley, T., Edwards, J. and Watterson, C., Increasing Engineering Awareness Through Targeted Outreach. *Proceedings of the IEEE Engineering Education Conference (Educon 2011)*, Amman, Jordan, 4 – 6 April, 2011, 128 – 135, ISBN 978-1-61284-641-5.

The prediction findings have been published in:

Carnegie, D.A., Watterson, C., Andreae, P., and Brown, W.N., Prediction of Success in Engineering Study. *Proceedings of the IEEE Engineering Education Conference (Educon 2012)*, Marrakesh, Morocco, 17 – 20 April, 2012, 57 – 65. ISBN: 978-1-4673-1455-8, ISSN: 2165-9559

The retention initiatives have been published in:

Carnegie, D.A., Watterson, C., Browne, W.N., MacKay, J., Lock, M., Williams, J., and Forret, M. Strategies to Improve Engineering Retention. *Proceedings of the IEEE Engineering Education Conference (Educon 2012)*, Marrakesh, Morocco, 17 – 20 April, 2012, 101 – 110. ISBN: 978-1-4673-1455-8, ISSN: 2165-9559

MacKay, J., Lock, M., Carnegie, D., Watterson, C., and Pitawala, S. Inducting Students into the Engineering Community: A Case Study of the Development of a Project Based Engineering Foundation Programme. NZARE Conference, Tauranga, New Zealand, 2011.

Watterson, C., and Carnegie, D.A., Increasing Student Retention and Success: Survey Results and the Success of Initiatives to Create an Engineering Student Community. *Proceedings of the IEEE Engineering Education Conference (Educon 2011)*, Amman, Jordan, 4 – 6 April, 2011, 191 – 200, ISBN 978-1-61284-641-5

A presentation on some of this material was also given in 2011 to the Tertiary Education Commission and at the NZ Engineering Education Leaders Forum, August 2011, Auckland

Other Sources

Adamson, J., & Clifford, H. (2002). An appraisal of A-level and university examination results for engineering undergraduates. *The International Journal of Mechanical Engineering Education*, 30(4), 265-279.

Aufschnaiter, C. (2003). Interactive Processes between university students: Structures of interactions and related cognitive development. *Research in Science Education 33*(3), 341-374.

Awad, E. M. (2004). *Knowledge Management*, Pearson Education India.

Boles, W. (2009). *Barriers to Student Learning in Engineering: Annotated Bibliography*, Australian Learning and Teaching Council, http://www.altcexchange.edu.au/barriers-learning-annotated-bibliography

Campbell, A., Künnemeyer, R., & Prinsep, M. R. (2008). Staff perceptions of higher education science and engineering learning communities, *Research in Science & Technological Education*, Volume 26 Issue 3 – 'Higher Education Science and Engineering Learning Communities', 279 – 294.

Carrick Institute (2009). *Addressing the Supply and Quality of Engineering Graduates for the New Zealand*, Australian Council of Engineering Deans/ University of Technology Sydney, An initiative of the Australian Department of Education, Employment and Workplace Relations.

Clark, J., Dodd, D., & Coll, R. K. (2008). Border crossing and enculturation into higher education science and engineering learning communities, *Research in Science & Technological Education*, Volume 26 Issue 3 – "Higher Education Science and Engineering Learning Communities", 323 – 334.

Coll R. K. (2008). Rationale and methodology for a national study of higher education science and engineering learning communities, *Research in Science & Technological Education*, Volume 26 Issue 3 – "Higher Education Science and Engineering Learning Communities", 259 – 277.

Coll, R. K., & Eames, C. (2008). Developing an understanding of higher education science and engineering learning communities, *Research in Science & Technological Education*, Volume 26 Issue 3 – "Higher Education Science and Engineering Learning Communities", 245 – 257.

Coll, R. K., & Eames, C., (2008). Implications arising from a national research project on higher education science and engineering learning communities, *Research in Science & Technological Education*, Volume 26 Issue 3 – "Higher Education Science and Engineering Learning Communities", 335 – 338.

Cronje, T., & Coll, R. K. (2008). Student perceptions of higher education science and engineering learning communities, *Research in Science & Technological Education*, Volume 26 Issue 3 – "Higher Education Science and Engineering Learning Communities", 295 – 309.

Dawes, L. (2004). Research Report. *International Journal of Science Education*, *26*(6) 677-695.

Deynzer, M. (2009). *The transition to university of Pasifika students from low to mid decile schools*, Unpublished masters thesis, The University of Auckland, Auckland, New Zealand.

Deynzer, M. (2009). *Lost in transition: Pasifika students' transition from school to university*. Presentation to the Pasifika Fono.

Deynzer, M. *Great expectations and new territory: The transition of Pasifika students to university*, Starpath NZARE Symposium 2.

Eames, C., & Stewart, K. (2008). 'Personal and relationship dimensions of higher education science and engineering learning communities', in *Research in Science & Technological Education*, Volume 26 Issue 3 – "Higher Education Science and Engineering Learning Communities", 311 – 321.

Earle, D. (2009). *Advanced trade, technical and professional qualifications*. *Tertiary: Trends in Supply*, Sector Performance Analysis and Reporting, Strategy and System Performance, Ministry of Education, Wellington, New Zealand.

Ferreira, M., (2003)."Gender issues related to graduate student attrition in two science departments". *International Journal of Science Education*, Vol. 25(8), 969-989.

Forret, M., Eames, C., Coll, R., with Campbell, A., Cronjé, T., Stewart, K., Dodd, D., Stonyer, H., Clark, J., Maclean, C., Kunnemeyer, R., & Prinsep M. (2007). *Understanding and enhancing learning communities in tertiary education in science and engineering*. Teaching and Learning Research Initiative, New Zealand.

Godfrey, E. (1999). Learning the Culture: The First-year Experience, *Proceedings of the 11th Australasian Association of Engineering Education Conference: Unfolding Landscapes*, (208-214), Adelaide. Available from http://search.informit.com.au/fullText;dn=217850420973905;res=IELENG

Godfrey, E. (2001). 'Defining Culture: The way we do things round here', *Proceedings of the 2001 American Society for Engineering Education Annual Conference & Exposition*.

Godfrey, E. (2008). Exploring the Culture of Engineering Education: The Journey, *Proceedings of the 2008 AaeE Conference*, Yeppoon,.

Godfrey, E., Jonathan, A., & Godfrey R. (2008). *Work in Progress - What Do Selection Criteria Tell Us About Our Students?*, ASEE/IEEE Frontiers in Education Conference,.

Godfrey, E., Archer, R., Denny, P., Hyland, M., Smaill, C., & Stol, K. (2009). *Innovation and Integration in an In-house First-year Engineering Program: A Fast Track to Engineering Enculturation*, American Society for Engineering Education.

Hestenes, David, Wells, Malcolm and Swackhamer, Gregg. (1992). 'Force Concept Inventory', *The Physics Teacher*, Vol. 30, 141-158.

Hestenes, David and Wells, Malcolm. (1992). 'A Mechanics Baseline Test', *The Physics Teacher* 30, 159-166.

Hipkins, R., Bolstad, R., Baker, R., Jones, A., Barker, M., Bell, B., Coll, R., Cooper, B., Forret, M., Harlow, A., Taylor, I., France, B., & Haigh, M. (2002). *Curriculum, Learning and Effective Pedagogy: A Literature Review in Science Education*, Report to the Ministry of Education, University of Waikato and New Zealand Council for Educational Research with Auckland College of Education, Ministry of Education, New Zealand.

Hipkins, R., & Bolstad, R. (2005). *Staying in Science Students' participation in secondary education and on transition to tertiary studies*. Report prepared for the Ministry of Research, Science and Technology, Wellington.

Hipkins, R., Roberts, J., Bolstad, R., & Ferral, H. (2006). *Staying in science 2: Transition to tertiary study from the perspectives of New Zealand year 13 science students*. Wellington: New Zealand Council for Educational Research.

House of Commons. (2009). Innovation, Universities, Science and Skills Committee, 'Engineering: turning ideas into reality', Fourth Report of Session 2008–2009, Volume I, Ordered by the House of Commons to be printed 18 March 2009, http://www.publications.parliament.uk/pa/cm200809/cmselect/cmdius/50/50i.pdf

IPENZ. (2009). Future Education of Professional Engineers in New Zealand: What form should the exemplifying qualification take in 2020? The National Engineering Education Plan.

IPENZ. (2009). National Engineering Education Plan Project Progress Report for the Tertiary Education Commission, The National Engineering Education Plan.

IPENZ. (2009). Review of Engineering Qualification Structures – Overview, The National Engineering Education Plan.

IPENZ. (2009). *The Demand for and Supply of Engineers.* http://www.ipenz.org.nz/ipenz/Education_Career/Final_Statement_on_Demand_and_Supply.pdf

IPENZ. (2010) Minority Groups in Engineering Education., http://www.ipenz.org.nz/ipenz/education_career/Report_Minority_Groups_in_Engineering.pdf

James, A., Montelle, C. & Williams, P. (2008). 'From lessons to lectures: NCEA mathematics results and first-year mathematics performance', in *International Journal of Mathematical Education in Science and Technology*, 39: 8, 1037 – 1050.

Knight. R. (2004). Five Easy Lessons**,** Addison Wesley.

Loader, M., & Dalgety, J. (2008). *Students' Transition between School and Tertiary Education*, Demographic and Statistical Analysis Unit, Ministry of Education. Available from: www.educationcounts.govt.nz

Lovitts, B. (1996). *Who is responsible for graduate student attrition- the individual or the institution? Toward an explanation of the high and persistent rate of attrition*. Paper presented at the annual meeting of the American Educational Research Association, New York.

Madjar I. & McKinley E. (2009). *The journey from there to here is not the same as the journey from here to there: A prospective, longitudinal, qualitative study of transitions from school to university*, Starpath NZARE Symposium 2.

National Science Foundation (NSF). (1998). Summary of a workshop on graduate student attrition. NSF report, 99-314, Arlington, VA: National Science Foundation, Division of Science Resources Studies (ERIC ED 427 966).

Parkinson, Tim. J., Hughes, Helen., Gardner, Dianne. H., Suddaby, Gordon. T., Gilling, Marg., & MacIntyre, Bill. R. Ako Aoteoroa Report (2011). *Engaging Learners Effectively in Science, Technology and Engineering: The pathway from secondary to university education*. Ako Aotearoa – The National Centre for Tertiary Teaching Excellence, New Zealand.

Phillips, Colin, (Unpublished, 2010), 'Transcripts of Bachelor of Engineering Student Interviews 2010' Base Two Ltd, Wellington, New Zealand.

Schagen, Sandie, & Hodgen, Edith. (2009). *Why engineering, technology, or science? The views of first-year tertiary students*, Report prepared for IPENZ, New Zealand Council for Educational Research.

Shulruf, B., Hattie, J., & Tumen, S. (2008). Individual and school factors affecting students' participation and success in higher education, *Higher Education*, Volume 56, Number 5, 613-632.

Smaill, C., Godfrey, E., & Rowe, G. (2007). The transition from final-year high-school Physics and Mathematics to first-year Electrical Engineering: A work-in-progress, *Proceedings of the 2007 AaeE Conference*, Melbourne.

Tertiary Education Commission, New Zealand Government, http://www.tec.govt.nz/Documents/Reports%20and%20other%20documents/sac-educational-perfromance-indicators-march-2010.pdf

UNESCO, (2010). Report, Engineering: Issues Challenges and Opportunities for Development. UNESCO Publishing, Fontenoy, France www.unesco.org

Ussher, S. (2007). *Tertiary education choices of school leavers*, Learners in tertiary education series, Ministry of Education. Available from: www.educationcounts.govt.nz.

Vaughan, K. (2008). *Student Perspectives on Leaving School, Pathways, and Careers*, New Zealand Council for Educational Research Ministry of Education, New Zealand. Available from: www.educationcounts.govt.nz/publications.

Welzel, M., von Aufschnaiter, C., & Schoster, A. (1999). How to interact with students? The role of teachers in a learning situation. In J. Leach and A.C. Paulsen (Eds), *Practical work in science education- recent research studies* (313-327) Dordrecht, The Netherlands: Kluwer

Wilson, Marc., Hunt, Maree., Richardson, Liz., Phillips, Hazel., Richardson, Ken., & Challies, Dana. (2011). Awhina: a programme for Maori and Pacific tertiary science graduate and postgraduate success. *Higher Education*. Volume 62, Number 6, 699-719, DOI: 10.1007/s10734-011-9413-3

Woodhead, C. (2009). *A Desolation of Learning-Is This The Education Our Children Deserve?,* Pencil-Sharp Publishing Ltd.

Yeo, S., & Zadnik, M. (2004). Students' responses to different first year science learning environments. *HERDSA Conference Proceedings,* 349-360.