Tertiary Education Commission
Te Amorangi Mātauranga Matua

Growing the pipeline of work-ready engineering graduates

A summary and analysis of engineering provider initiatives to grow the pipeline of engineering and link with industry

November 2013

This report was commissioned by the Tertiary Education Commission to provide an overview and analysis of initiatives and issues in growing the number of work ready engineering graduates. It is based on information provided to the Tertiary Education Commission by tertiary engineering education providers (delivering engineering provision at qualification levels 5 and above). Individual providers are not identified in the report. The information in the report does not represent the views of stakeholders such as industry, the secondary education sector, students and government.

We thank all tertiary education providers for the information provided. Every effort has been made to include relevant information supplied by providers.

This report is part of our on-going engagement with engineering education providers and industry on how to increase the number of engineering graduates and link with industry. This is a working document and we would value any feedback to help refine the issues and identify solutions. Please send any comments to: servicecentre@tec.govt.nz.

Contents

Introduction

An additional $42 million over four years was allocated in Budget 2012 to maintain the quality of engineering provision and increase the number of engineering graduates, with a target of an additional 500 engineering graduates per year from 2017. An additional $9.3 million over four years was allocated in Budget 2013.

In early 2013, a total of 15 tertiary education providers of priority engineering education in New Zealand responded to a series of questions regarding the recruitment and retention of engineering students, and industry connections to ensure relevance and quality of provision. This report provides a summary and analysis of provider's responses to these questions.

The report is in two parts. Part one gives an overview of initiatives undertaken by providers to increase the pipeline of students entering engineering study (at levels 5 and above) and to link with industry, including some of the issues providers face.

Part two provides an analysis of these initiatives and draws on additional research to identify further successful practice. This includes drawing on some international research on producing work ready engineering graduates.

Part One: Growing the engineering pipeline and strengthening connections to industry – summary of provider reports

This summary highlights some important initiatives taken by providers of engineering education, but does not identify individual providers undertaking the initiatives. It shows only the variety of initiatives used by providers as they work towards the twin goals of increasing the pipeline of students passing through their institutions, and ensuring that these students are well prepared for employment in the engineering industry at the end of their qualifications.

The following overview is divided into two sections. Section one describes the efforts tertiary engineering providers are making to bolster the number of students passing through their institutions, and the obstacles they face. Included in section one is a summary of those initiatives specifically aimed at increasing the numbers of women, Māori and Pasifika who are able to gain access to placements in engineering institutions and succeed in their studies.

Section two is concerned with initiatives aimed at aligning engineering education with industry needs, and the barriers providers face in their efforts to produce work-ready engineering graduates.

<u>Section 1: Recruitment and retention of new engineering students</u>

1. <u>Recruitment</u>

<u>Recruiting new students: what are the providers doing?</u>

Providers use a wide variety of means to attract students to their institutions. Almost all providers report that they use the following methods to attract potential students:

- open days
- information events
- secondary school visits, and
- scholarships.

Many providers also routinely employ other methods to attract potential engineering students:

- social media/on-line activities
- VEX robotics (kiwibots)
- billboards/posters/press advertising
- ‘tasters’/’try it for a day’ events
- recruitment through industry
- internships
- promotion of newly offered programmes, and
- IPENZ Techlink Pathways Project (TPP).

More novel approaches include:

- one-on-one interviews
- formal invitations to consider engineering sent to all qualifying students, and
- a monthly magazine.

<u>Recruiting new students: what works?</u>

Institutions were generally reluctant to speculate on which initiatives are the most effective in the recruitment of new students. Of the (five) institutions who did respond to the question of effectiveness, all stressed the importance of linking with secondary schools to ensure that students are engaged and aware of the engineering opportunities available to them. Crucially, visits need to be early enough that students realise the importance of choosing STEM subjects at school. One provider stated that getting students on campus for open days and other events was an important step. Another emphasised the effectiveness of sending current engineering students back to their old schools to talk to students about their experiences of studying engineering at university. Given the unwillingness of most providers to hypothesize as to which of their methods are most effective, providers could consider interviewing a subset of students to find out why they chose to study engineering, or adding a ‘how did you find out about us?’ type question to their application forms.

Though they do not say explicitly what is working, providers readily report on what is *not* working in the sector. The following section summarises the obstacles faced by providers in recruiting new engineering students.

Obstacles and issues in recruiting new students

Growing the pipeline of students entering engineering from secondary school is critical to boost the engineering workforce. Examination of providers’ reports shows three major (related) issues are acting as barriers to increasing the number of engineering graduates. Firstly, students are failing to meet the entry criteria due to having taken the wrong subjects at secondary school. Secondly, they are failing to progress beyond their first year because they are insufficiently prepared for study at the tertiary level. Thirdly, providers struggle against a lack of public knowledge of engineering and what their institutions can offer.

Students not taking mathematics and science at school

One of the major problems providers face in recruiting is that prospective students are not studying the right courses at school. This reduces the pool of students that providers can draw from. One provider now offers an intermediate year as a result of students not meeting the entry criteria from secondary school. In another provider’s view, the additional TEC-funded places in engineering degrees across the country may not be filled because of the lack of school leavers with the required level of mathematics and physics.

Providers depend on growth in the number of applicants well grounded in mathematics and science. Some students have good results in mathematics and science, but not in calculus, algebra and physics. Many secondary school graduates who have high marks in the requisite subjects are often diverted away to other professions, notably medicine and law. Offering additional scholarships, in one provider’s experience, has not significantly affected the number of students interested in engineering. It is clear that efforts to expand the pipeline need to start well before the point that school leavers are contemplating their next steps. The answer, according to many providers, is an increase in resourcing for outreach activities in secondary schools. These activities include:

- upskilling teachers in engineering and technology curricula
- motivating students to continue with mathematics and physics
- offering advanced engineering-related courses to promising year 13 students, and

- helping year 13 teachers from small and low decile schools with teaching and resources.

Poor mathematics skills

Students entering first year tertiary engineering qualifications are generally not well grounded in mathematics. This was highlighted as a major issue for almost all providers. Some prospective engineering students are not equipped with basic numeracy skills. As noted earlier, even moderately achieving secondary school students struggle to connect what they have learnt at NCEA level with the demands of tertiary engineering study. In response to this, a number of providers now offer remedial or foundation courses for mathematics. One provider is concerned that the reduced level of mathematics from the NZDipEng has repercussions for staircasing from one qualification to another: in their view, this will make the transition to the BE (hons) more difficult.

In one provider's assessment, NCEA 'achieved' grades are not a good predictor of future success in engineering study. This provider is concerned with NCEA more broadly, and notes that the NCEA system does not prepare students for the work required at the tertiary level, both in the sense of providing the necessary prior knowledge, and in encouraging the creation of a work ethic that will stand them in good stead throughout their first year of engineering study and beyond.

Issues with how ITP engineering qualifications are perceived

Several (non-BE) providers note that it is difficult to attract NZ students to BEngTech, certificate and diploma qualifications, as they are not seen as attractive by secondary school students. One provider comments that potential students are not informed about the careers available to non-university engineering graduates. Another is frustrated that schools and students are still unaware that degrees can be done at ITPs. Other ITP providers suggest that most secondary school teachers have a very limited understanding and/or value of the options for studying engineering across the tertiary sector, nor that one qualification can 'staircase' into another from the trades level, through to postgraduate study.

Public perception of engineering as a career

Some university providers also have problems with public perception of their offerings. Two relatively new providers are striving to have their engineering programme recognised by parents or teachers in secondary schools.

Many providers observe that public perception of engineering – which is usually associated with building tall buildings and bridges, rather than electronics, software and computing – is significantly different from what is actually taught, which impacts upon the level of interest and understanding of engineering and its career opportunities among school leavers. In one provider's view, this may be partly because there are no engineering specific subjects at secondary school. Another provider is combating the lack of quality advice about engineering as a career in schools by bringing careers advisors and teachers on campus, which they say is working well.

Facilities

Some of the issues relate to the costs of maintaining facilities for student use. One provider notes the necessity of keeping up with technological advances in laboratories, research facilities, and classrooms to maintain appeal to prospective students. Another is struggling with the availability and quality of physical space for teaching and learning.

Funding

Two providers called attention to problems with the funding system under which they are working. One noted that continual changes detract make it hard to develop long term strategies for increasing the number of new engineering recruits, while the other suggested that the funding system acts as a disincentive against collaboration with other providers.

Insufficient demand

There is a disparity between the talk of skill shortages in engineering and actual employer investment in upskilling their staff, in one provider's experience. They add that many staff are unwilling to undertake further part-time study even when employers are willing to pay. Another provider's intake of new students has been restricted by trends in the wider economy, noting that one of the first thing firms cut in the face of an economic downturn is expenditure on training.

2. <u>Student Retention</u>

<u>Retaining students: what are the providers doing?</u>

As noted earlier, providers generally agree that tertiary engineering study is a significant step up from what secondary school students experience in the NCEA system. In response to this, all providers offer certain support services to their first year students. Examples include:

- senior student mentors/buddies and peer mentoring groups
- brief on-line lectures
- web-based self-testing
- a glossary of technical terms
- small tutorial groups

- website support, e.g. Piazza.com, and
- after-hours phone support.

Even with this kind of support, many first year students still struggle academically. Some students do not cope. It is clear that most providers accept some degree of responsibility for students who are at risk of dropping out. This usually means tracking all students' progress, diagnosing marginal students, and offering advice and help early. This monitoring and intervention takes a number of different forms:

Monitoring:

- a quiz on (or before) day one to assess prior knowledge
- math testing marginal students on entry
- early assessment and continual grades monitoring
- monitoring attendance, and
- english language needs assessment for international students.

Intervention/action:

- interviews with academic staff
- staff open door policy
- staff mentoring
- summer school options/'second chance' timing
- more flexible course timing (e.g. mid-year starts to fit in with foundation/fundamentals courses)
- reviewing previous cohorts to determine issues by subject area
- changing course design to fit student interest and learning styles, e.g. moving towards 'project- and problem-based learning, and
- redirecting the struggling student to another institute/qualification.

As well as being intellectually demanding, providers accept that beginning a tertiary qualification can be an emotionally trying experience for new students, especially those coming directly from secondary school. When they commence tertiary study, students have to learn to balance new work and social commitments with a vastly more demanding intellectual schedule than they are used to. Many providers indicated that there is institutional support that struggling students can access. Within engineering faculties and departments, most providers are making an effort to foster strong group cohesiveness and a positive engineering identity at their institution. Efforts to promote a positive identity for engineering students include:

- engineering-specific orienteering activities
- student-centred engineering website
- dedicated student space on campus

- social events to promote a sense of belonging
- opportunities for exhibiting work, and
- networking opportunities.

Student retention: what works?

As noted earlier, providers across the sector are working to retain students who are poorly prepared from secondary school. For this reason, most of the issues around retention are concerned with raising the majority of students up to the level at which they are able to continue their studies to completion. According to one provider, when the problem is addressed early enough, repeated, personal intervention with marginal students is effective. Providers can be commended on the level of care they provide for their students in this area.

Most providers do not explicitly state which of their retention methods are the most effective. They do, however, invest heavily in pastoral care for their students, and recognise the value of making their campuses sociable and supportive places to study. Many specify this as an ongoing goal. While older institutions have a rich engineering tradition to draw on, newer providers have made efforts to promote their own engineering identity, and in this, foster a student's sense of belonging.

Future initiatives

Providers' future plans around recruiting and retention fall roughly into four categories:

1) Increasing connectedness with secondary schools
2) Initiatives to promote students' academic success
3) The development of new courses, and
4) General promotion and marketing.

In terms of their future aspirations, a major theme shared by providers was their intention to engage more closely with secondary schools, both to lift the standard of mathematics and physics education and to raise the profile of engineering. Some providers are already contributing to the professional development of secondary school teachers in their region, while others plan to embark on this in the future. Most providers propose increasing connectedness with the secondary schools in their region in some way or another. Initiatives include:

- aligning with other providers regarding secondary school targeting
- research on understanding secondary school students' perceptions of engineering
- creating a telephone helpline for secondary school advisors

- running one- and two-day science and engineering programmes in secondary schools
- assisting in secondary school physics teaching, and
- taking the VEX robotics programme to schools in the region.

Initiatives to improve student's chances of academic success include:

- closer contact between students and academic staff
- greater use of e-learning platforms (e.g. Moodle)
- improving campus environment for students
- expanding student support services (e.g. telephone)
- employing more tutors, and
- assessing prior learning.

Many providers are developing new courses in response to student or industry demand. These include:

- block summer courses in mathematics and physics
- creation and modification of foundation courses
- development of pathway qualifications/new foundation certificates
- specialisation into new areas of engineering, and
- restructuring course timing to make it easier for students to continue to work while they study.

Almost all providers are committed to maintaining and expanding their marketing initiatives. Many intend to expand their general promotion (advertising), whilst others intend to pursue other avenues to attract students:

- promoting student involvement in international competitions
- saturday information sessions on campus
- more visits to employers and industry, and
- expand marketing (and improve affordability) to international students.

3. <u>Expanding opportunities for women, Māori and Pasifika</u>

<u>What are providers doing?</u>

With one exception, all providers are making an effort to increase the numbers of female, Māori and Pacific students who are able to gain entry to and pass through their engineering qualifications. These efforts fall roughly into four groups:

1) targeted recruiting
2) targeted student support
3) efforts to improve institutional inclusiveness, and

4) partnership with other groups and organisations working to promote better outcomes for women, Māori, and Pasifika.

Targeted recruitment efforts include:

- scholarships (both general/institutional and engineering-specific)
- targeted admissions criteria
- for Māori and Pasifika:
    - recruitment campaigns targeting secondary schools with high concentrations of Māori and Pasifika students (including Kura Kaupapa and Māori boarding schools)
    - accompanying Māori and Pasifika recruiting teams when they go off-campus
    - current Māori and Pasifika engineering students acting as role models/mentors to secondary school students.
- for women:
    - inviting secondary school girls to campus events which promote women in engineering
    - starting an intermediate and secondary school computing club for girls
    - targeted visits to all-girls schools
    - senior women academics involved in recruitment
    - promotion of female student successes in marketing materials.

Many providers also offer some form of targeted student support and encouragement:

- for women:
    - visits by female engineers in industry
    - events for women (e.g. Women in Engineering Network)
    - practice time using tools and machinery (industry supported)
    - mentoring and access to senior women academics
    - social activities.
- for Māori and Pasifika students:
    - mentoring programmes
    - dedicated pastoral care agents.

A number of providers are actively pursuing the creation of a more inclusive engineering environment, both for staff and students. Efforts include:

- female, Māori and Pasifika staff appointments
- inclusion of women, Māori and Pasifika in programme advice and strategic planning
- specific equity-promotion appointments, e.g. equity advisors
- use of Te Reo

- Marae visits, and
- marketing with more female, Māori and Pasifika images.

Many providers partner with other organisations to include Māori and Pasifika students in their programmes. Examples range from:

- recruitment through local organisations
- working with Māori and Pasifika organisations within universities and ITPs in providing student support
- specific ‘staircasing’ from Te Wananga o Aotearoa into higher level study
- working with Māori and Pasifika campus organisations/development teams on school outreach and recruiting activities, and
- working with SPIES and SPPEEX (South Pacific Engineering organisations).

To project-based cooperation, such as:

- cooperation on research projects in the Pacific Islands, and
- the Engineers Without Borders Challenge.

What is working?

As above, a number of providers emphasise the active targeting of secondary school students as the most effective way to increase enrolments, in this case, schools with high concentrations of girls, Māori and Pasifika. One provider notes that the introduction of its Undergraduate Targeted Admissions Scheme (UTAS) has significantly raised the proportion of Māori and Pasifika students in its first year engineering cohort. Once students are studying, providing resources for tutoring and mentoring female, Māori and Pasifika students helps to lift rates of retention.

Providers offered a number of future initiatives to increase numbers of female, Māori and Pasifika engineering students, indicating that – given more funding – providers would like to do more in this area. Tentative (funding dependent) plans include:

- more foundation courses centred on accessibility to undergraduate degrees for Māori and Pasifika, including numeracy programmes
- research on how to recruit more women into engineering/discovering barriers preventing women entering engineering study
- scoping the feasibility of a women’s trade academy
- research into employment obstacles preventing the upskilling of Māori and Pasifika workers through part-time study
- new equity appointments
- developing a Māori leadership network, and
- more recruitment of Māori students through community organisations.

Section 2: Connecting with industry

1. What are the providers doing?

Engineering education providers are aware of the importance of producing graduates who are work-ready. In order to prepare their students for the workforce, all providers seek to ensure that students have experience in engineering firms before they graduate. This is done in a variety of different ways, including:

- industry placements/work experience as a degree requirement
- industry moderation of third year/final year papers/projects
- industry sponsorship of final year projects
- summer work components/summer scholarships, and
- site visits.

One positive outcome of these efforts is the linking of students with opportunities beyond what the provider can offer. A number of providers accept some responsibility in helping students network with potential employers, and offer their students a number of other services to help them prepare themselves for the workplace:

- representatives from industry advise first year students as to how they can go about finding and securing work
- students are required to submit a CV and a covering letter, which is assessed
- hosting an on-line student job board from which industry can recruit students
- a faculty 'Specialisation Evening' detailing what different engineering specialists do
- industry-student networking events, and
- mock interviews.

Staff cannot connect students with job opportunities in engineering unless they themselves have meaningful connections with engineers in industry. Providers establish and maintain relationships with engineers working in industry in the following ways:

- staff undertake consultancy projects with industry
- industry specialists are part-time lecturers/guest lecturers
- industry funds academic chairs/in-residence positions
- staff are engineers with substantial industry experience
- staff are encouraged to join engineering professional societies
- staff work through the Christmas holidays
- apprenticeship coordinators spend most of their time in industry
- tutors visit students during placements, and

- staff continue to maintain personal contacts for increased enrolments and course maintenance.

Utilizing their connections with engineering firms, providers align what they teach with industry needs. More formally, providers use industry advisory boards (IABs) as a means of ensuring industry input into engineering curricula. IABs meet at least once a year, but many meet more frequently. Formal industry connections are also used to publicly recognise student excellence, for example in linking industry award ceremonies with student successes, and providing sponsorship for graduation prizes.

Another frequent outcome of industry input into curriculum (and industry involvement in final year student projects) is the development of collaborative Research and Development (R&D) projects. Providers offer a number of examples of research collaboration:

- sponsorship for masters students on industry projects (supported by TechNZ funds)
- using R&D vouchers to carry out research with smaller firms
- industry sponsored research fellowship position
- research/Innovation centres on campus funded and used by industry
- public (govt) funded civil projects (with industry), and
- offering research vouchers to industry for staff to carry out research on behalf of industry.

In addition to these connections with industry, providers liaise with firms in a number of other ways, including:

- tailoring short courses/specialised training programmes in response to industry demand
- cold-calling businesses to provide opportunities for students
- a full-time employment manager facilitates links between students and firms
- attendance and participation at industry forums, and
- hosting industry expos, seminars and research conferences.

2. <u>Future initiatives and obstacles</u>

<u>Future initiatives</u>

Providers intend to engage more closely with industry in the future. Though they identify several problems they have encountered in their efforts, with increased access to resources, cooperation between engineering educators and firms is likely to continue positively. Firms generally seek to increase their connectedness with industry in the following ways:

- recognise and reward staff interaction with industry
- ensure new staff appointments demonstrate a degree of engagement with industry
- organise industry-hosting events
- widen the scope of industry members on IABs
- aligning qualifications with industry needs
- market research into what industry wants from graduates, and
- aligning industry R&D with PBRF criteria.

Student placements

Many providers intend to strengthen their commitment to student placements in industry. Methods include:

- identifying key employers and emerging skill gaps
- new staff appointments to coordinate student placement
- increased staff consultancy activity with an eye to building connections for student placements, and
- more cold calls to industry.

In terms of demand for engineering student placements, there appears to be regional variation. Some providers are unable to meet industry demand, whilst others struggle to provide all their students with the requisite number of placement hours before the end of their coursework. One provider notes that students are generally only available over the Christmas break. Looking ahead, one provider notes that with the pipeline increasing, many more industry placements will be required. Another provider notes that international students are not as readily accepted by industry as their NZ counterparts.

<u>Obstacles</u>

Responding to firms

A common obstacle identified by providers is the problem of trying to meet industry needs within a relatively inflexible and prescriptive qualifications system. Some providers have responded to this by designing new qualifications for specific industries. Related to this is the problem that providers are frequently unable to respond to firms in a timely manner. This was highlighted as a common problem with small to medium sized engineering firms. One provider noted that interaction with smaller firms is generally restricted to consulting, thus precluding any opportunity for student interaction. Another has noticed a disconnect between firms expectations and students' capabilities (given the resources small firms are willing to provide). A number of firms have sought to address issues with smaller engineering firms by investing in on-campus research equipment and employing research-only staff. In one case, industry is directly involved in the delivery of a programme in exchange for use of laboratory facilities.

Cost

Investment in modern facilities is costly, and more than one provider mentions the high cost of keeping up with technical developments and more generally, establishing and maintaining links with industry contacts. Many providers intend to recruit more staff in order to more effectively link engineering education provision and research with industry requirements. This too, is expensive. Providers note the following financial costs involved in connecting with industry:

- the need to increasingly invest in modern facilities
- the time-cost of building industry partnerships for research and student project work, and
- specialist engagement with non-local engineering firms requires the use of electronic tools and staff visits to distant sites.

Part Two: Growing the engineering pipeline and strengthening connections to industry – analysis

Overall summary of provider responses

Tertiary engineering education providers are committed to increasing the pipeline of students as well as ensuring that their students graduate with the skills they need to commence work in the engineering industry. In their assessment of their own initiatives to link with industry, providers see their efforts as working well.

By contrast, engineering education provider's overall efforts to grow the pipeline of students are not working as well. Providers draw attention to a connected set of issues in the New Zealand secondary school mathematics and science education system. They cannot increase the number of engineering graduates if students are unable to meet the entry criteria for their qualifications. Furthermore, the majority of students entering first year engineering courses, even with the prerequisites, are inadequately prepared to study science, technology, engineering and mathematics (STEM) subjects at the tertiary level. In addition, providers struggle against low awareness about engineering, specifically: a lack of knowledge about the breadth and value of tertiary engineering qualifications, and misconceptions about what modern engineers actually do.

This part of the report has two main sections. The first analyses the problems providers face in their efforts to grow the pipeline, and the effectiveness of the strategies they are using to overcome these problems, considers the role engineering education providers can play in New Zealand schools to enhance the interest levels and academic outcomes of secondary school science students. This is followed by a brief discussion on what providers are doing to strengthen their connections to industry, what is working well, and the issues that are arising in this area. The final section also includes key findings from some international literature on the qualities that employers value in engineering graduates and the practices that providers can adopt to instil them.

Section 1: Growing the pipeline: Issues for providers

Public perception

A number of providers are still struggling to get certain key messages to secondary schools. ITPs complain that students are not informed by their schools that degrees can be done at ITPs. They are also concerned that the value of Diploma level qualifications is not well appreciated, nor do teachers and careers advisors appear to know

> 'how one qualification can staircase into another, all the way from trades level engineering through to postgraduate qualifications.'

One BE provider is frustrated to find that

> 'even after 10 years of producing graduates the [university] is not recognised by many parents and teachers as having an engineering programme at all.'

Other university providers explain students' lack of interest in engineering as resulting from a lack of knowledge that their advisors and influencers have of modern engineering. One notes that:

> 'There are no engineering specific subjects at secondary school, and perceptions of what engineering entails often revolves around building bridges or roads. The modern engineering careers of electronics, software and networking are generally very poorly known.'

In interviews with New Zealand secondary school students, Dale Carnegie and Craig Watterson note that students and their teachers have little idea about what makes engineering different to science. They asked students what they thought engineering was:

> '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 ...'[1]

Providers are keen to improve public understanding of engineering and the kinds of career pathways available across the tertiary sector. This will require significantly more involvement between tertiary institutions and secondary schools.

International students and the pipeline

Providers are struggling to fill places in their engineering programmes, because too few New Zealand students meet the criteria for entry into engineering. Providers have filled many of these places with international students, though this may be of questionable benefit to the New Zealand economy in the longer term if those students choose not to (or are not able to) remain in this country to work. A number of tertiary education providers have indicated that they intend to market more aggressively to international students as a means of increasing the pipeline of students entering engineering degrees. One ITP provider reveals that one of their

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[1] Carnegie, D. and Watterson, C. (2012) Engineering Pathways Project: Summary Report for the Tertiary Education Commission, http://ecs.victoria.ac.nz/Main/TechnicalReportSeries [30/07/13], p.66.

biggest recruitment issues is now attracting New Zealand students to its degree programme.

> 'We have good numbers attracted to the diploma programme but less than half of our degree recruits this year are New Zealanders. It does appear that the majority of New Zealand students have been accepted into university degree programmes.'[2]

Providers have had significant success marketing their qualifications in countries in which engineering enjoys a higher profile than in New Zealand, and which have a far greater pool of students with the requisite prior knowledge. This is easier for providers than competing against other professional degrees (and engineering providers) to attract the small number of qualifying New Zealand students to their engineering courses. If an inflow of international students is going to be part of increasing the pipeline, government needs to consider allowing, and indeed, encouraging NZ-qualified engineering graduates from overseas to become permanent residents in New Zealand after they graduate.

Not meeting the entry criteria

Increasing the pipeline of New Zealand engineering graduates will require growth in the number of school leavers well-grounded in science and mathematics. Provider responses indicate that the limited pool of secondary school students adequately prepared for tertiary engineering study is the biggest problem they face in finding new engineering recruits.[3] This is an issue at both universities and ITPs. ITP providers state this very clearly, for example:

> 'The greatest barrier to students entering engineering is failure to meet the entry criteria. Further, students that do meet the entry criteria are still underprepared in maths.'
>
> 'We turn away significant numbers of students who want to study but they need more maths and physics.'

Universities also face this issue:

> 'We are still seeing students who wish to study engineering but who – whether by choice or due to poor advice – take the wrong combination of subjects at school and are poorly prepared to go directly into the degree.'

Poor careers advice around engineering was expressed in all but one engineering provider report received by the TEC. It is clear that students are unprepared in two main ways:

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[2] Another ITP provider laments that 'IPENZ qualifications are not seen as attractive by secondary students and
[3] One provider reported that providing scholarships for first year study 'has not been a significant drawcard,' which to them indicated that there are not sufficient numbers of qualified students in the pipeline.

1) They wish to study engineering, but have not taken STEM subjects at school, and
2) Even with the prerequisites, the majority of students are still unprepared for tertiary level mathematics and physics.

There is a significant gap between the abilities of secondary school graduates, and what is expected of them in tertiary engineering study. Secondary school students also display little interest in engineering, perhaps stemming from a lack of public knowledge about what engineers actually do. Providers are already investing considerable resources to get students motivated to take STEM subjects, and to improve the teaching of these subjects. Providers have responded in two ways. They are:

1) accepting the weaker abilities (or lack of prerequisites) of secondary school graduates, and addressing the issue at their institutions. This they do by:

- developing and delivering new foundation courses
- creative timetabling, enabling students to start their qualifications with lower level mathematics and physics, but with the plan to ‘catch up’ to their more advanced peers, and
- investing heavily in additional tutorials and student support, and/or

2) attempting to improve STEM teaching and advice at secondary school:

- ensuring high school students are getting early and correct advice by visiting schools and forging closer relationships with careers advisors, and
- increasing ‘outreach’ activities to high schools, upskilling maths and physics teachers.

The following section discusses how providers are attempting to bridge the knowledge gap between secondary schools and tertiary engineering study.

Foundation courses

Many providers intend to develop and deliver more foundation courses to allow more students to progress to higher level engineering study. Providers who are able to access funding for them clearly express that foundation courses are effective in bringing students up to standard, and are especially important as a means of access into tertiary engineering study for disadvantaged groups. In its report to the TEC, one provider proposes a new foundation course, which would

> ‘provide access to a range of undergraduate programmes not only at the campus but also at other University campuses ... Given that one of the foundation stones of the [South Auckland] campus is centred on accessibility (particularly for Māori and Pasifika peoples),

> this would be one opportunity to increase the number of Māori and Pasifika students who would have the necessary entrance criteria for undergraduate programmes in engineering.'

Provider responses indicate that the provision of engineering foundation courses is an area which is still 'under construction.' Many universities and ITPs are still working on how to ensure students learn the theory they need to know to progress whilst maintaining interest in engineering. One ITP provider notes that its one year foundation course was too long, and students lost motivation. It has abridged the course to six months, and timetabled remedial maths, which it says is working better. Another ITP provider has found that creative timetabling has enabled unqualified students to start higher level qualifications at the same time as they pick up the basic academic skills that underpin their chosen area of engineering. Carnegie's evaluation of the effectiveness of Weltec's newly established foundation course showed that students who had taken the foundation course went on to outperform their (previously academically stronger) mainstream counterparts in the first year of their diploma course.[4]

Student support

Almost all providers indicated that they provide some form of student support to retain their students. Some providers' reports show that student learning support is becoming essential to get their students through their first year of engineering study. In one provider's words:

> 'An extremely significant concern is the poor preparation of the *bulk* of our student cohort following NCEA study.'

Student support usually involves tracking all students' progress, diagnosing marginal students, and offering advice and help early. Early assessment of students' mathematics knowledge – in one case a quiz offered before the first day – is considered a useful tool by many providers.

Once a student is identified as having difficulties, one provider offers that it is

> '...personal, and repeated, intervention that has proven to be most effective.'

Many institutions offer additional student support to Māori and Pasifika students. Creating an 'engineering identity' on campus was also considered important for retaining students, and a number of providers also specified making their campuses sociable and supportive places to study as an ongoing goal.

[4] Carnegie, D. And Watterson, C. (2012) Engineering Pathways Project: Summary Report for the Tertiary Education Commission, http://ecs.victoria.ac.nz/Main/TechnicalReportSeries [30/07/13], p.52.

Connecting with secondary schools

Foundation courses and student support may work well, and they are clearly seen by some providers as an ethical duty on the part of providers as well as a financial necessity to keep engineering places at tertiary institutions filled. But their effectiveness should not be seen as a cause for celebration. It is surely far better if students progress directly into engineering courses prepared, having had an excellent education in science and mathematics.[5] Provisions of foundation courses and student support represent a significant diversion of resources away from the teaching of engineering, and as Carnegie observes, they mask a much larger issue.

> 'These solutions are costly and have also ignored the larger problem: why are students, who are supposedly prepared through NCEA, poorly prepared?'

Carnegie's concern with secondary school science and mathematics education is mirrored in Australia, where the Chief Scientist has called for an overhaul in the way STEM subjects are taught across the country. Similar calls to improve students' interest, learning experiences and academic outcomes in school science and mathematics education have also been made in the UK, the US and many other developed countries.

In this country, the limited pool of students who qualify for entry into tertiary engineering qualifications is a problem across the board, but is most pronounced in the case of Maori and Pasifika students. Of the Māori and Pasifika students who have achieved good science and mathematics results at school, many end up studying medicine and law. A number of providers have targeted schools with high concentrations of Māori and Pasifika students and found this to be an effective way of bringing in a more diverse cohort of students.

As well as targeting schools with high proportions of Māori and Pasifika for recruitment, some providers have broadened their school connections more generally to improve the way science and mathematics is taught. By increasing their presence at secondary schools, providers have sent engineers and engineering students to showcase the applications of science and the possibilities a career in engineering offers. This practice is not widespread, though the providers who have engaged more deeply with particular schools have enjoyed positive outcomes.

Yet overall, the disconnect between tertiary institutions and secondary schools is widespread. In his recent research Carnegie notes that

[5] Foundation courses act as stepping stones for students who have not enjoyed success at school or have not made informed subject choices. The Weltec/VUW experience shows that students who have taken them may outperform those who do not take them. However, there is evidence that students who go directly from secondary school to tertiary study on the whole enjoy greater academic success, higher completion rates and are more likely to continue to study further. 'TEC Framework for youth and transitions,' available at www.tec.govt.nz/Documents/.../Youth-and-Transition-Framework.doc [last accessed 30/07/12].

> ‘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.’

Providers agree, with one noting that there is a

> ‘lack of connectedness between many University teachers of STEM subjects with their high school colleagues.’

As already noted, engineering education providers in New Zealand have begun to address this issue, accepting a role in re-igniting teenagers’ waning interest in science and mathematics. The following is one of many examples detailing the dedication of tertiary engineering staff to improving secondary school students’ interest in, and knowledge of, STEM subjects. The provider notes that its staff

> ‘... work many additional hours travelling and speaking to school groups ... Their efforts are well received in the communities and have played an important part in maintaining the numbers of students studying engineering ... [the] programme that was offered after school class hours in the Auckland Region for several years is another example of staff commitment towards increasing student participation in science, technology and engineering.’

Because they have already begun to partner with secondary schools in this way, universities and ITPs who provide engineering education are well-placed to enhance the quality and status of science and mathematics teaching at secondary school. School targeting has also been effective in raising the application rates of women, Māori and Pasifika in engineering. One university notes of its inaugural visit to an all-girls school in its region that

> ‘[the visit] resulted in 2012 in a spectacular rise in applications from females at one such school, compared to the zero applications in previous years.’

The same results can be seen in the University of Auckland’s assessment of its new programme which targets schools with a high concentration of Māori and Pasifika students:

> ‘In 2012, this programme involved 520 students in 85 schools and has resulted in a tripling of applications for the Faculty’s UTAS scheme since 2011 and contributed to a 17% rise in Māori and Pasifika engineering applications compared to last year.’

Carnegie was part of a Weltec/Victoria University project to engage secondary school students in electronic engineering by providing them with a printed circuit board. The initiative was extremely well received by students, generating ‘an overwhelmingly positive response.’ In Carnegie’s assessment, this effort, among other initiatives, has contributed to a marked increase of enrolments in Victoria's engineering programme.[6]

Engineers in schools

Students' experiences with science at school, and knowledge of the range of career opportunities that involve science are two major factors that influence students' decisions as to whether they continue to learn science.[7] Tertiary engineering education providers are well placed to address both of these influential factors. Increasing the coverage and intensity of connections between tertiary institutions and secondary schools is likely to increase the number and academic quality of engineering applicants in the long term.

Crucially, connections between tertiary institutions and secondary schools need to begin early enough that school students have not yet made specialised subject choices. A 2012 Royal Society report notes that:

> 'three recent New Zealand studies confirm that here, as in other countries, students are making up their minds about science and science careers well before age 15, when they can choose not to study it. These early choices dictate who enters our future science workforce and they have an impact on the general population's understanding of and attitude towards science.'[8]

International literature on improving STEM teaching suggests that a national plan for science and mathematics collaboration in schools should:

- target every secondary school in the country, including rural schools
- provide secondary school teachers opportunities for professional development
- align providers' incentives with desired national education outcomes; and most importantly,
- identify for delivery *core content which is essential for entry into tertiary study.*

Additionally, some engineering providers with experience in New Zealand schools draw attention to the following issues which they would like to see quickly resolved:

1) The trend of schools protecting their academic reputations by actively discouraging marginal students from studying STEM subjects needs to be immediately investigated and stopped.
2) TEC's funding system needs to incentivise tertiary providers' collaboration.

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[6] Ibid, pp. 69-73.
[7] Buntting, C. et al (2013) 'Securing Australia's Future STEM: Country Comparisons,' http://www.acolasecretariat.org.au/ACOLA/PDF/SAF02Consultants/Consultant%20Report%20-%20New%20Zealand.pdf [30/07/13].
[8] Royal Society (2012) 'The future of Science Education in New Zealand,' available at http://www.royalsociety.org.nz/publications/policy/ [31/07/13].

3) Small and lower decile schools face particular challenges resourcing year 13 science classes.
4) Attention needs to be paid to the ‘work ethic’ created by the NCEA system.

Victoria and Weltec’s successful secondary school initiatives suggest the following may be useful as considerations to inform the content and method of outreach activities in New Zealand (Victoria and Weltec’s activities were specifically related to digital engineering; the following have in some cases been abridged and generalised in order that they might apply to a wider range of activities that universities and ITPs can offer). Outreach activities should:

- inform the students and people who influence them about engineering, and how it is related to the activity
- work within school curricula to assist the teacher’s delivery of an NCEA module,
- provide the students with an engaging hands-on activity
- leave the students with a lasting impression
- illustrate engineering concepts, not just science
- show the relevance of the activity in terms of the branch of engineering, and the role that this it plays in the everyday world
- show that the activity is the first part of a journey towards participating in that branch of engineering
- motivate the student to study that branch further
- offer opportunities to extend the activity, and
- emphasise the creative character of engineering by showing students how to create something of their own.[9]

In addition to these considerations, special attention needs to be paid to the styles of teaching and messages which specifically encourage female and minority students to continue to study science and mathematics. In line with the literature on encouraging girls’ achievement and persistence in STEM subjects, messages should incorporate the following two messages:

1) visits to adolescents need to emphasise *the usefulness of mathematics and science*, and,
2) impart the feeling that *one controls one’s own destiny.*’

Both of these techniques have been shown to be effective in influencing teenage girls’ subject choices at secondary school.[10] A survey of the research and literature in this area specific to New Zealand, including research on best practice in encouraging

[9] Carnegie, D. And Watterson, C. (2012) Engineering Pathways Project: Summary Report for the Tertiary Education commission, http://ecs.victoria.ac.nz/Main/TechnicalReportSeries [30/07/13], pp. 66-7.
[10] See Leslie, L., McClure, G. and R Oaxaca (1998) ‘Women and Minorities in Science and Engineering: A life sequence analysis,’ *The Journal of Higher Education,* **69** (3) May-June 1998, pp 239-276.

Māori and Pasifika teenagers' persistence with STEM subjects needs to be carried out and research gaps addressed. Lifting rates of participation of these equity groups in engineering is essential to creating an ongoing positive cycle which is likely to produce more diverse Māori and Pasifika engineers annually.

Section 2: Creating work-ready engineering graduates

In terms of industry-readiness, providers consider themselves to be well-connected with industry, particularly in the case of Institutes of Technology and Polytechnics (ITPs). All providers ensure that students undertake work experience and are exposed to engineers and industry during their qualifications. Many providers offer additional opportunities for students to connect with industry, such as networking events, guest lectures and site visits, to name only a few. Providers are involved in research partnerships with industry, giving students the opportunity to work alongside engineers both on and off campus. Professional engineers are increasingly sought after for academic positions in engineering departments. All providers intend to continue to engage with industry in the future, with most planning to deepen this engagement.

The issues providers raised concerning industry connectedness were:

- the high cost of keeping up with modern engineering facilities
- matching an inflexible qualifications system with the fast responses demanded by many firms, especially smaller firms
- the staffing cost of building new connections with industry, and
- finding work placements and suitable project-work for students in the final year of their degrees.

A number of providers intend to address these issues by making new staffing appointments (research-only staff appointments to improve responsiveness to industry, as well as industry liaison appointments), and applying for funding from both public and private sources to invest in new facilities. Some providers voiced concern at the number of student work placements that will be required as the pipeline of students increases.

Producing work ready graduates: Literature review

Engineering education providers in New Zealand want their graduates to be as prepared as possible for the rigorous demands of the engineering industry. The remainder of this report details the attributes that experienced engineers and industry value in engineering graduates, and the curriculum initiatives that providers can employ in order to foster these qualities in their students as they work through their qualifications. The first section briefly scopes the international literature on the desired qualities of engineering graduates, with an emphasis on the experiences of recent graduates who have found success in the workforce. The second section offers a short summary of what providers are doing internationally to better prepare engineering students for what lies ahead.

1. Graduate qualities

The improvement of graduates' *non-technical* engineering skills is a major focus in the literature on engineering education. This has been the case for some time. Vital non-technical capabilities of successful engineering graduates can be understood as falling into roughly three themes:

- *Emotional maturity*: the ability to work in teams and communicate well,
- *Life-long learning*: the ability to assess and improve their abilities and performance, and
- *Contingent reasoning*: the ability to work in a context of risk and uncertainty.[11]

Any improvement in other aspects of engineering curricula must not come at the cost of reducing graduates' understanding of engineering fundamentals. Some commentators express their concern that engineering education reform in the last two decades (emphasising emotional intelligence over technical knowledge) has indeed come at this cost; namely, a weakening of fundamental engineering skills.[12]

Rather, recent literature on best practice in engineering education suggests that technical knowledge is a necessary but insufficient criterion for an engineering graduate's success in the workplace. As one engineering graduate in Sageev and Romansovski's study reflects, 'technical abilities are a given, communication and leadership differentiate.'[13]

Engineers with experience in the workplace stress the desirability that engineering graduates have a contingent – rather than linear – approach to problems. Moreover, it is connected to other important non-technical qualities. In their interviews with high performing engineering graduates, Scott and Yates discover this theme repeated by many of their respondents. They summarise:

[11] For more detail on these capabilities and deficiencies in engineering education more broadly, see Mason, G. (1999) 'The Labour Market for engineering, science and IT graduates: are there mismatches between supply and demand?' UK Department for Education and Employment Research Brief No. 112, Martin, R. et al (2007) 'Engineering graduates' perceptions of how well they were prepared for work in industry,' *European Journal of Engineering Education,* Vol. 30, Iss. 2; Meier et al (2000) 'Refocusing our efforts: Assessing non-technical competency gaps,' *Journal of Engineering Education*, Vol. 30, Iss. 3; Sageev, P. and C. J. Romanovski (2001) 'A message from Recent Engineering Graduates in the Workplace: Results of a Survey on Technical Communication Skills,' *Journal of Engineering Education,* Vol. 90, Iss. 4, pp. 685-693; and Scott, G. and Yates, K.W. (2002) "Using Successful Graduates to Improve the Quality of Undergraduate Engineering Programs,' *European Journal of Engineering Education*, Vol. 27, No. 4, pp. 363–378, 2002.

[12] In a report for the Australian Council of Engineering Deans, employers and professional engineers advise that recent graduates are less proficient in technical knowledge than previous cohorts. Specifically, they report that modern engineering graduates had a weaker grasp of fundamentals, were less able to work from first principles, were more reliant on software tools than desirable, and were not able to independently verify computed answers. King, R. (2008) *Engineers for the Future: addressing the supply and quality of Australian engineering graduates for the 21st century*. Accessed at http://www.altc.edu.au/carrick/go/home/grants/pid/343 [1/9/2013].

[13] Sageev, P. and C. J. Romanovski (2001) 'A message from Recent Engineering Graduates in the Workplace: Results of a Survey on Technical Communication Skills,' Journal of Engineering Education, Vol. 90, Iss. 4, p. 689.

> 'First... when the unexpected occurs, when a project does not pan out as expected, when things are not running routinely, that professional capability in engineering is most tested. Second, that it is the combined effect of emotional intelligence, intellectual ability [among other key skills] which makes the difference at these times.'[14]

Whether they know it at the time or not, graduates enter a working world of uncertainty with only a skeletal framework of knowledge. From then on, it becomes a graduates' responsibility to improve their understanding of their field. Given the short half-life of engineering knowledge, practising engineers need to keep up with advances in engineering science over their careers: in short, good engineers have a propensity for life-long learning.[15] Reflecting on the purpose of learning technical knowledge, Scott and Yates find that

> '...learning profession-specific content serves the important purpose of providing the "scaffold" around which such subsequent workplace learning can be developed. This has direct implications for how we enable students to develop the generic skills necessary for career long professional learning.'[16]

It is clear that training students to independently produce the correct answer – as is required to pass exams – is not enough. New Zealand engineering education providers are aware of this, and all endeavour to provide their students with experience in industry before they graduate. Despite this, it is likely that there is room to improve the way New Zealand engineering students are taught and assessed before (and during) their work placements.

Though there is little academic literature on the quality of New Zealand engineering graduates, industry feedback in a recent forum[17] draws attention to eleven non-technical skills (combined with technical knowledge) which are seen as desirable in the ideal engineering graduate. This list is very similar to the attributes described above.[18] In New Zealand, for the most part, many of these skills are currently learned in the workplace, at the expense of industry.

The following section discusses what engineering education providers can do to help their students take on the professional attitudes and behaviour sought by engineering employers.

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[14] Scott, G. and Yates, K.W. (2002) "Using Successful Graduates to Improve the Quality of Undergraduate Engineering Programs,' *European Journal of Engineering Education*, Vol. 27, No. 4, pp. 363–378, 2002.

[15] *Life-long learning is a commonly used phrase in the literature on the desired attributes of engineers. For more on this, see Scott and Yates (ibid), and Martin, R. et al (2007) 'Engineering graduates' perceptions of how well they were prepared for work in industry,' European Journal of Engineering Education, Vol 30 Iss.2, p. 168.*

[16] Scott, G. and Yates, K.W. (2002) "Using Successful Graduates to Improve the Quality of Undergraduate Engineering Programs,' *European Journal of Engineering Education*, Vol. 27, No. 4, pp. 363–378, 2002.

[17] The Tertiary Education Commission hosted two forums with engineering industry, education providers and government in August 2012.

[18] Attributes identified in the forums were technical knowledge, problem solving, an understanding of complex environments and anomalies, the ability to deal with situations when things go wrong, the ability to learn on the job, a focus on collaboration and teamwork, with an ability to work across an organisation, communication skills (including being able to communicate engineering ideas with non-engineers), the ability to manage relationships, work experience, independent thinking, risk management and business expertise.

2. Training engineers for industry

International literature on engineering education offers a number of useful curriculum responses to the above issues. Outlined here are four broad areas for improvement that providers could consider strengthening within their curricula. Improving teaching in these areas is likely to help engineering students emerge from their education better able to collaborate with others and work under conditions of uncertainty, as they build the 'scaffold' for life-long learning.

Teaching emotional intelligence

In terms of teaching non-technical skills, such as the ability to communicate well with others, Scott and Yates suggest that engineering education providers might draw attention to the importance of these skills at the beginning of the course. Doing so, their interviewees suggested, would 'give their learning far more relevance and focus.'[19] Furthermore, the successful graduates in Scott and Yates' study strongly recommend that that it is *the complete tertiary education experience* that helps students to develop the emotional intelligence required in the workplace, 'not just what happens in the classroom.'[20]

Given that secondary school students who show comparative strength in technology rather than interacting with people or dealing with uncertainty[21] are more likely than their peers to be encouraged to pursue engineering by career advisors,[22] it is likely that engineering students will benefit from increased curricular emphasis on non-technical skills. They are more likely to require training and practice with people, and working with contingencies than the general student population. Scott and Yates suggest that these skills can be set as 'a central focus in the observation and assessment guides used by students during work placements.'[23]

It may also fall to engineering education providers to prepare their students for other non-technical realities of life in the workforce, to wit, the large amount of time spent in communication with other workers. Sageev and Romanovski write:

> 'No longer is it sufficient to educate students only in engineering subjects. The average 64 percent time they spend on various types of communication validates industry's requests that engineering schools urgently address this major "competency gap." These former students also taught us that most graduates are insufficiently prepared for the job-related communication demands they face.'[24]

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[19] Scott G. and Yates, K.W. (2002) 'Using Successful Graduates to Improve the Quality of Undergraduate Engineering Programs,' *European Journal of Engineering Education*, Vol. 24, p. 370.
[20] Ibid, p. 372.
[21] See Carnegie, D. and Watterson, C. (2012) Engineering Pathways Project: Summary Report for the Tertiary Education commission, http://ecs.victoria.ac.nz/Main/TechnicalReportSeries [30/07/13], pp 59-60.
[22] Scott G. and Yates, K.W. (2002) 'Using Successful Graduates to Improve the Quality of Undergraduate Engineering Programs,' *European Journal of Engineering Education*, Vol. 24, p. 370.
[23] Ibid, p. 370.
[24] Sageev, P. and C. J. Romanovski (2001) 'A message from Recent Engineering Graduates in the Workplace: Results of a Survey on Technical Communication Skills,' *Journal of Engineering Education,* Vol. 90, Iss. 4, p. 690.

A respondent in Scott and Yates' study suggested that rather than teach communication skills through formal presentations and the like, these skills are more usefully taught in different ways, such as:

> '...trying to relate technical information to a non-technical person and seeing what they understand or trying to communicate an idea to a workgroup and getting feedback on how well this worked.'[25]

To equip engineering students with what they need to succeed beyond university, communication skills can be trained, assessed, and rewarded at the same time as students are learning the technical skills they need to become engineers.

Conceive-Design-Implement-Operate

The CDIO framework, according to its proponents, provides students with an education stressing engineering fundamentals set in the context of Conceiving — Designing — Implementing — Operating (CDIO) real-world systems and products.[26]

CDIO is highly regarded in international engineering education literature. The first recommendation in a major study intending to reform engineering education is to institute a curriculum 'interwoven with CDIO activities.'[27] Robin King, in a 2008 Australian report for the Australian Council of Engineering Deans, suggests that 'the CDIO concept, based on experiential learning theory, is probably the most important recent formal development in engineering education.'[28] CDIO learning activities, King reports, 'are crafted to support explicit pre-professional behaviour.'[29] This form of education is very likely to help students understand the need to think in terms of contingent outcomes, but will require significant investment. As King recommends of the Australian context, the ability of engineering schools to implement CDIO to the highest standards is very much limited by the resources available to the schools and the richness of their industry linkages.'[30]

Industry work experience

Throughout the literature on best practice in engineering education is the call for greater emphasis on internships and work placements in the qualifications process. This has also been highlighted by some New Zealand industry representatives, who mentioned in the 2012 TEC-hosted engineering forum that they are committed to making industry-supported internships an 'integral part of the learning and

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[25] Scott G. and Yates, K.W. (2002) 'Using Successful Graduates to Improve the Quality of Undergraduate Engineering Programs,' *European Journal of Engineering Education*, Vol. 24, pp. 363–378, p. 372
[26] See www.CDIO.org [6/9/13].
[27] Brodeur, D.R. et al (2002) 'International Collaboration in the Reform of Engineering Education,' Proceedings of the 2002 American Society for Engineering Education Annual Conference & Exposition, Massachusetts Institute of Technology/Linköping University/Chalmers University of Technology/Royal Institute of Technology, available at www.cdio.org/files/document/file/CDIO_inter_collab.doc *[Accessed 6/9/2013].*
[28] King, R. (2008) *Engineers for the Future: addressing the supply and quality of Australian engineering graduates for the 21st century*. Accessed at http://www.altc.edu.au/carrick/go/home/grants/pid/343 [1/9/2013].
[29] Ibid.
[30] Ibid.

assessment aspect of qualifications.' A greater degree of flexibility in the semester system may be required to bring this about, but more involvement in industry will help students to understand how to use their engineering knowledge in the real world, and specifically that 'there is never a fixed set of steps for solving workplace problems.'[31]

Multidisciplinary team working

Working in multidisciplinary teams during undergraduate study helps students to learn how different branches of engineering work together, as well as the vital communication, team working and leadership skills they will need in industry. In a study of interdisciplinary engineering project programme at Plymouth University, Skates finds from his research

> '... that both undergraduate and postgraduate engineering students would benefit from working in interdisciplinary teams whilst at university and that having done so they would leave university better fitted for careers in engineering.'[32]

In their survey, Scott and Yates interviewees ranked 'being able to contribute positively to the team-based projects' as the most important attribute for successful engineering practice.[33] This, they report, was accompanied by a set of qualities 'concerning personal aspects of emotional intelligence,' which included 'a willingness to face and learn from errors and listen openly to feedback,' and 'being willing to take responsibility for projects, including how they turn out.'[34] These qualities are an integral requirement for – and a product of – learning from teamwork. Similarly, some New Zealand industry representatives have called for more learning that is project-based and multi-disciplinary to better 'reflect the reality of the workplace, and provide an understanding of how business operates.'[35]

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[31] Scott G. and Yates, K.W. (2002) 'Using Successful Graduates to Improve the Quality of Undergraduate Engineering Programs,' *European Journal of Engineering Education*, Vol. 24, p. 369.
[32] Skates, G.W. (2003) 'Interdisciplinary project working in engineering education,' *European Journal of Engineering Education,* Vol. 28, Iss. 2. p 187.
[33] See also Sageev, P. and C. J. Romanovski (2001) 'A message from Recent Engineering Graduates in the Workplace: Results of a Survey on Technical Communication Skills,' *Journal of Engineering Education,* Vol. 90, Iss. 4, p. 690.
[34] Scott G. and Yates, K.W. (2002) 'Using Successful Graduates to Improve the Quality of Undergraduate Engineering Programs,' *European Journal of Engineering Education*, Vol. 24, p. 368-9.
[35] Tertiary Education Commission hosted engineering forums in August 2012.

Conclusion

Providers are committed to both growing the pipeline of students and producing work-ready engineering graduates. Their connections with industry are increasing, and are set to deepen further as they become more able to devote resources to this endeavour in the future. Growing the pipeline of students is a more difficult task, and will require a national plan for increased connectedness between the tertiary and secondary education sector.

Increasing secondary school students' exposure to engineers and engineering concepts is one of a number of initiatives that providers have found useful as a recruiting technique. It is also an effective way of bringing more female, Māori and Pasifika students into engineering programmes directly from secondary school. Increasing these connections is a fundamental step towards increasing the pool of New Zealand students who are able to enter tertiary engineering qualifications.

Engineering education providers in New Zealand know the importance of ensuring that their students are ready and able to contribute positively to the workplace they choose to enter as graduates. By drawing attention to the non-technical skills required by industry, and by ensuring the formation of these skills through the curriculum, providers will produce graduates with a skill set well-suited to satisfying life-long careers in engineering.