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A New Model for Engineering Education

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BACKGROUND

Chisholm Institute's Centre for Integrated Engineering and Science (CIES) has developed a unique industry focused engineering technology degree program with two streams: mechanical and manufacturing; and mechatronics. The program was developed in close consultation with local industry and professional bodies including SEMMA, Engineers Australia, and the South East Business Network to ensure the program is relevant.

Advanced manufacturing accounts for around half of Australia's A$104 billion annual manufacturing output and is one of the fastest growing export sectors. In Victoria, for over a decade there has been strong growth in elaborately transformed manufactures (ETMs). To remain globally competitive it is essential Australian manufacturing becomes increasingly efficient, innovative, use new technology to best effect, and minimise defects through effective continuous quality improvement.

This demands higher level technical skills, a broader range of skills and the need to update skills more often. To address this Chisholm's Bachelor of Engineering Technology program started a full first year delivery this year in the new well equipped $14million CIES building.

PURPOSE

This paper investigates the research questions:

What contribution can a TAFE delivered engineering technology degree program make to alleviate the Australian engineering skills shortage?

What advantages and shortcomings arise from the different learning outcomes?

DESIGN/METHOD

A descriptive background of the unique feature of the program and their impact on the research questions shows the potential advantages, problems and limitations surrounding the delivery of this unique program.

RESULTS

In its first year intake of 30 students the program shows a significantly different demographic from that of a similar Commonwealth supported university degree program.

An independent survey of student perceptions of this program was highly positive and industry guests at the first year experience concept presentations spoke positively of the written and oral presentation standards of the students.

CONCLUSIONS

Industry and student perceptions of the program are high. Unique features of the program including an industry project based first year experience, industry experiential learning, and industry standard on-campus equipment, will better engage students to learn and equip them to support Victorian manufacturers compete in a global economy.

KEYWORDS

Experiential learning, industry focused engineering programs, engineering technologist, CDIO Initiative, engineering attributes, first year experience.

Introduction

In 2011 Australian manufacturing employed 19.4% of Australia's engineers (47,129) being second only to 'Professional Scientific and Technical Services' which employed 20% of Australian Engineers (Kaspura 2011).

Advanced manufacturing produces approximately half of Australia's A$104 billion annual manufacturing output and is amongst the fastest growing export sectors (Australian Trade Commission 2012). It is also a prime media for foreign direct investment (FDI). In 2006 FDI in Australian manufacturing reached A$60 billion (ibid.).

Manufacturing plays a major role in Victoria's economy accounting for $30.6 billion or 11.4% of Gross State Product (DIIRD 2008 p8). Across Victoria, for more than a decade there has been strong growth in elaborately transformed manufactures (ETMs). Between 1999 and 2008 export of products from Victoria's ETMs rose 42% (ibid.p.9) As a consequence of the growth in modern manufacture there has been a rising share of higher skilled professionals within the manufacturing workforce with an increase in the proportion of managers and professionals from 20% to 30% (ibid. p.9).

Elaborately transformed manufacturing represents high value-added niche areas demanding high level technical skills. Victorian examples include air traffic management systems to Asia, utility aircraft and missile systems to the US, and automotive instrumentation to Europe (ibid.).

To remain globally competitive – particularly in the face of the high Australian dollar exchange rate – it is essential Australian manufacturing companies become increasingly efficient, innovative, use new technology to best effect, and minimise defects through effective continuous quality improvement. The skill implications are a need for higher level technical skills, a broader range of skills and the need to update skills more often. However continuing critical engineering skills shortages persist as evidenced by the referal to senate on 7th November 2011, and the resultant senate inquiry report into strategies to address the shortage of engineering skills (Black et. al, 2012).

It is note-worthy that from 1990 to1998 there had been a 77% increase in the annual graduation rate of professional engineers (including engineering technologists). Contributing factors included:

a. The introduction of the Lloyd et al. (1989) proposed articulated pathways through three year engineering technology degrees. By the end of 1999 nineteen university engineering schools offered a total of fifty separate engineering technology degree programs.
b. A significant increase in university engineering schools and Engineers Australia accredited professional engineering programs. From 1980 to 2000 there was an increase from 26 to 35 engineering schools and 113 to 229 four year engineering degree programs.
c. An accelerating proliferation of engineering undergraduate courses in specialist or hybrid areas.

However the subsequent decade saw the local supply of engineering skills fall well short of demand. A survey by the Australian National Engineers Taskforce (ANET Engineers Survey, 2010) found 60% of the individual engineers they surveyed report that they had engineering skills shortages in their work sections. From 2001 to 2008 the average annual growth in the number of domestic graduates was just 1% whilst the graduation rate of overseas students grew 11%. New Australian engineering graduates account for only 40% of total supply; migrant engineers account for 60% (Towards a National Strategy for Migrant Engineers – a discussion paper 2011).

Mature students provide the main growth area in higher education. They include not only those who did not have the opportunity to go to university when they left school but also the increasing number changing career direction, studying for higher degrees or engaged in continuing professional development to update or broaden their education (Ferguson 1998; Brodie 2007; Ferguson et.al 2008).

However engineering shortages are across the full engineering spectrum from the engineering trades to the professional engineer. The Chisholm model embraces another approach to increasing the overall engineering skills base through linking the Lloyd et al. (1989) engineering pathway approach with the co-location of the engineering technology degree program with the engineering trades and further education programs. Chisholm is also developing well mapped articulation and guaranteed pathways between the programs, providing significant advantages at all levels. Students entering at trade level have the assurance of a clear pathway to the degree program if capable, and those enrolling in the degree program, concerned that they may find it too difficult, have the assurance that they can articulate into a less academic program - rather than leave their engineering studies with nothing (Ferguson, C. 2012).

Chisholm Institute, the largest of Victoria's TAFE Institutes, was registered by the Victorian Registration and Qualifications Authority in 2010 as a higher education provider. Thus, with the formation of the new national regulatory body, it is registered as a higher education provider with the Tertiary Education Quality and Standards Agency.

Chisholm has the only Engineers Australia (provisionally) accredited Australian Bachelor of Engineering Technology program outside the university sector. It commenced in pilot mode in the latter half of 2011 and started a full first year program in 2012. This TAFE located industry focused program better facilitates increasing the number of graduates with VET qualifications (e.g. Diplomas and Advanced Diplomas) progressing to professional engineering technologist and professional engineer. Graduates of this program can progress to professional engineering status through a distance education based 'conversion' master degree qualification with the University of Southern Queensland who will provide Chisholm engineering technology graduates some advanced standing.

Currently only approximately 6% of all Australian students commencing engineering bachelor degrees are admitted on the basis of VET qualifications (King et.al 2011). Thus this program contributes to the strategies for increasing the number of commencing students in bachelor degrees in engineering outlined by King et.al in their Pathways from VET Awards to Engineering Degree: a higher education perspective (ibid.).

This program also has the potential to facilitate higher engagement with higher education for those from a lower socio-economic background as Greater Dandenong is Melbourne's poorest area (Butt 2012)

This paper describes the development of the Chishom Bachelor of Engineering Technology program in association with Engineers Australia, The South East Melbourne Manufacturers Association (SEMMA), the South East Business Network (SEBN), the Australian Industry Group (AiG) and local industry. It then describes the main features of the program, the advantages and disadvantages of the program provider being from the TAFE sector, the substantial difference in demographics of the small student base from a typical university delivered Bachelor of Engineering Technology program and the initial student and industry perceptions of the program and investigates the research questions:

> *What contribution can a TAFE delivered engineering technology degree program make to alleviate the Australian engineering skills shortage*?
>
> *What advantages and shortcomings arise from the different learning outcomes?*

The Chisholm Bachelor of Engineering Technology

Chisholm Institute's Centre for Integrated Engineering and Science, with support from SEMMA, Engineers Australia, the South East Business Network, (SEBN), the Australian Industry Group (AiG) and local industry, developed a unique industry focused engineering technology degree program from the ground up to develop graduates more suitable for contemporary manufacturing industry. It has two streams: mechanical and manufacturing; and mechatronics.

The centre is a founder of the South East Melbourne Manufacturer's Alliance (SEMMA) which now represents over 200 leading manufacturers. It is based in one of Australia's most dynamic manufacturing regions, producing almost half of Victoria's manufactured goods.

Chisholm has a strong reputation for industry focused tertiary education needs, and has considerable engineering laboratory facilities in its new $14 million Centre for Integrated Engineering and Science facility, thus ensuring students have high level access to the latest industry standard technology.

SEMMA members also provide suitable industry projects throughout the program, industry practicums, and course advice through membership of the Bachelor of Engineering Technology course advisory committee. They feel ownership of this program.

Engineers Australia provisionally accredited, this degree program was also accredited by the Victorian state government's Victorian Registration and Qualifications Authority (VRQA) and thus is now under the accreditation regime of the Australian Tertiary Education Quality and Standards Agency (TEQSA).

Unique features of the program

The unique features of the Chisholm Bachelor of Engineering Technology program include industry project based learning aligned with the teaching strategies of the CDIO Initiative. Through the development of this degree program Chisholm's Centre for Integrated Engineering and Science became a CDIO collaborator in January 2011.

Industry focused subjects

A large number of industry-focused subjects supplement the traditional discipline based engineering science and this is probably the most visible unique feature of the program. For example, the subject originally conceived as Vibration Analysis has been redeveloped as Machine Condition Monitoring (of which vibration analysis is of course the key component). This better enables the subject to be offered in the context of its engineering use in industry and the subject involves group industry based projects to reinforce the knowledge base. Similarly, the subject originally intended as Advanced Materials Science has been redeveloped as Materials and Process Selection with a focus on how a mechanical engineering technologist may be expected to apply that knowledge base in industry.

Other industry focused subjects are directly the result of industries 'wish list' and include subjects such as quality management, programmable logic controllers, industrial networking, data acquisition systems, industrial automation, project management and estimating and costing.

First year experience

The CDIO approach suggests all programmes include a 'First Year Experience' to address CDIO Standard 4. The first year experience should seek to illustrate the roles and responsibilities of professional engineers and the people with whom they interact; to show how disciplinary knowledge is applied in the solution of engineering problems; and to target the development of knowledge, skills, and attitudes essential in professional engineering (Ferguson et.al 2008). In the Chisholm program this is covered by four linked subjects across both semesters:

1. The 1st subject The Professional Engineering Technologist introduces the skill sets of literature research, referencing, report writing and oral presentations before addressing the professional issues of ethics, sustainability, intellectual property etc. In this subject they also consider the range of attributes they need to develop for the engineering roles to which they aspire.
2. In the 2nd subject Engineering Design and Practice they are introduced to an industrial issue to be resolved through engineering design. The groups create three or more solutions to assess. They then present their proposals to industry, both as a report and as a group oral presentation.
3. The 3rd subject CADII they develop the engineering drawing package and submit their material requirements to the company for their approval and to purchase the components.
4. The engineering drawing packages are then built by the groups in the 4th subject Engineering Practice II – a six week practical subject on welding and fabrication that follows the nine week subject CADII.

An issue of particular concern with such a significantly industry centric program delivery is the assurance of the essential local industry support in the form of suitable engineering projects at each level of the program. The 'first year experience' industry projects were our first call on industry (through SEMMA) to support our program and this support was immediately forthcoming.

Industry focused experiential learning

Several subjects, particularly those with an industry focus have industry focused experiential learning, often in the form of group project based learning, to show how disciplinary knowledge is applied in the solution of authentic engineering problems.

Industry Capstone Project/ Engineering Practicum

To further ensure our graduates are industry ready, all final year projects will be sourced from SEMMA unless the student is already employed with a company that can provide a suitable industry project.

An eight week engineering practicum is, of course, already an Engineers Australia requirement for all Bachelor of Engineering Technology programs. SEMMA will arrange these practicums. (Students already working in a suitable engineering work environment may be exempt from the SEMMA arranged practicums.) All students must produce a report on their work experience.

Engineering support for mathematics teaching

This concept was originally proposed by the author to ensure those teaching the mathematics subjects had access to suitable engineering related tutorial problems. These would be provided by the engineering technology degree program team. The concept was based on the more conventional university practice of mathematics being delivered as service teaching from the mathematics department. Frequently these lecturers are unaware of the engineering applications of their teaching and thus fail to inspire the students. However the current lecturer teaching mathematics in the Bachelor of Engineering Technology program is an engineer and engineering mathematics is proving to be one of the more popular subjects!

Addressing deficiencies in mathematics

King et al. (2011p37) suggest that the absence of mathematics as defined units of competency in the engineering Advanced Diploma defined Training Packages is an ongoing concern for articulation. This deficiency does not occur in the Victoria Advanced Diploma Training Packages developed by a consortium of Victorian TAFEs with the support of the

Engineers Australia Australian Engineering Accreditation Centre. However as many mature age applicants have not studied mathematics for many years some will have forgotten much of their mathematics training. To assess this, a computer based mathematic skills diagnostic test is carried out for all applicants who have not studied mathematics at an appropriate level within the last two years. Depending upon their score, applicants may be directed to complete a mathematics revision program prior to enrolling in the degree program. For the same reason an additional mathematics subject is included in the program to enable the starting level to be lower than the university offered engineering technology degree programs whilst the final mathematics level is slightly higher.

Industry experienced team members

Whilst meeting the requirement that academic staff members have a master degree or above, the program also seeks staff with suitable industry experience to bring authentic experiences into the class room. King et al. (2011 p40) indicates that an increasing majority of university staff have no industry experience, having followed a research path.

Evening classes

To facilitate part time study for mature age students with full time work most classes each semester are repeated in the evening. The evening delivered subjects will be rotated each year. They are delivered as long lecture/tutorial/laboratory classes of up to four hours duration to minimise the number of evenings the students need to attend. A strategy of delivering one subject per semester only by evening delivery to encourage interaction between the full time and part time cohorts of students is currently being trialled.

Oral presentations

To better develop oral communication skills, and taking into consideration the maxim ‘the best way to learn is to teach’, a number of subjects each semester include an oral presentation as a minor part of the assessment.

Small class sizes

Small class sizes are largely imposed by the complexities of the industry project based learning focus of the program as well as the limitations of a TAFE teaching infrastructure. Nevertheless much larger class sizes than the program currently supports can still be accommodated. However the restriction on class size provides major pedagogical advantages. The ‘rolling tutorial’ strategy that mixes lectures with tutorials (and laboratory sessions) is only possible when the class size is small enough for meaningful tutorials and laboratory sessions. This also better facilitates the most enjoyable development of this program: open class discussion that relates each topic to the industry experience of the mature age students and lecturer.

Long Semesters

Noting the negative impact on pedagogy resulting from the recent move by many universities to reduce the semester length to 12 weeks, it was determined that deep learning would be better achieved by increasing the semester length to 15 weeks. In addition the assignment submission dates were mapped to ensure anyone studying full time subjects that are all at the same year level would not have more than two assignments due in the same week.

Advantages and disadvantages of TAFE delivery of a Bachelor of Engineering Technology program

Advantages

A graduate of an engineering technology program should have a strong understanding of practical situations and applications, be abreast of leading-edge developments in his/her technology domain and understand how they relate to established practice (Engineers

Australia n.d.). An ideal way to deliver these and other Engineers Australia engineering technology graduate attributes is through industry focused experiential learning. The Australian vocational education and training (VET) system, founded on strong connections between the training providers and industry sectors (Misko 2001), is well placed to provide this.

Many TAFE institutes (such as Chisholm) are well equipped with exceptional industry standard equipment capable of providing simulated industry focused experiential learning in close proximity to the usual teaching environment. In addition small class sizes common for this sector better facilitate 'rolling tutorials'.

Perhaps most significant is the wide range of programs from pre-apprenticeship programs through to degree programs providing the potential to better address the engineering skills crisis through well mapped articulation pathways between the programs. A clear pathway leading to opportunities for bachelor and master level study should better attract students into all skills levels.

Disadvantages

In commencing this program in a TAFE environment were identified as needing addressing. One is the need for suitable library facilities for degree level study for each of Chisholm's degree programs. Others comprise the different academic infrastructure and procedures than exist in universities. These include room timetabling, and academic progress mechanisms as well as much smaller class rooms.

Opportunities for scholarship are also reduced through the unavailability of many of the research funding mechanisms available to universities.

However, possibly the greatest disadvantage is the continuing unavailability of Commonwealth Supported Places. Whilst FEE HELP is available for domestic students to defer payment through the tax system, there is no Commonwealth subsidy of the students study fees: instead the federal government adds a 25% 'administration fee'!

The Bradley Review (Bradley et al. 2008) considered an extension of Commonwealth Supported Places to other higher education providers could occur when new regulatory and quality assurance arrangements had been implemented through TEQSA. The previous Victorian labour state government also stated that it '*will advocate to the Commonwealth Government to extend Commonwealth Supported Places to undergraduate degrees delivered by TAFE institutes and other approved higher education providers'* (DIIRD 2011 p19). The new Victorian state minister for Higher Education and Skills, Peter Hall (2011), has also offered to continue to strongly advocate to the Commonwealth Government for the extension of Commonwealth Supported places to VRQA accredited degrees (now TEQSA accredited). The Senate Committee Report on the shortage of engineering skills also recommended that the government considers extending funding for government supported places to all students accepted into public higher education Engineering Technology programs accredited by TEQSA (Black et. al, 2012).

The difference in student demographics

The demographics of the small student population of this program of just 30 students are substantially different from that of a typical university delivered Bachelor of Engineering Technology program. Due to the need for full fee delivery almost one third of the current cohort are those who would not qualify for Commonwealth Supported Places because they are international students or already have an Australian first degree in another discipline. Only one student is direct from secondary school.

The largest single cohort is mature age students predominantly employed full time with most being funded by their employer to study part time. The next largest cohort is full time students who have recently completed a Diploma or Advanced Diploma. A few transferred from other engineering higher education providers. Most did not have the opportunity to complete secondary school studies up to year 12 but gained entry through VET studies.

An internal study found most students learned about the program through direct enquiry or from the Chisholm home page. Most Chisholm Advanced Diploma and Diploma graduates learned of the program through their teachers. A few students were referred to the program by SEMMA member companies.

There are several dynamics that can be anticipated to affect future student demographics for this program. One is a proposed China focused international campaign. A second is a more visible presence on campus to attract more Advanced Diploma and Diploma graduates. Finally, for 2013 the program is listed on the Victorian Tertiary Admissions Centre (VTAC) and so could attract a notable number of local school leavers. This would most likely be enhanced if Government Supported Places were to become available.

The initial industry and student perceptions of the program

Industry perception

At its regular seminars and workshops SEMMA often promotes the program to its industry members as their collective achievement. This has led to a very positive image of the program with local manufacturers. Members of the industry panel at the group oral presentation of the concept stage of the first year experience project expressed surprise that the students were only in their first year. They felt the standard of the group oral presentations was more in keeping with final year project presentations and they were also pleased with the standard of their group project interim reports. This reflected the skills developed predominantly through the subject The Professional Engineering Technologist.

Student perceptions

First semester student perceptions of the program were independently surveyed by the Director of the Centre for Integrated Engineering and Science. Whilst the response rate was only 47% the results indicated **all** respondents considered the subject content 'met or exceeded their expectations'. **All** respondents were satisfied with the training facilities, course material, the presenter's subject knowledge, presentation, sequencing and content. 88% of respondents considered the program increased their capacity to perform future tasks and the combined presentation skills of the lecturers were above average or outstanding.

The Research Questions

As all elements of this program were introduced together and the cohort is considerably different from the normal university engineering technology degree, it is not possible to separate out the impact of each variable**.** The research questions addressed are:

> *What contribution can a TAFE delivered engineering technology degree program make to alleviate the Australian engineering skills shortage?*

This industry designed program has significant potential to best address the needs of south east Melbourne manufacturers for the higher level technical skills needed to become globally competitive through the best use of new technology, minimisation of defects through effective continuous quality improvement, and through becoming increasingly efficient and innovative.

This program delivers to a radically different demographic than has become common for engineering degree programs. Many current students already have substantial industry

experience which they contribute in class discussions. The program streams have high level industry engagement to best develop graduates that meet the needs of local industry in addressing global competition. The promotion of this pathway into the engineering profession should also positively impact the programs that form the pathway and thus lead to an increased supply of engineering skills at all levels.

Previous substantial subjective experience of the author has shown the three year engineering technology degree to be more popular than the four year engineering degree with those studying part time because of the less daunting program duration. However they also welcome having a pathway to professional engineer status through further study. Nevertheless the aims of a degree program leading to engineering technologist status should (but often doesn't) differ from a program leading to professional engineer status.

A more effective contribution could be made in the development of domestic engineering technology skills through delivering to a substantially larger cohorts of students (within the limits previously discussed) if the decision is made to extend Commonwealth Supported Places to all Bachelor of Engineering Technology programs accredited by the Tertiary Education Quality and Standards Agency.

What advantages and shortcomings arise from the different learning outcomes?

The Chisholm Bachelor of Engineering Technology program has been designed to best develop engineering technologist with a strong understanding of practical situations and applications as well as keeping abreast of leading edge developments in their area of specialisation. The program streams help them develop a strong understanding of the principles of engineering science and a well-developed capacity for analysis. It supports this skill development through authentic industry based situations and through the study of industry ready subjects so they can readily appreciate the relevance of the knowledge base to engineering practice. This best meets the aims of a program to develop engineering technologists.

The major shortcoming of this method of delivery is that it is dependent on the support of an industry body such as SEMMA and thus is unlikely to cope with the student numbers typical of many of the larger universities.

Conclusions

The Chisholm Bachelor of Engineering Technology program is unique not only in being the only Australia engineering technology degree program outside of the university sector, but also in its content, delivery and student demographic. The program's advantages include small class sizes and industry involvement. Its disadvantages also include the cost associated with small class sizes, the need to develop higher education processes and suitable library facilities. This paper has highlighted the major features of the program and the issues that affect its development. The perceptions of the program from both an industry and student perspective are high. The first year experience, authentic industry projects, industry standard on-campus equipment, and a host of other initiatives have contributed to a program that engages students to learn and be able to better support Victorian manufacturers compete in a global economy.

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