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Development of Mathematical Pathways for VET Students to Articulate to Related Higher Education Courses: a Focus on Engineering

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Abstract

Australia needs more qualified professionals in the Science, Technology, Engineering, and Mathematics (STEM) areas. The national focus on widening participation in higher education (HE) includes strengthening pathways from vocational education and training (VET). VET students often lack the mathematics skills necessary to articulate successfully to their chosen university degrees. Current approaches such as bridging and foundation mathematics programs are not tailored or sufficiently contextualised for VET articulants. This project is developing a mathematics pathway designed to improve the readiness of VET engineering diploma graduates for higher education study in engineering degree programs. Arrangements are flexible so that students can complete these pathways either as part of their engineering diploma as a VET student or as part of preparatory study at the diploma level at university.

Many VET students are granted credit when entering a HE course in engineering and can transfer directly to second year units which may assume a level of mathematical knowledge by the university. However, in the VET Diploma of Engineering Technical (MEM50212), there is only one core unit in mathematics (MEM30012A) equivalent to year 9 level and there are two mathematics electives, MEM23004A and MEM23007A, which are part of the advanced diploma and often not taught by many TAFE providers due to student demand and staff capabilities. The lack of required mathematics often leaves the student with a large gap in the required knowledge for success in HE.

The project has been underway for over a year and significant progress has been made in developing the pathway for engineering. To date, the mathematical knowledge outcomes from the VET courses have been mapped to the requirements of the HE courses at the University of Tasmania, Flinders University and James Cook University. Gaps in mathematical knowledge have been identified. A formal articulation agreement has been established through TasTAFE and the University of Tasmania where current VET students will be able to enroll in the university foundation mathematics units and receive credit towards their VET diploma in engineering. In addition to the foundation units, the students need to do an online component. This consists of a few compulsory topics which are not covered in the foundation units with supporting examples, practice

problems, practical application and self-assessed quizzes for each mathematics topic covered in the foundation units, contextualised to engineering. VET students are applied learners and therefore often struggle with the transition to HE. The online component of the pathway is designed to support the student by providing the context to the mathematics they are learning. Another advantage of the pathway is that it exposes the VET students to HE units and the university environment while satisfying the university mathematics entry requirements.

Introduction

Australian post-secondary education is divided between the Vocational Education and Training (VET) and Higher Education (HE) sectors. The two sectors differ in many ways, particularly in learning approach and students' characteristics (Karmel, 2008), which raises issues as a growing number of students move between the two sectors (Karmel, 2008; Watson, 2008; Moodie, 2012). Where VET learning is competency based, the HE sector is knowledge based (Karmel, 2008). The sectors' learning and teaching approaches and cultures are linked to the desired employment outcomes for each sector. The VET sector trains students for a particular skill and employment outcome while HE educates students for a contemporary, changing knowledge economy and emphasises independent study (Dawson, Charman and Kilpatrick, 2013). Utilising VET as a pathway to HE has recently been supported by the government (Bradley, 2008) and has generated a growing activity around articulation pathways from VET to HE institutions (Karmel, 2008; Dawson, Charman and Kilpatrick, 2013).

In Australia, there has been increasing demand for skilled professionals in the areas of STEM (Office of the Chief Scientist, 2012). More specifically, there is a shortage of engineering graduates from the HE sector (King, Dowling and Godfrey, 2011; Watson and McIntyre, 2011; Yu, Bretherton and Buchanan, 2013). One way to meet these industry demands is to increase the number of students pursuing higher education degrees in these areas. This also assists in meeting the goals of the Australian Government. The previous Government had a target to increase the participation of 25-34 year olds pursuing a higher education degree to 40% by the year 2025 (Australian Government, 2009). The government wants to increase the pathways available to make higher education more accessible to students from a wide range of backgrounds, including those from a lower socioeconomic background (Wheelahan, 2009).

The importance of mathematics is receiving a great deal of attention both in Australia (Office of the Chief Scientist, 2012; Freeman, 2013) and worldwide (Breiner, Harkness, Johnson and Koehler, 2012) as STEM education is seen as essential to support the modern knowledge based economy (Abbott-Chapman, 2011). A number of occupations rely on a good foundation of mathematics, such as teaching, business, health sciences, information technology as well as engineering and the traditional sciences (Freeman, 2013). These occupations are also identified as areas where there are skill shortages (Freeman, 2013) and where the government is interested in promoting growth (Office of the Chief Scientist, 2012). Mathematics spans across all of the STEM disciplines and underpins it (Rice, 2011).

Students from lower socioeconomic backgrounds tend to be underrepresented in higher education and in the upper levels of VET qualifications with only 20% of commencing students being from the lower socioeconomic background (Wheelahan, 2009). It has been shown that VET qualified students are accessing the post-1992 (UK) and lower ranking Universities both in Australia and overseas (Hoelscher, Hayward, Ertl and Dunbar-Goddet, 2008; Abbott-Chapman, 2011; O'Shea, Lysaght and Tanner, 2012). Hoelscher, Hayward, Ertl and Dunbar-Goddet (2008) suggests that a student with a VET qualification is often seen as disadvantaged and they tend to follow institutional pathways in to the less prestigious

Universities. This notion is also supported by Dawson, Charman and Kilpatrick (2013) who suggests that HE staff presume VET qualified students will not perform as well as traditional students based on their preparation for HE. However, there is conflicting evidence in the literature and there is also research that shows that a VET entry qualification doesn't hamper a student's ability to successfully complete their HE studies. Langworthy, Johns and Humphries (2011) has shown that VET qualified students perform equal to or better than their traditional student counterparts across a range of disciplines.

The VET sector may provide the entry requirements to HE and therefore serve as a pathway for students who would otherwise not meet the entry requirements for their chosen degree (Stanwick, 2006; Wheelahan, 2009; O'Shea, Lysaght and Tanner, 2012). By obtaining a VET qualification, some credit towards a HE degree may be awarded (PhillipsKPA, 2006; Guthrie, Stanwick and Karmel, 2011; Langworthy, Johns and Hymphries, 2011). Many higher education institutions review transcripts on a student by student basis to arrange credit transfer and in the case of engineering, Dowling (2010) points out that because there is such variability in the number of electives that a student can take to make up their qualification, the suitability of the qualification as a pathway to HE also varies. Each higher education institution will have its own requirements for the pathways and pathways agreements need to be in place between HE and VET providers. These arrangements are not always transparent to the student and can lead to confusion for those trying to navigate this landscape. One way to address this is to form strong links between the VET and HE sectors with transparent agreements as done in the current study with the development of the engineering pathway in Tasmania.

Utilising the VET to HE pathway seems to be dependent on the field of study. Over 50% of students studying banking and accounting used their VET qualification to gain entry into a higher education institution and overall 32% of young students (<24 years) continued on to further study in Australia (Stanwick, 2006). The student population of VET qualified articulants varies greatly (Round, Brownless and Rout, 2012). Many students are mature aged, studying part-time or through work arrangements. Students who transition to HE from the VET sector do so in a number of ways (Harris and Rainey, 2006) and it is not always the straightforward, school to VET to HE, it often involves working and changing of disciplines (Harris and Rainey, 2006; King, Dowling and Godfrey, 2011) which can delay a student's progression into HE. Abbott-Chapman (2006) outlined a mosaic of student experiences from education to employment and highlights that an increasing number of students are following fragmented pathways to HE. Many of these students are from lower socioeconomic backgrounds (Wheelahan, 2009) and attaining a VET qualification may seem more achievable than HE. The interconnection between VET and HE is essential to create a pathway for these students to progress their education (Abbott-Chapman, 2011).

One barrier for articulating VET graduates is having the mathematical background needed for their chosen course in HE. This can be especially challenging for VET students as it may be a number of years since they studied mathematics and there may not have been any mathematics in their VET qualifications. It is reasonable to expect that this often leaves the student with gaps in their assumed mathematical knowledge. This is not a phenomenon which is limited to VET students. Mathematics readiness is a major issue facing all students' whether they are traditional school leavers, mature aged or VET students (Brown, 2009; Wilkes, 2010; Belward, Rylands, Matthews, Coady, Adams and Simbag, 2011).

It has been identified at a number of universities within Australia (Cuthbert and MacGillivray, 2003; Rylands and Coady, 2009; Skalicky, Adam and Brown, 2010) and

internationally (Selden, 2005; Newman-Ford, Lloyd and Thomas, 2007; Brandell, Hemmi and Thunberg, 2008) that first year students often lack the mathematical skills necessary to successfully make the transition to tertiary education. This is not a phenomenon only associated with VET qualified or mature age (i.e. non-traditional) students, this gap in knowledge is becoming more commonplace for all students (Brown, 2009). Many university programs have lowered their pre-requisites to mathematics based disciplines to accommodate the trend of secondary students to not take mathematics (Jourdan, Cretchley and Passmore, 2007; Brandell, Hemmi and Thunberg, 2008; Varsavsky, 2010). This creates a cycle where secondary students do not believe that mathematics is required for the course (Rylands and Coady, 2009; Belward, Rylands, Matthews, Coady, Adams and Simbag, 2011) which allows for students to avoid studying math at secondary school (Cuthbert and MacGillivray, 2003). This then results in an increasing number of students that do not have the necessary skills to undertake their chosen course and the need for each university to have a bridging unit in mathematics (Belward, Rylands, Matthews, Coady, Adams and Simbag, 2011).

General (non-discipline specific) mathematics bridging or foundation units are offered at universities worldwide (specialised bridging courses/pathways are detailed below). There are conflicting results in the literature as to whether they solve the problems of mathematics readiness for first-year undergraduate students. Boland (2002) describes the bridging program at the University of South Australia and its overwhelming success. Over 70% of students in their bridging unit continued on to study at the University and a statistically significant positive correlation ($r=0.494$, $p<0.01$) existed between their bridging unit marks and their undergraduate math unit marks (Boland, 2002). Monash University offers three introductory level maths units to students with varying mathematics backgrounds (none – intermediate – advanced), they have found that 33% of students with little to no maths background succeed with high marks and often engage in further mathematics studies (Varsavsky, 2010). These students progress at the same rate as students with an intermediate level of maths background (Varsavsky, 2010). This is in contrast to the University of Western Sydney where the bridging units have not solved the mathematics readiness (Rylands and Coady, 2009). One reason may be the length of the bridging units, many are only 1-2 weeks immediately prior to the start of the semester and, for lack of a better term, cramming a years' worth of mathematics learning into an intensive study period is insufficient for real comprehension of the topics (Rylands and Coady, 2009). However, there is a gap in the literature which tests this theory. Many universities are also implementing diagnostic testing (Heck and Van Gastel, 2006; Jennings, 2009; Rylands and Coady, 2009) to accurately understand the wide range of student mathematics abilities and backgrounds in order to strategically support first-year students.

One aspect that needs to be considered when examining mathematics preparedness is 'maths anxiety' (Maloney, Schaeffer and Beilock, 2013). Maths anxiety is a real physiological response to mathematics and can begin as early as primary school but is usually set sometime during secondary school (Maloney, Schaeffer and Beilock, 2013) and can affect career and study choices towards disciplines which are light in mathematics (Sheffield and Hunt, 2006). Many students with maths anxiety will avoid maths altogether. Of particular concern for our research, when mathematics skills are not regularly used it can also lead to anxiety (Mackenzie, 2002). This is important to acknowledge when teaching non-traditional students (i.e. adult learners) who may not have studied mathematics for many years (Galligan and Taylor, 2008; Berghella and Molenaar, 2013).

The aim of this project is to develop contextualised mathematics pathways for VET students, designed to assist AQF compliance and articulate to related HE courses, in engineering,

education, business and health science. The pathways are designed to improve student readiness for HE study. This paper specifically describes the process undertaken to develop the mathematics pathway for engineering.

Development of the Engineering Pathway

Engineering context

The 2013 statistical overview by Engineers Australia discusses the engineering labour market (Kaspura, 2013). It suggests a slowdown in the recruitment of qualified engineers and problems experienced by employers following the recovery after the global financial crisis. Despite an apparent reduction in the demand, more than 30% of employers experience *major problems, including project delays and costs* because of difficulty in recruiting qualified engineers (Kaspura, 2013). Thus while there has been an easing in recent years in problems in recruiting, due to undersupply of qualified engineers, there is still a need for further graduates with engineering qualifications.

Engineers Australia is an organisation "established to advance the science and practice of engineering for the benefit of the community" (Kaspura, 2013, p. 1). The annual statistical report from Engineers Australia provides useful insight into the shape of the cohort of students who study engineering at university. In 2010 and 2011, roughly 11,000 year 12 students accepted a place in a university engineering course (Kaspura, 2013). By considering all enrolments in engineering courses we can gain some idea as to where these year 12 graduates study in the suite of offerings in engineering at university. Upon leaving secondary school the range of courses available include Certificates, Diplomas, Associate Degrees, Advanced Diplomas and Bachelor Degrees. In 2011, just over 13,000 domestic students commenced a Bachelor degree in engineering, while just over 2000 commenced associate degrees, advance diplomas, diplomas or certificates (Kaspura, 2013, table 5.3, p.29). These figures show that the minimum number of students who articulate from year 12 into a Bachelor Degree in engineering must be around 9000 out of the total cohort of 13,000. This minimum would be achieved if the entire cohort of students in Associate Degrees, Diplomas, Advance Diplomas and Certificates were from the cohort of those year 12 graduates from 2010 who accepted a place in engineering at university. The more likely scenario is that nearly all of the 11,000 year 12 students accepted a place into a Bachelor Degree, meaning that only about 2000 out of the roughly 13000 who commenced a Bachelor Degree did so on a pathway that was not directly from year 12. The statistics show that the dominant pathway in to bachelor degrees in engineering is direct, through completion of year 12 in secondary school. These statistics align with the comments made by King, Dowling and Godfrey (2011) who report that the majority of Australian students who enter bachelor degree programs do so directly from year 12 in secondary school.

The figures presented above are consistent with those in two earlier publications that analysed the relationship between VET and HE in engineering programs. These publications show the figure of six percent of commencing bachelor degrees in engineering articulating from VET courses (King, Dowling and Godfrey, 2011; Watson and McIntyre, 2011). One question that perhaps needs to be answered is: *What is a reasonable rate of articulation from VET courses to bachelor degrees in engineering?* An upper bound on the figure can be estimated by using figures in King, Dowling and Godfrey, (2011) showing that in 2008 almost 1800 domestic students completed VET diplomas in engineering and just over 1500 domestic students completed VET advanced diplomas in engineering. If we use figures from Kaspura (2013) showing domestic commencements in 2009 of approximately 12,000

students, we can see that the greatest possible contribution from the diploma and advanced diploma students is around 15 to 20%, with the variation arising from the fact that some diploma students will articulate to advanced diploma courses before proceeding to a bachelor degree, while some may articulate directly from diploma courses.

This analysis above suggests that there is scope to increase the number of students studying bachelor degrees in engineering through increasing the number of students articulating from VET courses. This is one of five strategies indicated by King, Dowling and Godfrey (2011) to increase the number of students studying bachelor degrees in engineering and is the strategy that is the focus of the project this publication discusses. This also helps to meets the goals of the Australian Government to increase the number of HE graduates by 2025 (Australian Government, 2009).

Of interest to this project are the success rates of students who articulate from VET programs to bachelor degrees in engineering. It is important that those students who do articulate have a reasonable chance of success in their chosen field. The study by King, Dowling and Godfrey (2011) reports findings from an associated ALTC funded project (Godfrey and King, 2011) in which a group of over 3000 commencing students from 2003 were surveyed as to their success in completing their engineering degree. This survey showed that those students with the lowest chance of completing, at only 20%, were domestic students who entered on the basis of VET studies or on mature age or special entry criteria. Thus, the six percent of the entering cohort to engineering bachelor degrees from VET diplomas and advanced diplomas are even further under-represented in graduating cohorts, because their completion rate is well under the rate of 40 - 75% across the whole cohort of 3000 commencing students from 2003. We conclude that in addressing the pathway from VET courses to bachelor degrees in engineering it is prudent to take account of information from previous studies on the obstacles encountered by students in taking such paths.

Two studies in 2011 provide important insight in to the barriers students face in using VET courses as a pathway to bachelor degrees in engineering. The study by King, Dowling and Godfrey (2011) suggests that these arise from: the competency basis of VET diploma and advanced diplomas and inconsistencies in their assessment; variations in credit awarded by different higher education providers for the same VET qualification and the absence of mathematics as defined units of competency in engineering advanced diplomas. The study by Watson and McIntyre (2011) reports that obstacles for VET graduates in articulating to bachelor degrees in engineering are caused by: the inflexibility of vocational training that makes it difficult to ensure graduates are equipped with necessary foundation knowledge to undertake engineering degree programs; the lack of collaboration between the VET and higher education sector in identifying and addressing gaps in provision for such a pathway and the failure of both the VET and higher education institutions in providing academic support and meeting individual learning needs.

While the challenges in negotiating the VET to HE pathway in engineering exist, the insights provided by the studies above allowed this project to move forward. In particular we noted the following statement from Watson and McIntyre (2011):

> *Successful cross-sectoral partnerships are based on negotiated curriculum models designed to equip students in para-professional programs with adequate knowledge and skills for successful engagement in formal learning at the higher education level. Such models identify and eliminate knowledge and skills gaps for students on a VET-HE pathway, by specifying*

> *exactly what components of the curriculum each institution will provide, and by providing additional learning support to students where necessary (p. 73).*

The project proceeded on the basis of a need to increase the number of students articulating from VET diplomas and advanced diplomas to bachelor degrees in engineering and once there to provide them with a program that allows them to transition successfully. The project developed a pathway collaboratively using employees from both sectors, with a focus of enabling the pathway through ensuring adequate preparation of VET articulants in the mathematics they need for a bachelor degree in engineering.

Identifying the solution

This pathway investigated a way in which sufficient mathematics could be embedded into the VET AQF Level 5 awards to enable successful transition to first year Bachelor of Engineering courses (Figure 1). The project team was aware that a number of pathways already exist including those to non-Bachelor of Engineering awards that may in turn allow transfer to Bachelor of Engineering and courses that require a longer study period. The traditional VET pathway through the Advanced Diploma, no longer exists in some states (e.g. Tasmania), hence the gap from the Diploma to the Bachelor's Degree is large for mathematics (Figure 1). Our solution incorporates contextualised learning to make the transition from competency/skills based learning to higher order thinking required in the HE sector smoother.

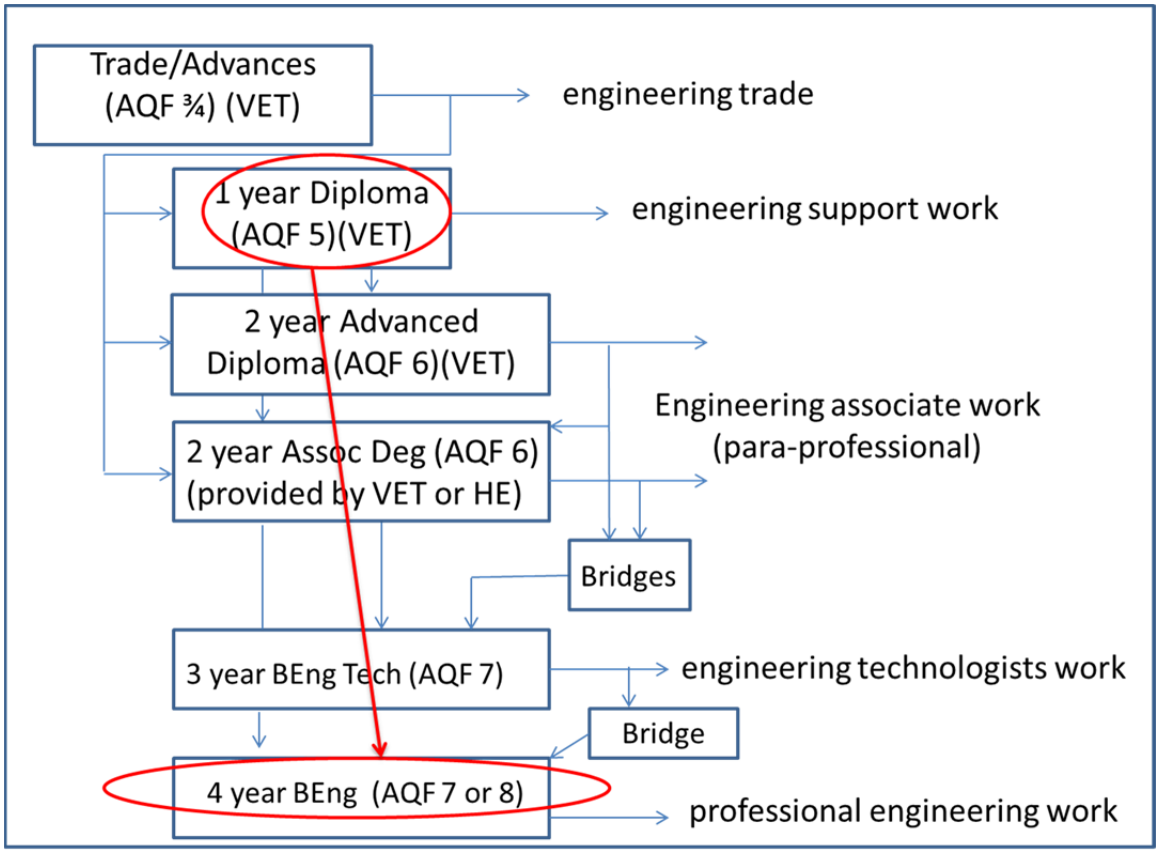

Figure 1. Pathways from VET engineering qualifications at AQF Levels 5 and 6 to HE programs. (Not all possible transfer paths are shown, and the bridging requirements and points of articulation vary between programs and for individual students) (modified from King, Dowling and Godfrey, 2011)

The project team initially identified the gaps in mathematics content between MEM50212 (Diploma of Engineering – Technical) and the typical mathematics entry requirements to Bachelor degrees in Engineering at The University of Tasmania. Once these knowledge gaps were identified, bridging units in mathematics available to VET to HE articulants were carefully examined to clearly pinpoint any remaining gaps in this pathway. New mathematical support resources were developed and housed as Open Education Resources (OER's) on a project website http://www.utas.edu.au/mathematics-pathways/ to facilitate this transition with a specific focus on engineering applications and contexts. These resources aim to encourage articulants to pursue in their efforts to navigate the pathway from VET to HE by highlighting how mathematics plays a central role in solving modern engineering design problems in an applied setting.

The original goal of the mathematics pathway project was to ensure that those students who complete the pathway have mathematics knowledge equivalent to that they would have if they studied Mathematical Methods in the new suite of mathematics offerings provided by the Australian Curriculum, Assessment and Reporting Authority (ACARA). The rationale for this choice was that it is anticipated this subject will be the benchmark level of preparation in mathematics from secondary school for those choosing to study a Bachelor of Engineering degree at university: "the subject Mathematical Methods is designed for students whose future pathways may involve mathematics and statistics and their applications in a range of disciplines at the tertiary level." (ACARA, 2014)

The pathway identified by the project team used existing VET units with mathematics content as the way by which students studying VET engineering diploma programs would cover mathematics content equivalent to that in Mathematics Methods from ACARA. These VET units are: MEM30012A (Apply mathematical techniques in a manufacturing engineering or related environment), MEM23004A (Apply mathematical techniques in a manufacturing engineering or related environment), MEM23007A (Apply calculus to engineering tasks).

The pathway provides access to these units through collaborative arrangements between VET and university providers. This collaboration arose because the VET units identified by the project team are not widely accessible in the VET sector. The collaborative arrangements involve VET students enrolling in units provided by tertiary institutions which when completed successfully give the students credit for study in the corresponding VET units. The units provided by the tertiary institutions are often used by students undertaking bridging study as preparation for study at university and are generic in nature (KMA002 and KMA003 at the University of Tasmania; Math1701 and Math1702 at Flinders University and MA1020 and MA1000 at James Cook University, Figure 2). Therefore significant effort was put toward developing online resources aligned to the mathematics in the units provided by the tertiary institutions, but with an applied engineering focus such as that VET students in engineering would experience.

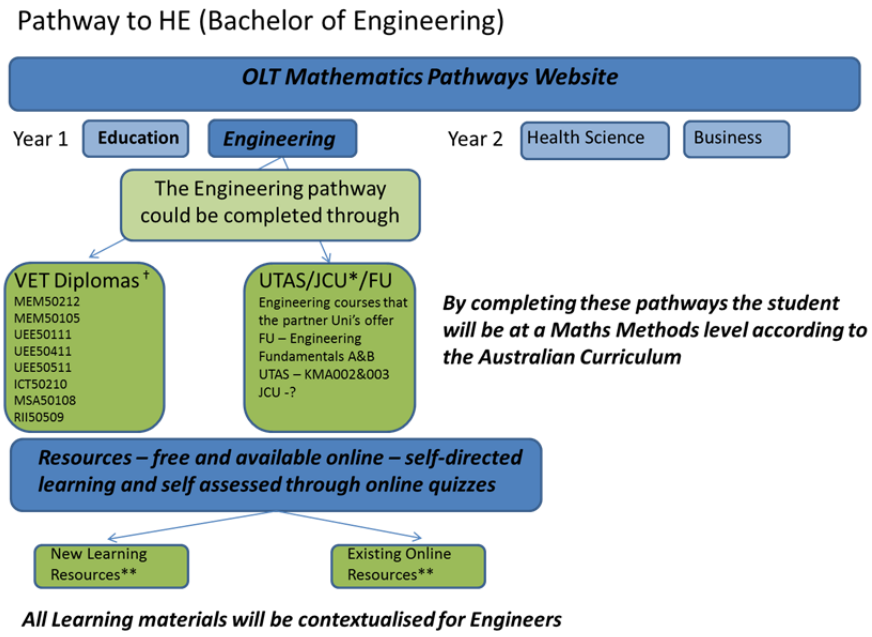

Figure 2. Roadmap to the engineering mathematics pathway

To ensure that the pathway identified using these VET units appropriately matched the content in Mathematics Methods from ACARA, a detailed mapping of mathematics content between the ACARA Mathematics Methods subject, the identified units from the VET sector and the university bridging mathematics (University of Tasmania, Flinders University and James Cook University) units was undertaken. The mapping process revealed three mathematics topics which are covered in the VET units but are not covered in any of the bridging mathematics units at any of the participating universities. These are complex numbers, 1st and 2nd order differential equations and partial differentiation. These topics are also not included in the ACARA Mathematical Methods subject and are not considered a requirement of entry to the Bachelor of Engineering; however they need to be covered because students using this pathway ultimately receive credit for VET units.

The three topics that are not covered in the university bridging mathematics units are made available to students in the pathway using the online resources mentioned earlier. The mathematics is built on curriculum concept, supported by appropriate instruction and assessment, and designed to raise students' academic and vocational skills. The students are assessed using online testing to ensure competency in these topics before credit is granted for the corresponding VET units.

Summary

The mathematics pathway has been designed with an applied and integrated curriculum approach that connects academic and vocational learning to improve VET diploma of engineering students' transition and readiness for higher education study in engineering degree programs. It supports the engineering industry needs and fosters a broader engagement with, and valuing of, continuing engineering education.

The arrangements are flexible, so that students can complete these pathways as part of their engineering diploma as a VET student or as preparatory study at the diploma level at university. Students who are currently enrolled in one of the specified VET qualifications can

enroll in the mathematics foundation units at UTAS, complete the online component for the topics which are not covered in the foundation units, and if they successfully pass, will receive Recognition of Prior Learning (RPL) towards their Diploma of Engineering – Technical. Successful completion of the mathematics units will develop their mathematics skills to the level needed for entry (equivalent to Australian Curriculum Mathematical Methods) into the Bachelor of Engineering at UTAS.

The establishment of the pathway has been successful due to the collaboration between UTAS and TasTAFE, and valuable input and resources from the other University partners. To date, a Memorandum of Understanding (MOU) has been signed between UTAS and TasTAFE outlining the collaborative arrangements between the two institutions for the provision of the delivery of engineering courses and intent to work together to deliver the pathway for Engineering programs at all VET and HE campuses across Tasmania. This will include collaborative teaching where possible, working closely with TasTAFE staff to ensure teaching arrangements enable the smoothest possible transition for students between both institutions, and promotion of the pathway to schools and the broader community. The success of the pathway agreement between TasTAFE and UTAS will serve as a model for the other partner states (South Australia and Queensland) to complete an official pathway with their partner VET providers. These discussions will be facilitated by the project members in SA and QLD.

This pathway is part of a larger project addressing mathematics readiness of VET students not only in engineering but also education, health science and business. All of these pathways are currently under development (health science and business) or being trialed (engineering and education) with local VET and HE students. This project will run until mid-2015 upon which the results of the trial will be published.

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