Full Paper

Introduction

Charles Sturt University (CSU) is establishing a new degree in Civil Systems Engineering, with the first intake of students in February 2016. CSU initiated its engineering course as a response to demand from local government and regional industry to address a shortage of engineers in the regions. While the genesis of the program was based in a regional outlook, the mission of CSU Engineering is far more than just providing access for regional students – there was a deliberate mission to anticipate and pre-empt global trends in higher education.

The key aim is to train entrepreneurial engineers in a regional setting. Regional engineering practice requires a number of valuable and transferrable skills – resilience, adaptability, a willingness to accept responsibility early, communicating with non-engineers. These skills are essential for regional practice; however they are also in demand throughout all of industry. As the only Australian engineering program based in a Faculty of Business, we have set ourselves a goal of educating a very different type of engineering graduate, and doing so in a very different learning environment.

The engineering degree program has completed all of the CSU internal governance processes, and is available to students for a February 29th, 2016 commencement. The keystone of this process was Tangible Curriculum Week in February 2015 (Lindsay and

Morgan, 2015), where 16 delegates ranging from national and international academic leaders in Civil Engineering Education, industry partners, CSU experts in online learning and development, representatives of the service teaching areas and including the Vice Chancellor met to crystallise the vision into something that could be developed in detail. The course structure, with the Tree of Knowledge and the Portfolio stream, is largely a consequence of that gathering.

This paper details the specific goals of the program and the non-traditional nature of the curriculum that has been developed to meet them.

Rationale and G oals for the Course

A key feature of the development of the course was a mandate to produce an engineering program that was orthogonal to existing Australian engineering degree offerings. After careful consideration of existing engineering programs, we identified five key points of distinction for the program:

Entrepreneurial Graduates. Despite consistent demand from industry for graduates with better business skills, there is no Australian Engineering School that makes this their key focus. CSU Engineering is housed within the Faculty of Business, and one of the research strengths of the Faculty is Entrepreneurship. This allows these skills to be made part of the core business of the degree, rather than an add-on elective, or projects serviced by a central university unit.

4 x 1 year work placements. A key driver of our program was to help solve a workforce need in regional Australia. Many engineering organisations are already employing cadet engineers on an ad hoc basis – either employing them part time while they study by distance, or employing them every summer between teaching semesters at an on campus university. This workforce demand allows us the opportunity of embedding our student engineers in industry while they learn, and to provide them with real (rather than realistic or authentic) learning environments. The benefits of co-op programs are widely known; extending from a six-month placement to four years' work experience will only deepen the value of the

learning. This also provides an inherent solution to the imminent problem of many engineering students struggling to find adequate workplace experience in order to graduate.

An Innovative curriculum. Building a new program from the ground up allows us to take advantage of the leading edge in educational pedagogy and technology, rather than simply replicating the traditional lecture-tutorial-laboratory paradigm. When academic engineers do meet student engineers in a classroom setting, it will be in a cooperative learning paradigm (Johnson, Johnson & Smith, 1991) much more akin to an engineering workplace than a traditional classroom.

A Diverse cohort. The boutique nature of our program allows us to proactively ensure that the cohort is not homogenous – we are able to ensure that women, minorities, indigenous and regional students are all well represented. Our selection processes are geared towards interviews with potential students, rather than a simple reliance upon ATAR, with all of its inherent bias. There are significant efforts being made to “move the needle” with regard to representation of minorities in engineering programs; however the single most effective mechanism for having diversity in your intake appears to be to already have diversity in your cohort. Starting from scratch allows us to proactively seek critical mass from the beginning, rather than dooming ourselves to push uphill thereafter.

A Head start on Chartered status. The additional time offered by a Masters level qualification allows us to achieve more than the Stage One Washington Accord competencies; the embedded work placements will provide accelerated progress towards acquiring competencies of a Chartered Professional Engineer (CPEng) prior to graduation, fast-tracking your path to being recognised as an autonomous professional. A strong engagement with Engineers Australia ensures that we are able to progress our students towards this goal without misrepresenting or misleading people in the process.

The Course Structure

The course is 5 ½ year program, comprising 18 months face to face teaching at the Bathurst campus and then a sequence of four one-year paid work placements in industry. The program is a combined degree, with graduates awarded both a Bachelor of Technology and a Master of Engineering (Civil Systems). It is important to note that it is an integrated five- year program, and not a 3+2 structure; the award of two degrees is driven primarily by AQF volume of learning requirements, and not by course structure.

The course will cover the main areas of Civil Engineering – Structural, Water, Geotechnical, Roads etc. All graduates will require a baseline exposure to all areas. Our exact specialties will expand as the student pipeline grows and additional academic staff come on board.

The curriculum (Figure 1) is designed around a strong portfolio theme, where Student Engineers use examples from their on-campus challenges (years 1&2) or their workplace experience to demonstrate their achievement of the learning outcomes, rather than completing assignments contrived for an academic environment. Student Engineers will complete two extended projects while in industry – a Cornerstone project in their second placement and a Capstone project in their final year placement.

Period		Challenge / Portfolio / Thesis	Performance Planning & Review	Tree of Knowledge
Term 1	Face to Face	Engineering Challenge 0 - 2pt		
		Engineering Challenge 1 - 14pt		Tree of Knowledge - Student Engineer 48 pt
Term 2		Engineering Challenge 2 - 14 pt	Performance Planning & Review - Student Engineer 4pt	
Term 3		Engineering Challenge 3 - 14pt		
1st Work Placement			Performance Planning & Review - Junior Cadet 6pt	Tree of Knowledge - Cadet Engineer - 72 pt
		Engineering Portfolio - Introductory 14 pt		
		Engineering Portfolio - Developing 14 pt		
2nd Placement		Engineering Cornerstone Thesis 24 pt	Performance Planning & Review - Intermediate Cadet 6pt	
3rd Placement			Performance Planning & Review - Senior Cadet 6pt	
		Engineering Portfolio - Consolidating 14pt		
		Engineering Portfolio - Advanced 14 pt		
4th Placement		Engineering Capstone Thesis 32 pt	Performance Planning & Review - Professional Engineer 4pt	Advanced Topics in Civil Engineering 16pts
			Engineering Portfolio - Professional 2 pt	

Figure 1: The Curriculum Map

The curriculum is structured with three Pillars: a challenge / workplace / thesis strand; a mastery of topics from the Tree-of-Knowledge strand; and a Performance Planning & Review strand. The look and feel of each strand will be similar from year to year; however, the level of knowledge and skill demonstrated by the students in their portfolio is expected to increase each term – achieving Engineers Australia stage one competencies for the Technologist by the end of their second placement, and reaching beyond stage one competencies for a Professional Engineer by the end of the degree.

The challenge / portfolio strand is built around a project-based-learning approach (Capraro, Capraro & Morgan, 2013). The curriculum includes realistic challenges during the face-to-face first 18 months, as well as real projects students bring from work placements and theses in the next 48 months. Students will compile a portfolio clearly illustrating the work they have done, the knowledge and skills they have acquired, and a reflective self-assessment of their learning.

The Performance Planning & Review portion of the curriculum will provide a reality check for students and allow academic staff to help students maintain progress at an appropriate rate, as well as to maintain balance between their efforts related to the project-based-learning and mastery-learning strands of the curriculum. These subjects also help the student to develop into a reflective practitioner and from student engineer to professional engineer.

Although we commence with the Student Engineers on campus, the educational philosophy of the course is to take full advantage of the online experience. Where possible the teaching staff will take advantage of online technologies to deliver material, allowing academic staff to utilise our face-to-face time for more educationally valuable interactions with our Student Engineers. This online environment will be scaffolded in the first 18 months on campus, as we form a cohort identity. Then, as students move into industry, their everyday face-to-face support regarding practice will come from the workplace, while the academics continue to provide mentoring on the underpinning theory.

A strong theme of reflective practice runs through the program, with Student Engineers expected (and taught) to manage their own professional development, first in the highly scaffolded CSU Engineering on campus environment, then in the industry work placement environment, and then after graduation as professional engineers. In this way students are active participants in their learning and building these skills to take into their professional lives. In order to facilitate the transition to the workplace, several of the academic staff function as Engineers in Residence – specifically hired based on industry, rather than academic, experience.

The Civil Engineering Tree of Knowledge

The biggest point of difference in the CSU Engineering curriculum is in the Civil Engineering Tree of Knowledge. Traditionally Problem and Project Based Learning curricula embed a PBL subject (sometimes double-sized) amongst a range of standard sized traditional "content" subjects. The CSU Engineering curriculum disaggregates the content of these subjects into multi-semester shell subjects known as the Civil Engineering Tree of Knowledge.

The Tree of Knowledge subjects are essentially shell subjects, comprised of a collection of fine- grained learning topics, each having its own learning objectives and mini-syllabus. Pre-requisite knowledge is mapped to the topic, rather than to a whole subject; this allows a more precise calibration of what is required. Students will be required to plan and monitor their progress through the Tree using a custom-built online interface, identifying what they need to learn and when they need to learn it. Topics will be scaled such that an average student would require an average of three hours to complete the topic.

The Tree of Knowledge is best represented graphically (Figure 2). This small excerpt of the Tree of Knowledge illustrates six topics and the interdependencies between them: Integration along a line, integration along a curve, free body diagrams, shear force diagrams, bending moment diagrams and shear stress in an I-beam, with the arrows showing the pre-requisite links.

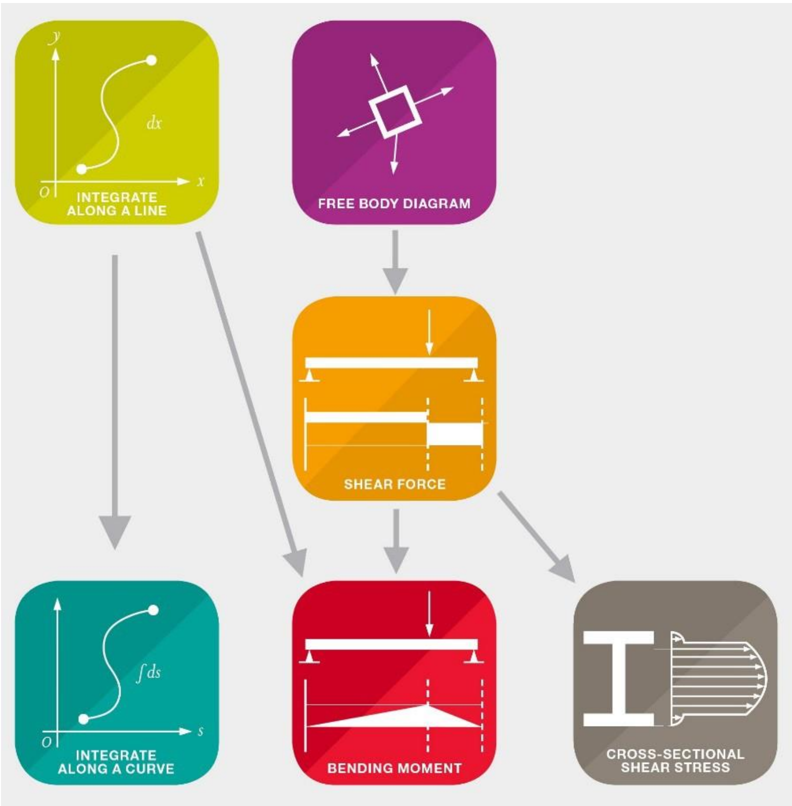

Figure 2: Excerpt from the Tree of Knowledge

It is this fine granularity that is the strength of the Tree of Knowledge approach. The Free Body Diagram – Shear Force Diagram – Bending Moment Diagram sequence is the traditional core of a first year Statics subject; however the other topics usually reside in other subjects, some in later semesters. This approach allows students to pursue knowledge at the time they require it, rather than learning things that they do not yet need because we have packaged them in the same subject. In particular, the Tree of Knowledge allows students to align their study with the work they are doing while on placement. As they encounter new tasks in the workplace, they are able to delve into the Tree of Knowledge for learning, working with a "just-in-time" approach to learning rather than a "just-in-case".

We anticipate that the overall Tree of Knowledge will contain around 1,000 topics, covering the range of different specialties within Civil Engineering, as well as accounting for different levels of preparation from the commencing students.

In order to pass the Tree of Knowledge – Student Engineer subject, students will need to complete an overall total of at least 240 topics, including all of the topics from specified Schedule A. In this way every student can be guaranteed to have acquired the key skills necessary for functioning in the workplace as a cadet engineer.

In order to pass the Tree of Knowledge – Cadet Engineer subject, students will need to have completed an overall total of least 600 topics, including those done for the Student Engineer subject. All CSU Engineers must complete the topics specified in Schedule B, which represents core topics for all Civil Engineers. Further, each student must also complete the version of Schedule C that corresponds to their intended major – Water, Structures or Geotechnical Engineering.

Mastery Learning

The Tree of Knowledge approach moves the students to a Mastery learning paradigm. Each topic is assessed based on a *mastered* or *not yet* basis. This is contrasted with a *pass* in a traditional subject; meaning that a student has mastered 50% of the topics in the subject, **or** is half proficient at each of the topics in the subject. Students progress when they have acquired the knowledge to a required standard. If this occurs quickly, they can advance quickly; if it takes longer, then the student can take the time, rather than missing out.

Where possible (and appropriate), automated assessment and feedback will be used to support the student learning. There are wide ranges of tools (such as Smart Sparrow www.smartsparrow.com) that are able to provide students with "near-miss" feedback in the event that they make common errors.

This approach is most powerful in the learning of topics that are usually implemented through the use of lots of tutorial practice questions, such as finding the maximum stress in a beam. Students can be provided with multiple, personalised, versions of the questions, and then given tailored feedback if they make the errors that have been anticipated by the academics. Once they are able to demonstrate they have mastered the skill, by completing sufficient questions correctly, they can be awarded the topic and then progress – without the need for direct intervention from an academic.

Freeing academics from the repetitive grind of basic marking allows them to instead focus their efforts on more high-value interactions with students (Hake, 1988) – working with teams (Seat & Lord, 1999), mentoring, role modelling and deeper exploration of content material.

Making use of data analytics provided by the interface tools will allow the academics to tailor their face-to-face teaching to respond to the errors most commonly made by the current cohort of students.

The Placements

One of the key features of the CSU Engineering program is 4 one-year work placements. Our student engineers will commence their studies with us full time on campus for 18 months; from then on their education will proceed with them working as cadet engineers on a sequence of four one- year paid work placements, while studying the theoretical curriculum online. Student Engineers use examples from their workplace experience to demonstrate their achievement of the learning outcomes, rather than completing assignments contrivedfor an academic environment. Student Engineers will complete two extended projects while in industry – a Cornerstone project in their second placement and a Capstone project in their final year placement.

Placements must consist of engineering work, in an engineering workplace, and under the supervision of an experienced (preferably Chartered) engineer. There are no specific constraints on where the placements can be located, however we anticipate that in the early stages the placements will be concentrated around CSU's various regional campuses.

Where necessary, the placements will be supported by weeklong residential schools. Residential schools will either be based at a CSU campus where a particular learning outcome is anchored (e.g. availability of specific equipment), or in a community where a specific project / problem is located. Residential Schools will also be used as an opportunity for later-year student engineers to serve as mentors for early-year student engineers.

Conclusion

The CSU Engineering degree represents a significant departure from traditional engineering programs. Grounded in both educational and market research, it will exemplify a different paradigm for engineering education in Australia, and provide a distinct alternative to Australia's existing engineering degree programs.

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