Electrical Engineering Education in the Brave New World – A Program Based Philosophy to Graduate Development

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ABSTRACT

Central Queensland University (CQU) has long been recognised as a provider of engineering teaching excellence to the Central Queensland region and beyond. As the requirements of the stakeholders in the engineering education process have changed, CQU has adapted its offerings and incorporated new, brave and innovative approaches to maintaining its market share in this industry. CQU currently offers electrical engineering undergraduate programs at Associate Degree (ADE), Bachelor of Engineering Technology (BET) and Bachelor of Engineering (BE) Levels.

This paper will outline the history of innovation at CQU, the previous program structure and the items which this review has tried to improve. The paper will also explore the process of review, the factors influencing decision making and the proposed new structure for all levels of undergraduate electrical engineering programs. In addition to the increased integration of the programs, the electrical engineering program has a greater power engineering focus and a stronger emphasis on Project/Problem Based delivery across the suite of programs. The new programs and associated assessment/delivery processes will shape the future of engineering education into the new millennium.

1. INTRODUCTION

Central Queensland University and its predecessors, primarily the Capricornia Institute of Advanced Education through the School of Engineering commenced delivering a relatively narrow range of engineering programs in the late 1960’s. Those programs evolved into offerings of Associate Diplomas of Engineering (2 years full-time equivalent), Bachelor of Technology (3 years full-time equivalent) and Bachelor of Engineering (4 years full-time equivalent), post secondary completion, by the early 1990’s [1,2].

These programs require continuous design, development and delivery, responsive to the practical needs of industry and the requirements of the professional bodies. Engineering programs are also influenced by various social factors, including changes in the secondary education curriculum, university requirements on contact time and term structures and economic constraints. Coupled with these factors is the current skills shortage and the mining boom in the Central Queensland region, which is expected to last for some years. As the constraints increase, it is obvious that the face of engineering education must change if engineering programs are to be sustainable into the future. It is this “Brave New World” which must be considered in program development, rather than the comfort of the past.

CQU is no stranger to brave steps and new educational philosophies. Through the 1990’s and early 2000’s a number of key innovations were introduced into CQU’s Bachelor of Engineering programs, starting with Cooperative Education in 1994. This program included two structured work placements as part of the engineering studies. The introduction of this program addressed the major issue of engineering practice experience, but maintained traditional delivery and assessment elements in the program. It soon became evident that while introduction of the cooperative program had a positive effect, many students remained poorly prepared for their cooperative placements , [3].

A philosophical review of the BE(Co-op) program was proposed and commenced in 1996, in parallel with the introduction of the Co-operative Education program. The aim of the review was to consider an alternative, improved learning paradigm that complemented co-operative education. A national study was co-incidentally being undertaken by the Institution of Engineers, Australia which culminated in a 1996 report, [4], calling for significant change in how engineering programs in Australia were to prepare students for their engineering careers.

In 1998 a completely new program philosophy utilising Project Based Learning (PBL) was introduced to better prepare students for their industry placements, and ultimately professional employment. This program based philosophy was substantially different to current offerings of engineering programs in Australia at the time. In 2004 the program evolved into a fully integrated Bachelor of Engineering (Co-op)/Diploma of Professional Practice with the latter element of this dual award specifically recognising and credentialing professional engineering practice incorporated in the program, [2]. This program has been referred to as the University’s ‘Jewel in the Crown’ in terms of its industry and community standing.

In 2005, as part of the regular continuous improvement cycle, the engineering programs at Central Queensland University commenced a major review. The program
review outlined a broad philosophy which governed the structure and delivery of courses in all discipline plans. Within this philosophy, the discipline groups were delegated the task of devising the program content for their discipline plans, under the guidance of the discipline leaders. The outcomes of this review for the electrical discipline are the main focus of this paper.

2. **EXISTING PROGRAMS AT CQU - 2005**

When the review commenced in 2005, CQU was offering a selection of programs including Associate Degree of Engineering (ADE), Bachelor of Engineering Technology (BET) and two Professional Engineering Programs (BE and BE(Coop)/DipProfPrac). All of the programs offered were accredited with Engineers Australia. These will be discussed as a precursor to understanding the outcomes of the review. Figure 1 shows the suite of programs and plans offered. It may be noted in Figure 1 that only the Electrical offerings had separate specialisations within the discipline.

![Diagram of program suite](image)

Figure 1. Existing Undergraduate Program Suite.

### 2.1. ASSOCIATE DEGREE OF ENGINEERING

The ADE Program was a nominal four year part-time program with graduates eligible for membership of Engineers Australia as Associates. The times discussed in this section are for a full time study load, and should be doubled for part-time study. The ADE program was closely aligned with the BET program such that it comprised the first two years of the BET program. This allowed direct articulation from the ADE into the third year of the BET with one year of additional study to complete the BET program.

The original formulation of the ADE program was as an exit award from the BET program. A consequence of this was the ADE did not have unique Graduate Attributes defined to clearly differentiate graduates of the two programs.

The Electrical plan of the ADE was further split into four specialisation plans as shown in Figure 1. The courses comprising each of these plans (electrical, civil and mechanical) were common for the first year and also shared four common courses in the second year. Within the electrical specialisations, two of the remaining courses were common to all specialisations and two additional courses completed the specialisation.

This structure, with a significant amount of common material and very little discipline specific content, also resulted from the close alignment of the ADE and the BET programs.

### 2.2. BACHELOR OF ENGINEERING TECHNOLOGY

The BET program was identical in structure and specialisations to the ADE for the first two years. The addition of another year of study completed the degree in any of the specialisations listed in Figure 1.

The additional year of study comprised four core courses (including the final project) and four courses chosen from a list of defined specialisation electives. This allowed students to gain more discipline specific knowledge and also to specialise within that discipline.

The ADE and BET suite of programs were only available in distance mode, as the number of internal students in the higher year levels were not sufficient to run these courses on campus. This problem was compounded by the use of specialisation electives, further diluting the student numbers in each course.

The ADE/BET had not been part of the review and consequent introduction of PBL in 1998. The structure of the programs, and the delivery and assessment of courses in these programs remained traditional.

### 2.3. BACHELOR OF ENGINEERING AND BACHELOR OF ENGINEERING (COOP)/DIPLOMA OF PROFESSIONAL PRACTICE

The flagship program for CQU was the Bachelor of Engineering (Coop)/Diploma of Professional Practice. This program was a four year professional engineering degree combined with two six month work placements and additional professional practice courses. The nominal program length was 4.5 years, but students exited the program with a full year of paid work experience. A standard Bachelor of Engineering was also offered which did not include the work placements and professional practice courses. This standard program was four years in length.

These two programs consisted of the same courses in the “engineering” component of the program. The first year of the program was common to all three disciplines. The later years included a few common courses (mostly mathematics and management courses) and the remaining courses were discipline specific. This program incorporated Project Based Learning (PBL) as a core philosophy and was developed based on a Hybrid PBL model. In any given term, 50% of the students course load was delivered in a PBL mode. Over the eight years since this structure was introduced, it has proven to be very successful in developing graduates who are professionally ready for the workplace as well as technically competent.

The BE and BE(Coop) programs were only available internally. This made articulation between the BET and the BE difficult for students, as they were required to change study mode from external to internal. Often this did not suit their personal circumstances, and they were
forced to seek other options for the articulation. The articulation path is illustrated in Figure 2.

![Articulation Pathway Diagram](image)

Figure 2. Articulation pathways for existing programs – 2006.

3. **Core Drivers of the Review**

The weaknesses identified in the previous analysis were core drivers in the reviewed program structure. Additionally, it was desired to preserve the strengths of the CQU programs identified in the 2002 accreditation, [5]. The key strengths were:

- The Coop Program and relationships with industry partners
- The Project Based Delivery in the Bachelor of Engineering programs
- The existing external delivery of ADE and BET

The accreditation report recommended these be extended to all of the programs offered by CQU.

The core drivers in the review process may then be summarized as:

- Economic Sustainability: This could be achieved by rationalising courses and reducing the number of low enrolment courses.
- More flexible articulation pathways
- Continuing innovation and leading edge educational programs

4. **Program Outcomes and Graduate Attributes**

As the first step in determining the structure of the new engineering programs it was deemed necessary to formally establish the respective programs’ overall learning outcomes for graduating students, i.e. take a top down approach in the program structure and particularly the curriculum design. These were designated the program’s ‘Graduate Attributes’ that all graduates of the respective programs should be able to demonstrate. In addition there were a set of generic tertiary Graduate Attributes that Central Queensland University required its degree program graduates to be able to demonstrate.

The Graduate Attribute’s determined in 1996 by then the Institution of Engineers, Australia, [4], have since become part (with minor modification) of the Engineers Australia Accreditation Board’s new Accreditation Management System for professional engineering programs, [6]. At the time of writing (August 2006) a draft set of Generic Attributes defined by Engineers Australia has just been developed for consideration by a national working party to form the basis for accreditation of Engineering Technology programs. No such generic attributes exist as yet for two year Associate Degree programs’ accreditation.

The consideration for three sets of Graduate Attributes for each of the program suites, BE, BET and ADE was predicated by the decision to maintain the usage of the Engineers Australia Generic Attributes for the Bachelor of Engineering programs’ Graduate Attributes. It was decided to adapt these graduate attributes for the BET and ADE utilising the 2004 Australian Engineering Competency Standards, [7]. This approach gave a common set of graduate attributes with clear distinction between the skills of the respective program levels.

The same number of attributes has been established for each program and the order of the attributes reflects the order defined by Engineers Australia in their Accreditation documentation. The respective programs’ Graduate Attributes are now presented:

4.1. **Bachelor of Engineering Programs**

On successful completion of a CQU Bachelor of Engineering program, graduates should demonstrate an:

1. ability to apply knowledge of basic science and engineering fundamentals
2. ability to communicate effectively, not only with others in engineering practice but also with the community at large
3. in-depth technical competence in at least one engineering discipline
4. ability to undertake problem identification, formulation and solution
5. ability to utilise a systems approach to design and operational performance
6. ability to function effectively as an individual and in multi-disciplinary and multi-cultural teams, with the capacity to be a leader or manager as well as an effective team member
7. understanding of the social, cultural, global and environmental responsibilities of the professional engineer, and the need for sustainable development
8. understanding of the principles of sustainable design and development
9. understanding of professional and ethical responsibilities and commitment to them
10. expectation of the need to undertake lifelong learning and the capacity to do so

These are identical in order and outcomes (minimal rewording of no. 2) to the current professional engineer generic attributes specified by Engineers Australia, [6].

4.2. **Bachelor of Engineering Technology Programs**

The BET program attributes are modelled from those presented in Section 4.1. Attributes 3, 4 and 5 have been adjusted to suit the BET programs. The remaining 7 are as specified in the BE programs’ Graduate Attributes. The modified BET graduate attributes are:
3. in-depth technical competence in one engineering discipline
4. ability to undertake problem identification and formulation, and to identify, apply and adapt appropriate procedures, techniques and resources in their resolution
5. in-depth knowledge and understanding of appropriate technology and its applications and evolution in equipment, installation and system design and operation

The BET program Graduate Attributes will be reassessed upon Engineers Australia’s determination of Graduate Attributes for the Accreditation of Engineering Technology programs.

4.3. ASSOCIATE DEGREE OF ENGINEERING PROGRAMS

Attributes 3, 4, 5, 6, 7 and 8 have been adjusted to suit the ADE programs. The remaining four are as specified in the BE (and BET) programs’ Graduate Attributes. The modified ADE graduate attributes are:

3. technical competence to support and complement engineering activities in one engineering discipline
4. ability to undertake simple problem identification and formulation, and to identify, apply and adapt appropriate procedures, techniques and resources in their resolution
5. understanding and knowledge of the application of standards, codes of practice and industry regulations in the specification, installation, testing, monitoring and operation of equipment and systems
6. ability to function effectively as an individual and in multi-disciplinary and multi-cultural teams, with the capacity to be an effective team member
7. understanding of the social, cultural, global and environmental responsibilities of the Engineering Associate
8. understanding of the need for sustainable design and development

This overall suite of graduate attributes provides a framework for program development, as well as clearly identifying the differences between the programs for articulation purposes. Within this framework, the new programs structure has been developed.

5. NEW PROGRAM STRUCTURES

The review process defined a structure for the suite of engineering programs. This structure included the need for PBL to become a core philosophy throughout all of the programs. This shifted the model from a Hybrid PBL model to a full PBL model. Although this does not change the core content, it is a critical change resulting from the review process. This defined structure included the amount of common (generic) courses required, the mode of delivery, the flexibility of delivery, and the articulation pathways and their definition.

5.1. ASSOCIATE DEGREE OF ENGINEERING

The Associate Degree of Engineering has now been decoupled from the BET offering. The required graduate attributes of the associate program identify an independent program with clearly defined articulation, but not the full two years. The Associate Degree is largely unchanged in level compared to the 2005 program; however, the decoupling from the BET program allows the ADE to be completely tailored to the needs of industry. The courses can be much more practically focussed without compromising the future needs of the students who will continue into the BET. Table 1 shows two of the three electrical specialisations that have been developed to suit the different needs of students. The “Electronics and Communications” stream is not presented as this is not relevant to the power engineering forum. The number of common courses has been reduced, allowing electrical students to develop a greater degree of discipline knowledge.

Table 1. Structure of the Revised Electrical ADE Program.

<table>
<thead>
<tr>
<th>Yr</th>
<th>Term 1</th>
<th>Term 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Professional Engineering Communication</td>
<td>Engineering Materials</td>
</tr>
<tr>
<td></td>
<td>Mechanics</td>
<td>Energy and Electricity</td>
</tr>
<tr>
<td>2</td>
<td>Engineering Drafting</td>
<td>Computer Aided Drafting</td>
</tr>
<tr>
<td></td>
<td>Technology Mathematics</td>
<td>Measurement and Data Analysis</td>
</tr>
<tr>
<td>3</td>
<td>Electrical Components and Modelling</td>
<td>Sustainability Technology and the Environment</td>
</tr>
<tr>
<td></td>
<td>Electrical Machines and Drives</td>
<td>Electrical/Electronic Circuit Computations</td>
</tr>
<tr>
<td>4</td>
<td>Computer Aided Drafting and Design (Electrical)</td>
<td>Electrical Power Systems</td>
</tr>
<tr>
<td></td>
<td>Electrical Services and Protection</td>
<td>Electrical Power System Modelling</td>
</tr>
<tr>
<td>5</td>
<td>Electrical Control and Instrumentation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Electrical Components and Modelling</td>
<td>Sustainability Technology and the Environment</td>
</tr>
<tr>
<td></td>
<td>Electronic Devices and Applications</td>
<td>Electrical/Electronic Circuit Computations</td>
</tr>
<tr>
<td>4</td>
<td>Computer Aided Drafting and Design (Electrical)</td>
<td>Control Technology</td>
</tr>
<tr>
<td></td>
<td>Introductory Electronic Communications</td>
<td>Instrumentation and Transducers</td>
</tr>
</tbody>
</table>

5.2. BACHELOR OF ENGINEERING TECHNOLOGY

The Bachelor of Engineering Technology has been redeveloped to align with new directions of Engineers Australia in defining the role of the Technologist. The wording of the documentation indicates that a Technologist may be the equal of an Engineer in their defined area of specialty, but the skills of a Technologist are not necessarily transferable to different areas of the discipline, or different industries. The revised BET program shares most of the courses with the BE program, allowing more flexible options for students. The use of different BE course combinations has allowed three electrical specialisations to be retained without additional courses being required. The revised structure for the two relevant streams is shown in Table 2. The timelines in this program are indicated for part-time study, as this is currently the most popular option.

Although many courses are common with the BE program, the BET program contains a greater amount of
CAD content compared to the BE graduates, but a slightly lower amount of pure mathematics. All courses will be available internally and externally, allowing students to select the study mode most suited to their personal circumstances and to change that mode as their circumstances change.

The complete program structure is shown in Table 3. The shaded cells represent those courses which are associated with the Diploma of Professional Practice. The Bachelor of Engineering Program shares the same structure as Table 2, with the Shaded cells removed, and the other courses redistributed into a four year delivery. These second year courses are common with mechanical and civil disciplines except for the two electrical courses.

The Project Based delivery mode will be extended to include all courses in the program, so that instead of a hybrid PBL structure, the program is now fully PBL. The course content has been redistributed and integrated with professional practice components to meet the full spectrum of Graduate Attributes in an explicit and clearly identifiable manner.

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6. NEW PROGRAM ANALYSIS

The program review has resulted in a very unique opportunity to address the overall content components of the electrical programs. The ADE now features an expanded discipline focus, and courses which can be more tailored to the professional level of the graduates of this program. This improvement has largely resulted from the decoupling of the ADE and the BET. The number of discipline specific courses in the program has increased from four to seven. Two of these are common to all electrical specialisations, and the remaining five are specific to only one or two specialisations. It is expected that as the market expands, new specialisations can easily be developed and tailored to the specific needs of industry. This has already occurred in some other disciplines and has resulted in some industry tailored mining ADE programs.

The level of the BET has shifted to align more with the BE. The ratio of common to discipline specific course has remained the same, but the use of electives for specialisation has been replaced with combinations of BE courses to achieve the same outcome. This shift allows a more focussed discipline specialisation to be achieved without requiring a large number of courses which only cater to a subset of students.

The BE programs have also had a shifted focus. The ratio of common to discipline specific courses has remained approximately the same, but the common courses now appear in the first two years. The discipline specific courses have been revised to increase the focus on Power Engineering, which is a major focus of the Central Queensland region. Table 4 shows broadly the ratio of different specialisation in the program. The brackets indicate dependence on elective choice.

7. CONCLUSIONS

The review of Engineering Programs at CQU has resulted in a much improved set of programs. The new programs have reduced the number of courses required, thus improving the economic sustainability of the programs. The articulation pathways for the programs are much more clearly defined as the programs were developed from the top down, with this goal. The extension of the delivery of all courses to external has also improved the flexibility for students to select their mode of study to suit their circumstances.

The program review resulted in the integration of Project Based Learning and Flexible Delivery across the entire engineering undergraduate program spectrum and has extended the innovation of previous reviews and continuous improvement processes into all the engineering programs at CQU. The new programs and associated assessment/delivery processes will shape the future of engineering education in Central Queensland and contribute to it across Australia and internationally in the new millennium. The program is expected to produce world class professional engineers, technologists and associates that are industry ready and highly sought after.

Table 4. Specialisation components before and after the review

<table>
<thead>
<tr>
<th>Area</th>
<th>Units of Credit (Before)</th>
<th>Units of Credit (After)</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>18 or [24]</td>
<td>18</td>
</tr>
<tr>
<td>Power Engineering</td>
<td>6 or [12]</td>
<td>18</td>
</tr>
<tr>
<td>Machines</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>Electronics</td>
<td>18 or [24]</td>
<td>12</td>
</tr>
<tr>
<td>Control</td>
<td>18</td>
<td>12</td>
</tr>
<tr>
<td>Communications</td>
<td>18</td>
<td>12</td>
</tr>
</tbody>
</table>

REFERENCES


