

Developing Integrated Standards for Systematic Civil Engineering Course Design

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Prof Lindsay's work in Remote and Virtual laboratory classes has shown that there are significant differences not only in students' learning outcomes but also in their perceptions of these outcomes, when they are exposed to the different access modes. These differences have powerful implications for the design of remote and virtual laboratory classes in the future, and also provide an opportunity to match alternative access modes to the intended learning outcomes that they enhance.

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Prof Lindsay was the 2010 President of the Australasian Association for Engineering Education. He is a Fellow of Engineers Australia, and a Fellow of the UK Higher Education Academy. Prof Lindsay was the recipient of a 2007 Carrick Award for Australian University Teaching. In 2005 he was named as one of the 30 Most Inspirational Young Engineers in Australia.

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Abstract

Engineering degrees are subject to a range of different quality assurance frameworks, which while often similar in their overall intent, can manifest quite differently. Some have requirements for the structure or content of the program; others have mandated expectations from the graduates. Most university courses are required to meet multiple standards to demonstrate accountability to professional organisations, employers and other governing bodies/government agencies for producing graduates with disciplinary knowledge and skills and generic skills for employability.

Introduction

At Charles Sturt University (CSU), this means meeting several different criteria before graduation: the Graduate Learning Outcomes (standards for the university), the Australian Qualifications Framework (AQF) Criteria (standards for the level of the degree), and the Engineers Australia (EA) competencies (national accreditation standards for the professional engineer). In addition to meeting these required standards for graduating as a professional engineer, the CSU Engineering degree at the Masters level also pushes its students towards the competencies for Chartered Engineer status; this adds an additional standard to be incorporated into the curriculum design and supported by the program while not explicitly needing to be completely satisfied by any of the graduating students. Further, the program offers exit awards for students seeking to leave the program early after meeting key intermediate milestones; as such these exit awards must also meet their respective standards, and the early subjects in the degree must ensure that this occurs.

The course design process at Charles Sturt University begins by developing a single set of integrated standards that become the course learning outcomes and provide a framework for the course design. This approach to course design ensures that student engineers automatically meet all criteria in the normal process of meeting degree requirements. The integrated standards also provide a quality assurance framework for curriculum mapping and benchmarking to demonstrate where and how each of the individual graduate standards are being achieved.

This paper outlines the process of developing integrated standards, as well as mapping them to each of the individual requirements. Whilst the multiple requirements are mostly aligned, the goal of the integrated standards is to inherently satisfy each of the separate requirements in the process of meeting the integrated standards.

CSU Engineering Course Model

The CSU engineering model is a 5-½ year Masters of Engineering program with earlier exit points (3 ½ years for Bachelor of Technology, and 1 ½ years for Diploma of Engineering Studies). It also is important to note that as part of the course structure, students are expected to have achieved the traditional engineering graduate attributes and competencies by the 4 ½ year mark (the commencement of final year), although no formal credential is offered at this point. Details of this program are available elsewhere [Morgan & Lindsay, 2015]. For the

purposes of this paper, it is sufficient to note that the program relies heavily on Project Based Learning and Work Integrated Learning.

Engineering Integrated Standards and the CSU Engineering Course Design Process

The goal of the CSU course design process is to ensure that students receive integrated, coherent learning experiences that contribute towards their personal, academic and professional learning and development. Course design begins with selecting a course team that includes Course Directors, academic staff and Educational Designers to ensure an appropriate range of disciplinary, pedagogical and education design expertise.

An important element of the course design process is the specification of Integrated Standards that guide the course design. Integrated Standards recognise that most courses need to meet multiple sets of standards that include professional accreditation requirements [Engineers Australia, 2013], institutional standards specific to CSU and sector standards [Approved Graduate Learning Outcomes, 2017], in particular the Australian Qualifications Framework (AQF) [Australian Qualifications Framework, 2013], which specifies the standards for educational qualifications in all CSU degrees as well as all others in Australia. These multiple standards provide accountability to professional organisations, employers and government for producing graduates with disciplinary knowledge and skills and generic skills for employability [Robley, Whittle & Murdoch-Eaton 2005, Bain & Zundans-Fraser 2016].

The Integrated Standards create a single set of standards through a process of integrating all of the relevant individual standards. The Integrated Standards become the course learning outcomes and provide a complete term of reference or framework for the course design. Each standard also comes with descriptors that help expand or clarify the meaning of the standard, or give examples of how that standard should be interpreted in the degree-specific context.

The process of developing a set of Integrated Standards begins by identifying the primary standards for the course, which are typically the relevant professional accreditation standards. Secondary standards include the CSU Graduate Learning Outcomes (GLOs) which specify the characteristics identified for all CSU graduates, and the AQF criteria for the appropriate course level. The Integrated Standards must also incorporate any additional outcomes that are not mandated by external bodies, but rather form part of the philosophy and ethos of the CSU Engineering Degree.

The course team works with University support staff, including Library support staff, Academic Literacy, Learning and Numeracy Advisors and GLO Advisors to draw on their expertise for embedding GLOs within the course.

The secondary standards are integrated with the primary standards by matching, merging or adding. The course team compares each secondary standard with the primary standards and decides whether it is fully met within the primary standards, in which case it becomes a match. If the secondary standard is almost, but not quite, met by the primary standards, it will be merged to incorporate the missing elements. If a secondary standard is not met by the primary standards then a new standard will be added. The three processes of integrating

standards are shown in Figure 1 below.

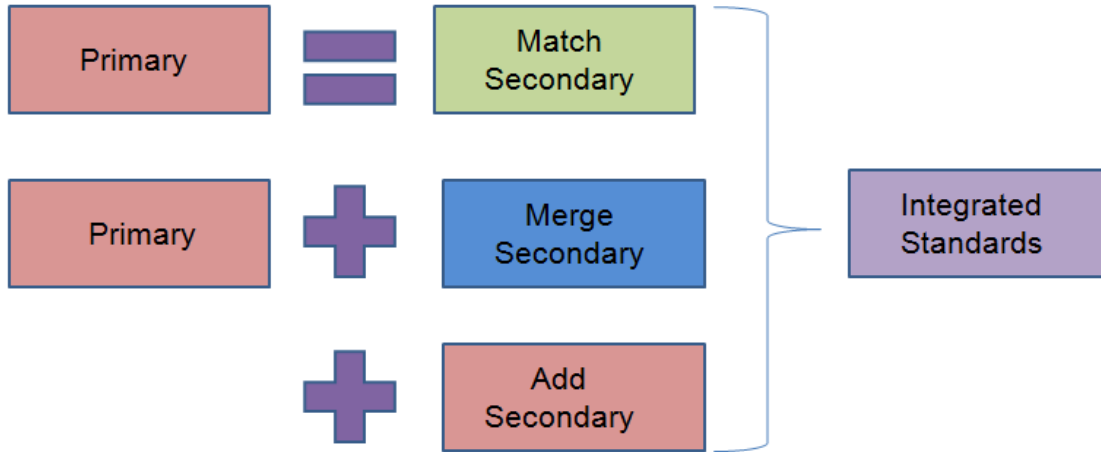


Figure 1: Developing Integrated Standards

It is important in this matching and merging process to determine whether the secondary standard should manifest in the integrated standard or its descriptors. It is not uncommon in modern curriculum development to encounter “laundry lists” of the many global, sustainable, digital, ethical, etc. requirements for a particular competency; the course design team must choose which of these dimensions are sufficiently important to warrant explicit inclusion in the standard, and which can be instead be incorporated into the descriptors. That said, whenever it was possible to avoid changing the primary standard, the integrated standards were matched to the primary standard.

For the Engineering Integrated Standards the EA Stage 1 competencies were selected as the Primary Standards. The *Stage 1 Competency Standard for Engineering Technologist* is the Primary Standard for the Bachelor of Technology and the *Stage 1 Competency Standard for Professional Engineer* is the Primary Standard for the Master of Engineering (Civil Systems).

The secondary standards are AQF level 7 for the Bachelor of Technology, AQF Level 9 for the Master of Engineering and the CSU Graduate Learning Outcomes, which need to be achieved at the Bachelor of Technology degree level.

In what is not normally part of the CSU course design process, one additional secondary standard is applied as an aspirational target – outcomes that are strongly desirable at the end of a degree, and which should be supported by the curriculum, but which are not essential for graduation. This standard is the EA Stage 2 competency standard for Chartered Engineers. The aspirational standards reflect the competitive advantage that CSU engineering course

offers to students through its project-based and work integrated learning approach and their graduation at Masters level, giving them a head start towards chartered engineering status.

We also offer a Diploma of Engineering Studies as an exit point after the 18-month face-to-face part of the degree. This degree is not professionally accredited, and as such for this Diploma the only relevant standard is AQF 5.

In summary, the standards used and incorporated into the engineering integrated standards are:

1. Stage 1 Competency Standard for Professional Engineer
2. Stage 1 Competency Standard for Engineering Technologist
3. Stage 2 Competency Standard for Chartered Engineer
4. AQF Level 9 Standards for Graduates of Masters Degrees
5. AQF Level 7 Standards for Graduates of Bachelors Degrees
6. AQF Level 5 Standards for Graduates of Diplomas
7. CSU Graduate Learning Outcomes

Each of these standards either must or should be satisfied at different stages as the students pass through the course; as such we must ensure that the overall design of subjects guarantees that students have indeed accumulated these competencies by the time they have completed the relevant subjects (Table 1):

Table 1. Summary of Timeline, Qualification, and Standards

Timeline	Qualification	Relevant Standards
1.5 years	Dip Eng	AQF Level 5
3.5 years	B.Tech	CSU GLOs AQF Level 7 Stage 1 Competency for Engineering Technologist
4.5 years	No exit point	Stage 1 Competency for Professional Engineers
5.5years	M.Eng	AQF Level 9 Stage 2 Competency for Professional Engineers (aspirational)

Professional Standards

The Stage 1 Engineering Competency Standards for Professional Engineer and for Engineering Technologist have a total of 16 standards expressed in three domains:

1. Knowledge and Skill Base
2. Engineering Application Ability
3. Professional and Personal Attributes

EA's accreditation standards have been designed such that the Technologist and Professional Engineers standards are well-aligned; this simplifies the task of ensuring that satisfying the Technologist standards can also serve as an intermediate outcome on the way to Professional Engineer.

The EA's accreditation standards also have been designed to mesh well with the AQF; they are

cognizant of engineering graduates also being university graduates, and are careful to ensure that the expectations of the two can be well reconciled. The professional engineering standards, however, are written for the expectation of a Bachelor Honours graduate (AQF8), not a Masters graduate (AQF9). This sees the introduction of a de facto standard for the commencement of final year, where students *should* have met the Primary standard, but for which compliance is not required until the end of final year, where students must meet the more stringent Integrated Standard.

Degree Level Standards

The AQF criteria identify the standards at different levels of qualifications expressed as three dimensions as follows:

1. Knowledge – defined as depth and/or breadth of knowledge and complexity and specialisation in discipline or areas of practice
2. Skills – defined as levels of cognitive processing, thinking and communication skills
3. Application of knowledge and skills – defined as complexity of applications and levels of autonomy, responsibility and expertise required as learners and practitioners.

CSU Graduate Learning Outcomes

CSU identifies nine Graduate Learning Outcomes:

- Professional Practice
- Academic Literacy & Numeracy
- Information & Research Literacy
- Digital Literacy
- Ethics
- Lifelong Learning
- Indigenous Cultural Competence
- Global Citizenship
- Sustainable Practices

There are nine CSU GLOs each of which are developed as two levels of dimensions. The top level has three dimensions for each GLO expressing Knowledge (K) Skills (S) and Applications (A) giving a total of 27 dimensions, and some of these are further expanded to create a total of 90 dimensions. The GLO dimensions are intentionally aligned with the AQF categories and meet the requirements for the AQF Level 7, Bachelor's degree.

Course teams can choose to integrate the GLOs at the top level of 27 dimensions or the detailed level of 90 dimensions. The CSU engineering course has chosen to integrate at the level of 27 dimensions.

As stated above, each of the nine GLOs expands into learning outcomes for Knowledge, Skill and Application, leading to the expanded set of 27 outcomes. For example, Sustainable Practices becomes:

- *SK Knowledge*: Demonstrate a multidisciplinary knowledge that empowers graduates to understand and critically analyse the challenges of balancing the social, economic and environmental factors essential for ecological sustainability,
- *SS Skill*: Apply acquired sustainability knowledge individually and collectively for the improvement of local and global environmental sustainability, and
- *SA Application*: Demonstrate attitudes and implement actions that meet the needs of the present without compromising the ability of future generations to meet their own needs and those of the environment.

Using integrated standards for a civil engineering course design

It is important to note that whilst the mapping of each standard used to judge the course to the integrated standards is very important for the design and management of the course, the reverse mapping is essential for the governing bodies. The university course approval process requires evidence of how each of the GLOs are met, government audits require evidence that each degree offered meets the appropriate qualification level, and the accrediting professional body requires evidence of how competencies are developed throughout the degree.

The appendix shows the mapping across two integrated standards. The MEng Integrated Standard typically is the same as the EA Stage 1 Competency and the Descriptors for inclusion provide a detailed list, explanation or examples of what is included in the standard by the matching and merging of the secondary standards.

Criterion 1.1 “*Comprehensive, theory based understanding of the underpinning natural and physical sciences and the engineering fundamentals applicable to the engineering discipline*” is merged with two GLOs the Indigenous Cultural Competence Application dimension (IA) and the Sustainable Practices Knowledge dimension (SK) to explain that engineering fundamentals includes “an understanding of the issues and challenges associated with decision making about sustainability and the use of resources that recognises the importance of Indigenous Australian's relationship with the land.”

Criterion 3.3 “*Project a creative, innovative, entrepreneurial, pro-active and reflective disposition*” is developed from the EA Stage 1 Competency Standards to express the attributes associated with CSU engineering graduate of being entrepreneurial and reflective which are mapped to a number of GLO dimensions related to ethics, lifelong learning, Indigenous cultural competence and global citizenship. These are expressed in the Descriptors for Inclusion as follows: “This standard should include the demonstration of initiative, application of creative and innovative solutions, seeking out new developments in engineering, evaluating and reporting on their potential; autonomy and accountability for professional, ethical, cultural and personal responses; and reflective practice to identify and act on areas for improvement”.

Developing the Integrated Standards is a significant exercise for establishing the framework for course design that is transparent and involves negotiation of meaning with a range of stakeholders and advocates for different graduate and professional attributes. Once this process is completed, the Integrated Standards express the intended program/course learning outcomes and provide a rational framework for making decisions about the detailed course

design through a process of constructive alignment [Biggs & Tang 2011].

The Engineering Integrated Standards provide a strong guide for subject design by aligning with subject learning outcomes, assessment tasks and teaching and learning activities. Mapping the integrated standards at the subject level provides the evidence for course accreditation, quality assurance and benchmarking. The concept of constructive alignment is enhanced by the progression of the standards throughout the stages of the program. Diploma leads to BTech, which leads to MEng in much the same way that AQF5 leads to AQF7 which leads to AQF9.

Both compliance and aspirational standards are incorporated into the integrated standards. Whilst the course must meet all compliance standards, the course is structured so that most student engineers also should meet the aspirational standards. This results in a program that satisfies the requirements of all of external bodies, and allows CSU Engineering to embrace our particular philosophies. To the extent that aspirational standards for achieving chartered engineering competency are met, EA has agreed to count the last year of the CSU Engineering program as the first year of practice.

The Integrated Standards also provide a framework that can be used to help students to manage their own learning by mapping their progress, reflecting on their learning and selecting future learning paths [Robley, Whittle & Murdoch & Eaton 2005]. This approach encourage students to be responsible for the extent to which they achieve the aspirational standards for chartered engineering competency by the end of their course and provides them with skills for managing their ongoing professional development.

Conclusion

The Engineering Integrated Standards draw from Professional Standards, AQF qualification level learning outcomes and CSU Graduate Learning outcomes to define a single set of course learning outcomes. The Integrated Standards provide a framework for course design that enables an evidence-based mapping of student achievement of knowledge, skills and their application of the intended professional and personal graduate attributes. Constructive alignment leads to the development of subjects that support students to demonstrate their capabilities and achievement of the course-level standards. Collaborative work within a course team and with CSU support staff enables multiple perspectives and skills to be incorporated in the course design leading to a better outcome. A further benefit of the Integrated Standards is their potential role in helping students to manage their learning by mapping their own progress and pathways.

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