Representing and valuing non-engineering contributions to engineering graduate outcomes in engineering combined degrees

Tim Lever, Doug Auld, Richard Gluga
University of Sydney, Sydney, Australia
tim.lever@sydney.edu.au, doug.auld@sydney.edu.au, richard@gluga.com

Abstract: *Efforts to incorporate broader cross-disciplinary learning pathways within engineering programs face a number of barriers. An essential requirement is a reliable mechanism for representing and valuing the non-engineering components that engineering students may have previously completed or may wish to include. The paper presents an alternative method for compiling and reviewing aggregate learning outcomes in engineering degree combinations that enables the contribution of the non-engineering component to be more readily defined and justified in engineering terms. The proposed method enables ready cross-disciplinary translation of outcomes achievement without requiring specific cross-disciplinary expertise or engagement by academic staff involved, and without additional workloads or information burden. The proposed method is demonstrated through an outcomes analysis of an existing engineering combined degree but has potential application in the review and validation of cross-disciplinary learning outcomes more generally.*

Introduction

Combined degree pathways in Australian engineering schools have grown considerably in enrolments and range of options since the late 1990s, but have also attracted criticism of their cross-disciplinary quality. Complaints include diluted engineering content, inadequate quality assurance and lack of real cross-disciplinary integration between the engineering and non-engineering component (Moulton, Iyer, Shortis, Vuthaluru, & Xing, 2011; King, 2008, pp. 14-15,81). However, engineering-based combined degrees are not unique in experiencing such failings. Attempts at developing cross-disciplinary pathways of university study face inevitable frustration from the discipline based structure of the university itself (Russell, Dolnicar & Ayoub, 2008).

This paper presents a method for more reliably capturing and evaluating the learning outcome opportunities within engineering combined degrees that addresses, at the same time, a broader obstacle to the development cross-disciplinary study opportunities in the university curriculum more generally. The practical problem addressed is the lack of mechanisms for representing and valuing the way learning attainments in one discipline may contribute to the intended outcomes of others. The suggested solution works by establishing a common framework for defining the expected learning progression of each discipline. The following pages discuss current methods of outcomes reporting and their limitations before outlining the alternative approach suggested and demonstrating its use in the case of a particular engineering/commerce combined degree.

Terminology

The term 'combined degree' describes a program of study that offers two different degree qualifications simultaneously at a single university, usually in a reduced time by comparison with the two single degrees. The alternative terms ‘dual degree’ and ‘double degree’ are also acknowledged (Moulton et al., 2011). The term 'program' describes a sequence of university study that is required for the award of a degree or other university qualification. The term 'unit of study' describes what is sometimes called a 'subject' and represents the main unit of enrolment within a university program. The term 'learning outcome' is used in the sense of 'intended learning outcome', representing a concise description of the educational intentions behind the teaching/learning activities and assessments provided in a unit of study or program. 'Graduate attributes' are understood as representing the overall intended learning outcomes of university study (Biggs & Tang, 2007).

Background

Documentation of the delivery of engineering learning outcomes is a core requirement of the educational quality assurance process for professional engineering degrees in Australia (Engineers Australia Accreditation Board 2008, Doc.G02). In the case of engineering combined degrees, the application of this requirement is complicated by the trade-offs between engineering and non-engineering outcomes within the combined degree structure and by the lack of any agreed method for determining the aggregate outcomes value of the degree as a whole in engineering terms. A typical five-year engineering combined degree offers a qualification equivalent to a four-year bachelor of engineering degree plus a three-year bachelor in a second discipline. The combined structure assumes that each discipline augments the learning outcomes of the other in such a way that less study time is needed to match the aggregate outcomes of a full degree. However, the extent of the value that each discipline adds to the other through the combined degree arrangement is difficult to measure let alone guarantee in the absence of a mechanism for systematically relating learning outcomes achieved across discipline boundaries.

Current recommended university approaches to learning outcomes reporting provide for three levels of outcome aggregation: unit of study, program, and university graduate attributes. (Biggs & Tang, 2007, p.64). A major limitation of current university approaches is an under-development of the program level. Current program level outcome specifications can be as detailed as those provided by engineering's Stage 1 Competencies for Professional Engineers. More often the program outcome lists are just direct reiterations of the university graduate attributes, with or without a small number of discipline specific elements (e.g. Sumsion & Goodfellow, 2004). Combined degrees highlight the limitations of existing program outcome descriptions by requiring a level of precision and flexibility that they are unable to provide.

Two proposed methods for aggregate reporting of combined degree learning outcomes reporting are identified by the ALTC Double Degree Project (Moulton et al., 2011, Appendix F). These two methods comprise a unit of study based approach on one hand, and a university graduate attribute based approach on the other. In the first approach, the individual unit level learning outcome serves as direct point of attachment for information about different discipline-specific program outcomes (Figure 1). In the second instance, the university graduate attributes serve as link between unit level outcomes and different program outcome frameworks for the two disciplines involved in the combined degree (Figure 2). The assumption is that when students achieve a particular graduate attribute, they automatically achieve the program outcomes that are linked to that attribute. Taken together, the two methods highlight a tendency for program outcomes to be treated as secondary aspects of either graduate attributes or unit level outcomes rather than a distinct set of curriculum parameters in their own right. The failure of both proposed models to progress beyond concept stage is further indication that an alternative approach may be needed.

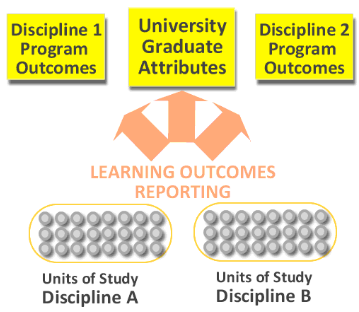

Figure 1: Unit of study driven outcomes translation

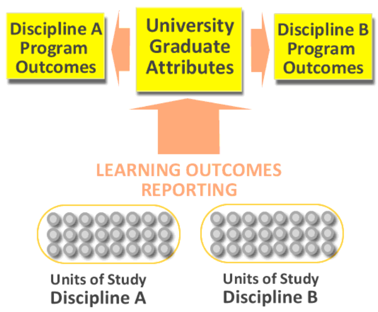

Figure 2: Graduate attribute driven outcomes translation

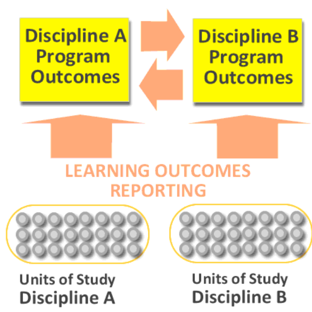

Figure 3: Program driven outcomes translation

An alternative framework for program level reporting of learning outcomes

The proposed alternative cross-disciplinary outcomes reporting method is based on the creation of a standardised program outcomes format at a level of detail that enables discriminating matches between outcomes in different disciplines. Matches at program level between outcomes in different disciplines enable links in turn between unit level outcomes and program outcomes within other disciplines. Program level outcome frameworks thus become the 'hub' for cross-disciplinary translation of unit learning outcomes (Figure 3). The discriminating capacities required by the program level learning outcome descriptors have been identified through previous experience in the use of university graduate attributes for curriculum reporting purposes. Limited discriminating power has been a major constraint on the use of graduate attributes as tool of educational analysis and communication (Green, Hammer & Star, 2009; Sumsion & Goodfellow, 2004), but the experience at least provides a clear indication of the kinds of discriminating power required.

1. Discrimination among disciplines. The kind of learning priorities that distinguish disciplines from each other need to be clearly evident.
2. Discrimination among the learning domains that characterise each discipline. The major differences between the learning priorities within disciplines should be equally easy to identify and track.
3. Discrimination among levels of performance within each domain. It should be possible to see where units and assessment tasks in later years differ from those encountered previously and what characterises 'advanced' expertise as distinct from that of novice or intermediate learners.

Program outcome descriptions addressing these requirements are organised in grid format. Key learning domains are listed vertically down the right hand column. Performance levels within each domain are listed left to right alongside. The domain and performance level divisions are based on whatever divisions appear to be most salient in previously available curriculum material plus extensive test mapping on existing units to identify and eliminate as far as possible any overlaps and blurred boundaries. Identification of performance levels is undertaken by comparative analysis of components considered most challenging, least challenging and moderately challenging within existing programs.

Sets of program level learning outcome descriptors have been developed to these specifications for both engineering and non-engineering disciplines as part of a cross-faculty curriculum systems initiative (Gluga, Kay & Lever, 2010). The program outcome descriptors have been integrated into student course information and program outcomes reporting through an electronic database developed at the same time. The database provides an environment where cross-mapping scenarios between different program outcome frameworks can be developed and investigated. Previous cross-mapping exercises, however, have focused on situations where outcomes need to be reported against frameworks in the same discipline area (Gluga et al., 2010), as may happen in accreditation, rather than between two entirely different disciplines.

The demonstration

The combined degree example has a project engineering specialisation (within civil engineering) plus an accounting specialisation within commerce. The combination provides an additional test of outcomes reporting capacity against the external accreditation standards used in accounting. The commerce/engineering combination also makes an interesting case study by reason of its popularity and high level of content outside traditional science-engineering curriculum areas. The commerce component of the combined degree comprises 96 credit points and the engineering component, 144 credit points. The reduction in engineering content by comparison with the single degree is 36 credit points of electives for the civil engineering and project engineering specialisations. There is no reduction in the standard commerce requirement of 96 credit points. The extent to which the 96 commerce credit points may compensate the missing 36 credit points of engineering electives is the critical quality control question in this case. Rendering the learning outcomes of the commerce units in terms that allow such questions to be more easily addressed is the main business of the demonstration.

The demonstration has two parts. The first part is a direct answer to the question of how the gains of the engineering/commerce combination weigh against the loss of engineering electives from the single degree equivalent. This part of the demonstration comprises a comparative analysis of program outcomes reports for single and combined engineering degrees, showing that an informative picture of the trade-offs between the two can be obtained. The second part comprises a review of the individual engineering outcome relationships assigned to each commerce unit of study learning outcome. The first part demonstrates an ability to perform a practical curriculum analysis task while the second part concerns the ability to verify the assumptions behind the translation, and to correct where necessary.

Setting up the demonstration was a matter of assembling the relevant curriculum documentation in the existing curriculum database. First step was definition of the combined programs themselves in unit by unit terms. Second was the development of existing commerce program outcome descriptors up to the required standard of detail within the database. Third step was defining equivalence relationships with engineering program outcomes. Fourth step was reporting of commerce unit outlines details including unit learning outcomes and assessment against commerce program outcome descriptors. Final step was verification of reported unit of study details by academic teaching staff. Once the relevant material was entered and confirmed, the demonstration itself could proceed.

Results

Program outcomes summary tables below compare assessment coverage of engineering program learning outcomes, on a unit-by-unit basis, for combined and single Bachelor of Engineering degrees in the Project Engineering and Management specialisation. The first comparison (Figure 4) focuses on the engineering learning domains of Information Skills, Professional Communication and Professional Values, Judgement and Conduct where the main differences are found.

Project Engineering and Management(Civil)/Commerce with CPA/ICAA accredited sequence (2010) - Assessed Course Goals: Engineering & IT Graduate Attribute Matrix (or Equivalents)

Print View

COMBINED Degree

This report will show an attribute matrix for the chosen attribute set. The matrix will only list units which have attributes linked directly to the unit and where attributes are linked to assessed learning outcomes.

	No Level	Level 1	Level 2	Level 3	Level 4	Level 5
4. Information Skills		ACCT1001 CLAW1001	ACCT2012 ACCT3011 CIVL2201 CIVL2410 CIVL3813 CLAW2201 ECON1001 FINC2011 INFS1000 INFS2001	ACCT1002 ACCT3012 ACCT3014 CLAW3201	CIVL4815 ENGG4000	
5. Professional Communication		ACCT1001 ACCT1002 CLAW1001 ECON1001 ECON1002 ENGG1800 ENGG1801 ENGG1803	ACCT2012 ACCT3011 ACCT3014 CIVL2410 CLAW2201 INFS2001	CIVL3010 CIVL3813 CIVL4024 CIVL4025 ECOF3001 ENGG4000	CIVL4815	Level N/A
6. Professional Values, Conduct and Judgment		ENGG1801 ENGG1803	ACCT1001 ACCT1002 ACCT2011 CIVL3812 CIVL3813 CLAW1001 CLAW2201 ECON1001 ECON1002 FINC2011 INFS1000 INFS2001	ACCT2012 ACCT3011 ACCT3014 CIVL3010 ECOF3001 ENGG4000	CIVL4815	Level N/A

Project Engineering and Management (Civil)) (2010) - Assessed Course Goals: Engineering & IT Graduate Attribute Matrix (or Equivalents)

Print View

SINGLE Degree

This report will show an attribute matrix for the chosen attribute set. The matrix will only list units which have attributes linked directly to the unit and where attributes are linked to assessed learning outcomes.

	No Level	Level 1	Level 2	Level 3	Level 4	Level 5
4: Information Skills			CIVL2201 CIVL2410 CIVL3813		CIVL4815	Level N/A
5: Professional Communication		ENGG1800 ENGG1801 ENGG1803	CIVL2410	CIVL3010 CIVL3813 CIVL4024 CIVL4025	CIVL4815	Level N/A
6: Professional Values, Judgement and Conduct		ENGG1801 ENGG1803	CIVL3812 CIVL3813	CIVL3010 CIVL4008	CIVL4815	Level N/A

Figure 4. Coverage of engineering outcomes in combined (above) verses single degree (below)

It is clear at a glance that the combined degree table at the top has a very substantial advantage. Across the three learning domains mentioned, the number of units of study with relevant assessed outcomes for the combined degree is more than triple the number found in the single degree. A further comparison focuses on the engineering domains of Design and Problem Solving, Discipline Specific

Expertise and Fundamentals of Science Engineering in Figure 5 below. Here the units with assessed learning outcomes are exactly the same for both combined and single degrees.

Project Engineering and Management (Civil)) (2010) - Assessed Course Goals: Engineering & IT Graduate Attribute Matrix (or Equivalents)
Print View
COMBINED Degree

This report will show an attribute matrix for the chosen attribute set. The matrix will only list units which have attributes linked directly to the unit and where attributes are linked to assessed learning outcomes.

	No Level	Level 1	Level 2	Level 3	Level 4	Level 5
1. Design and Problem Solving Skillls		CIVL2110 CIVL2410 CIVL2611 CIVL3812 ENGG1801 ENGG1802 ENGG1803	CIVL3010	CIVL4024 CIVL4025		CIVL4815
2. Discipline Specific Expertise		CIVL2810	CIVL2230 CIVL2410 CIVL2611		CIVL4024 CIVL4025 CIVL4815	
3. Fundamentals of Science and Engineering		CIVL2110 CIVL2810 ENGG1800 ENGG1801 ENGG1802 MATH1001 MATH1002 MATH1003 MATH1005 PHYS1001	CIVL2201 CIVL2410 CIVL2611 MATH2061	CIVL4024 CIVL4025	CIVL4815	Level N/A

Project Engineering and Management (Civil)) (2010) - Assessed Course Goals: Engineering & IT Graduate Attribute Matrix (or Equivalents)
Print View
SINGLE Degree

This report will show an attribute matrix for the chosen attribute set. The matrix will only list units which have attributes linked directly to the unit and where attributes are linked to assessed learning outcomes.

	No Level	Level 1	Level 2	Level 3	Level 4	Level 5
1. Design and Problem Solving Skillls		CIVL2110 CIVL2410 CIVL2611 CIVL3812 ENGG1801 ENGG1802 ENGG1803	CIVL3010	CIVL4024 CIVL4025		CIVL4815
2. Discipline Specific Expertise		CIVL2810	CIVL2230 CIVL2410 CIVL2611		CIVL4024 CIVL4025 CIVL4815	
3. Fundamentals of Science and Engineering		CIVL2110 CIVL2810 ENGG1800 ENGG1801 ENGG1802 MATH1001 MATH1002 MATH1003 MATH1005 PHYS1001	CIVL2201 CIVL2410 CIVL2611 MATH2061	CIVL4024 CIVL4025	CIVL4815	Level N/A

Figure 5. Coverage of engineering outcomes in combined (above) verses single degree (below)

The overall result is that the combined degree loses nothing by comparison with the single degree across the engineering learning domains as a whole while having a substantial advantage in the areas of Information Skills, Professional Communication and Professional Values, Judgment and Conduct. How did the combined degree manage to avoid losing any engineering learning outcomes while having fewer engineering units of study? The explanation is that the engineering units that were dropped from the combined degree were engineering electives (36 credit points) that had no consistent learning outcomes as a group. Learning outcomes achieved in these units could not be counted towards the program outcomes of the single degree since they would not across the degree generally, but only in individual instances, depending upon elective choice.

Review of unit learning outcome translation involved critically examining the mappings of unit level commerce outcomes against engineering program descriptors for potential mismatch. The match was readily confirmed for 90 out of 116 outcome descriptions, required investigation in 26 cases and was in need of correction for 14 cases. Where the relationship needed correction, the source of the error was in all cases with the way the unit outcome had been originally recorded against the commerce program outcomes, not the assumed equivalences with the engineering outcomes. The translation itself had operated smoothly. This was an improvement on previous experience where problems with the assumed cross-disciplinary equivalences were found in a small number of cases (Gluga et al., 2010).

There was still progress to be made in unit level descriptions, as indicated by the number of cases that needed correction. The situation was only to be expected when the learning outcomes had been written long before program outcomes existed. Some examples of the inferred links established between program and unit of study level outcome descriptions are provided below.

Engineering program outcome	Commerce unit learning outcome description
Information Skills	
Level 3 - Major review level	"Conduct applied business research to acquire and analyse economic, political, legal, commercial and business knowledge to specific client audit engagements." (24% of assessment based on group project, team assignment, final exam)
Professional Communication	
Level 2 - Technical documentation level	"You should be able to examine problems and present solutions for identification, measurement, recognition and reporting of corporate group activities for external users/decision makers." (12.5% of assessment based on group research task, presentations, final exam)
Professional Values, Judgement and Conduct.	
Level 3 - Professional decision-making level.	"Apply, analyse, and evaluate the two major methods of accounting for business combinations (consolidation accounting and accounting for associate companies), and other accounting standards learnt in this course." (12.5% of assessment based on group research task, presentations, final exam).

Figure 5. Sample learning outcome descriptions from commerce units

Issues regarding the interpretation and drafting of unit level learning outcomes are not unique to combined degree situations. The issues did not make a major difference as far as the contrast between the single and combined degrees were concerned. Once the outcome reporting errors had been corrected, a fresh report on engineering outcomes coverage was generated in order gauge their impact. The overall picture was still one of a program making a substantial contribution to engineering outcomes in information skills, professional communication and professional values and judgement.

Conclusion

The paper demonstrates a method for determining the aggregate engineering outcomes value of engineering combined degree programs on a systematic basis that enables combined degree outcomes standards to be reviewed and evaluated as for single degrees. The method works by addressing the root problem of lack of standardisation in the specification of university program outcomes. The problem is resolved through the creation of a simple common standard for program-level outcome specifications that identifies the key outcome differences, divisions and learning sequences of individual disciplines and organises these key elements in a common grid format. Once the expected learning outcomes of different university disciplines are defined in a consistent and well-differentiated manner, the relationships between outcomes in different disciplines can also be defined in a similarly consistent manner, taking account of the differences in learning difficulty and subject matter. By defining cross-disciplinary outcome mappings as part of the program outcome definitions within each discipline, the units of study that are mapped to the required program outcomes of one discipline can be automatically re-mapped to the required outcomes in other disciplines at the same time. With relationships between units of study program outcomes in other disciplines captured automatically, these relationships can be monitored and reported without additional workload as part of regular curriculum quality assurance.

The cross-disciplinary outcomes reporting method faces some practical difficulties in the need for organisational cooperation in developing new discipline learning outcome definitions and securing access to unit of study outcomes data. The present case shows however that incremental progress in these areas can be achieved one discipline area at a time, without need for a full-scale ‘curriculum revolution’ or expensive, centrally driven projects. It also shows that data access issues can be simplified or eliminated altogether where curriculum data is already managed through an electronic curriculum database, which already happens in some universities. In the longer term, some thought might be needed regarding the large number of combined degrees that exist and the potential burden on curriculum reviewers of having so many new learning outcome summaries to inspect. In the meantime, however, it would be useful progress simply to have one or two sample combined programs under full review as part of normal quality assurance of engineering schools and programs. Such a step should be within existing means, judging by the experience of this paper.

References

Biggs, J. & Tang, C. (2007). *Teaching for Quality Learning at University*. Maidenhead: Open University Press.

Engineers Australia Accreditation Board, (2008). *Accreditation Management System-Education programs at the level of Professional Engineer*. Sydney: Engineers Australia.

Gluga, R., Kay, J., & Lever, T. (2010). Modelling long term learning of generic skills. In V. Aleven, J. Kay, & J. Mostow, (Eds.), *ITS2010, Proceedings of the Tenth International Conference on Intelligent Tutoring Systems* (pp. 85-94). Springer.

Green, W., Hammer, S. & Star, C. (2009). Facing up to the challenge: Why is it so hard to develop graduate attributes?, *Higher Education Research & Development*, 28 (1), 17-29.

King, R. (2008). *Addressing the supply and quality of engineering graduates for the 21st century*. Sydney: Australian Council of Engineering Deans and Carrick Institute for Learning and Teaching in Higher Education.

Moulton, B., Iyer, R.M, Shortis, M., Vuthaluru, H. B. & Xing, K. (2011) *Final Report: Double degrees: research pathways, enabling cross-disciplinarity and enhancing international competitiveness*. Sydney, Australian Learning & Teaching Council.

Russell, A., Dolnicar, S. and Ayoub M. (2008). Double degrees: double the trouble or twice the return? *Higher Education*, 55, 575-591.

Sumsion, J. and Goodfellow, J. (2004). Identifying generic skills through curriculum mapping: a critical evaluation, *Higher Education Research & Development*, 23(3), 329—346.

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