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Enabling Engineering Curriculum Mapping for Course Design and Accreditation

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ABSTRACT

CONTEXT

During accreditation of multiple engineering programs, it can be challenging to audit and report on program details, which, in turn, can impact the defensibility of the program design. Such difficulties are exacerbated by the university's delivery of instruction across international campuses, necessitating a plurality of standards and reporting formats.

PURPOSE

A previous effort, Aligning Learning Outcomes and Assessment, resulted in high resolution data that wasn't as human readable as desired. As such, errors in mapping sometimes went undetected and the impact of gradual study design changes unmeasured. This paper describes the development and implementation of a web-based application designed to improve the visibility, reliability, and validity of curriculum mapping, unit details, and course structure.

APPROACH

Drawing upon extant, open-source software (Accreditool, from the University of Newcastle) a novel software solution was developed to meet unique requirements. Prioritisation of features and functionality was established, first, to serve the needs of the Engineers Australia (EA) accreditation panel, followed by those of teaching staff, faculty governance, and an overseas accreditation panel, Engineering Accreditation Council Malaysia (EAC).

OUTCOMES

Some important benefits have already been realised, including an interactive course-map, system of automatic fault detection, translation and comparison between different educational taxonomies and competency standards, and gaps-to-target analysis and reporting. These serve to guide, expedite, and validate the processes of course design, constructive alignment, and accreditation.

SUMMARY

The current version of the application has enjoyed accolades from the Engineers Australia accreditation panel. Further features are under development to benefit course design, the course amendment procedure, and to allow application outside of the sponsoring institution and faculty.

KEYWORDS

Constructive Alignment, Curriculum Mapping, Software, Accreditation, Digital Transformation

Introduction

Accreditation of engineering programs at a large, research intensive university in Australia is a complicated process requiring significant effort in documentation and communication. Panels have only a modicum of time to familiarise themselves with the specifics of the audited institution, their many degree programs, facilities, etc.

According to the primary accreditor of such programs in Australia, Engineers Australia (2019), Program Learning Outcomes (PLOs) should form the basis of the program design, both from a top-down approach, where said learning outcomes inform the design of the individual units of study, and from bottom up and aggregating approaches, where unit learning outcomes and assessments validate the achievement of PLOs. In an outcomes-based education environment, ensuring constructive alignment of the curriculum is important (Biggs et al., 2022). The structure, which ensures this is occurring, is not easily described or evidenced, and previous efforts by the institution, while thorough, have not been digestible in the short periods of time available.

Monash University's first holistic mapping effort consisted of individual spreadsheets per unit of study and aggregated program level reports produced manually through pivot tables, part of the ALOhA project (Halupka et.al., 2018). This provided primary evidence for the aggregated achievement of program learning outcomes since 2016. However, during audits by both program staff and the accreditation panel, individual unit inquiries were near-manual processes. Aggregated program outcomes were presented as static reports, with the program structure decoupled and referenced through separate course maps. Version control was difficult to implement, and the sign-off process often relied on off-line communication and was not verified using user credentials.

The technological limitations of the first spreadsheet-and-pivot based version created data that lacked integrity. Learning outcome to competency mappings were generally over-reported by unit staff and were often decoupled from assessment. The mapping process was often seen not as educationally constructive, but as an arduous compliance task.

This paper describes the development of a new application initially aimed at expediting the process of familiarising accreditors with the degree program of audit. This tool has also evolved to enable a more transparent unit development process and to gather higher-integrity, error-checked data with a robust sign-off system and version control. Also described are the aims for further development to be an integral part of both a systematic assessment review and the course amendment process. Please note that in this paper, 'Unit' refers to the subject level, and 'Course' refers to the program level.

Purpose

The primary purpose of the software application developed is to expedite and streamline the familiarisation process of accreditors with the degree program under audit. By distilling complex information and program structures into an easily navigable format, it significantly reduces the time and effort necessary for panels to grasp the specifics of the institution and its various degree programs.

Another key objective of this application is to enhance transparency and data integrity in the unit and course development process. By providing a robust sign-off system and version control, the application aims to eliminate the discrepancies and errors that previously plagued the process, leading to over-reported outcomes. With this application, individuals working within the institution can accurately perceive how units fit within the broader program, contributing to a better-informed, holistic design and implementation approach.

Moreover, the application has been designed to address current challenges and serve as a bedrock for future development. An integral goal is to evolve this application to become an essential part of systematic assessment review and the course and unit amendment process. This forward-looking approach aims to ensure the application's continued relevance and utility in the ever-changing landscape of program design, implementation, and accreditation.

The software application aspires to transform the traditionally tedious mapping process into an effective, efficient, and value-adding exercise by serving these purposes. Through this digital transformation, the application intends to support the university in meeting its accreditation requirements, ensuring a high standard of engineering education, and ultimately benefiting all stakeholders involved.

Approach

Program visualisation

An interactive course map is the foundation of the effort to expedite familiarisation for accreditors (see Figure 1). Based on legacy formatting of a semester-by-row grid, the tiles of this website allow visual distinction between elective and core units, these core units forming the basis of the program accreditation.

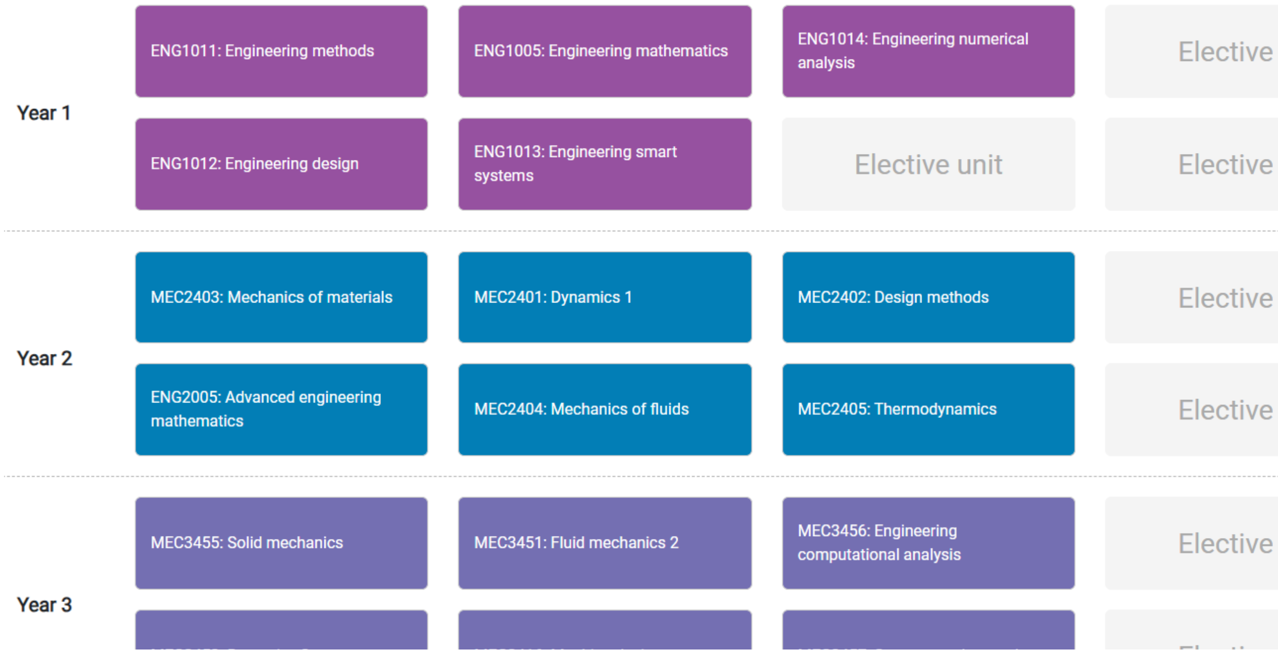

Figure 1: Course map view

The map implies a semester-by-semester progression, but it is well understood that students often diverge from this plan for various reasons, including unit failures. In the past, efforts have been made to visualise the unit requisite structure (Huang, 2019) implied by pre-requisite requirements of given units; this often comes in the form of human-generated diagrams or dedicated dynamic flow diagrams that are unable to conform to the course map grid. These types of applications serve a student well in understanding a pathway of study, e.g., to a desired elective or minor stream. However, they are more limited in showing unit administration information such as semester of offering, served better by a course grid visualisation. In this implementation, however, mouse-over (or hover) functionality highlights prerequisites and successor units (sometimes called 'post-requisites'); see Figure 2. Prerequisites of immediate prerequisites ad infinitum are displayed so that the progression of necessary studies can be shown from a final-year unit all the way to any required first-year studies.

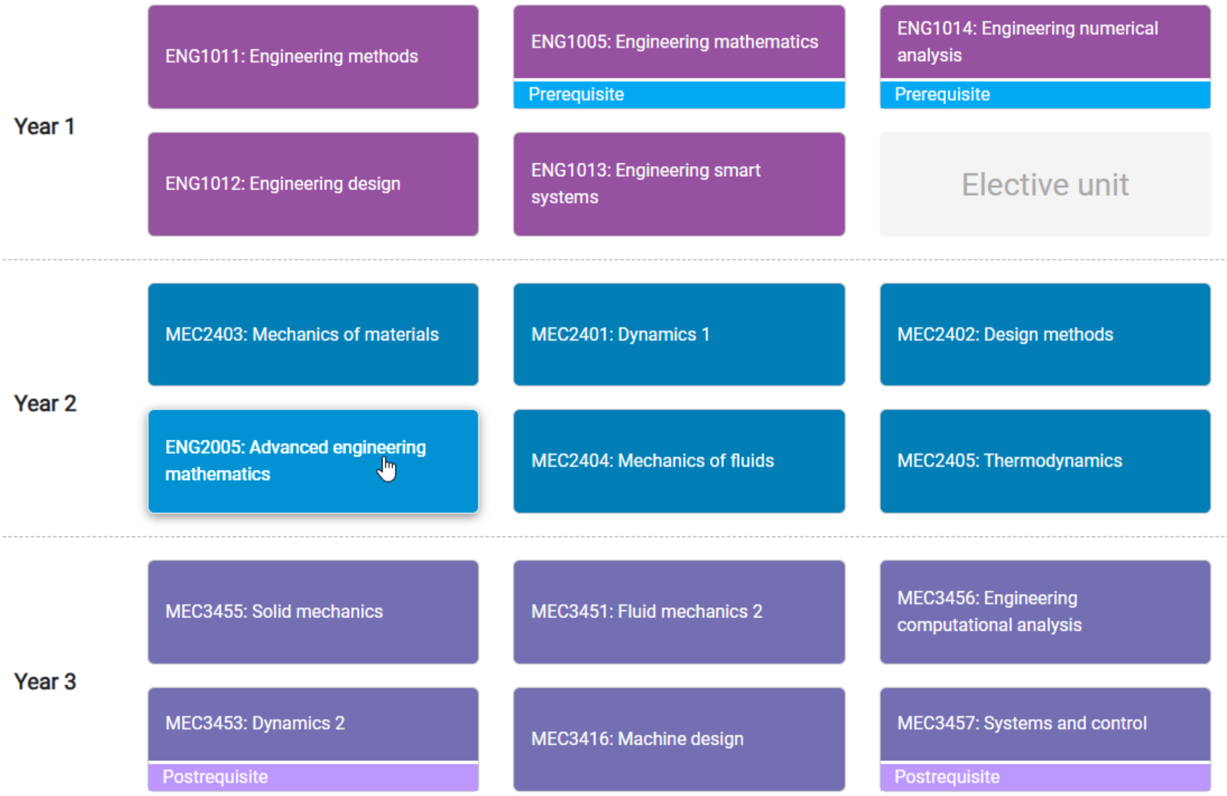

Figure 2: Hover functionality (pre/post-requisite visualisation)

In our application, to further visualise the program design, themes of study can be selected to allow the user to focus simply on the units which contribute to it. Sometimes referred to as 'spines', these 12 themes include 'design', 'project management', and 'professional practice'. When selected, all units within the theme remain coloured, while others are converted to grey and their mouse-over and click functionalities are disabled (see Figure 3). This allows auditors to quickly simplify the course-map to the desired theme and see which units, how frequently, contribute to it.

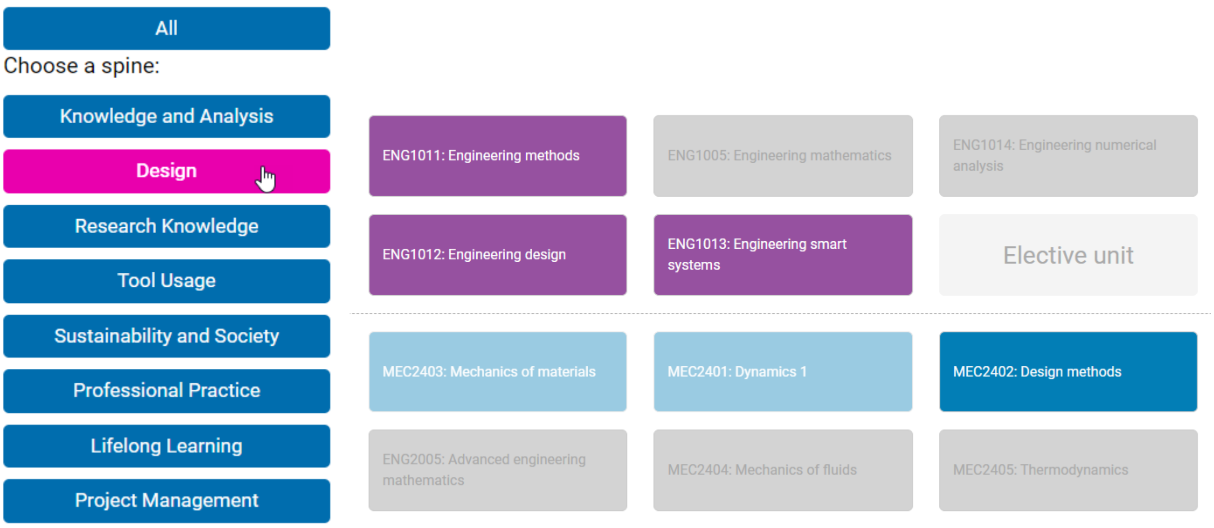

Figure 3: Theme visualisation

Assignment of themes is currently generated by two means; course (program) directors manually nominate units in a given theme, and an algorithm is used to detect which units have appropriate levels of assessment weighting assigned to combinations of specific program learning outcomes.

The latter, algorithmic, method is visually distinct (using transparency), allowing simple visualisation of these units peripheral to the theme. This also allows detection of units that may have misdirected assessments; e.g., some units may be heavily assessing design skills while not nominated as design-focused, and they will be seen as transparent when 'design' is selected.

When a unit tile is clicked, its synopsis, study requirements, and simplified competency mapping are provided in a pop-up window. These are the primary points of interest for auditors and this functionality, not requiring navigation away from the program map page, will generally address most needs during the exploratory phase. A link to the unit details page is also available within the pop-up so that users can access more detailed mapping, and information such as sample assessments, instructor CVs, and the learning management system page.

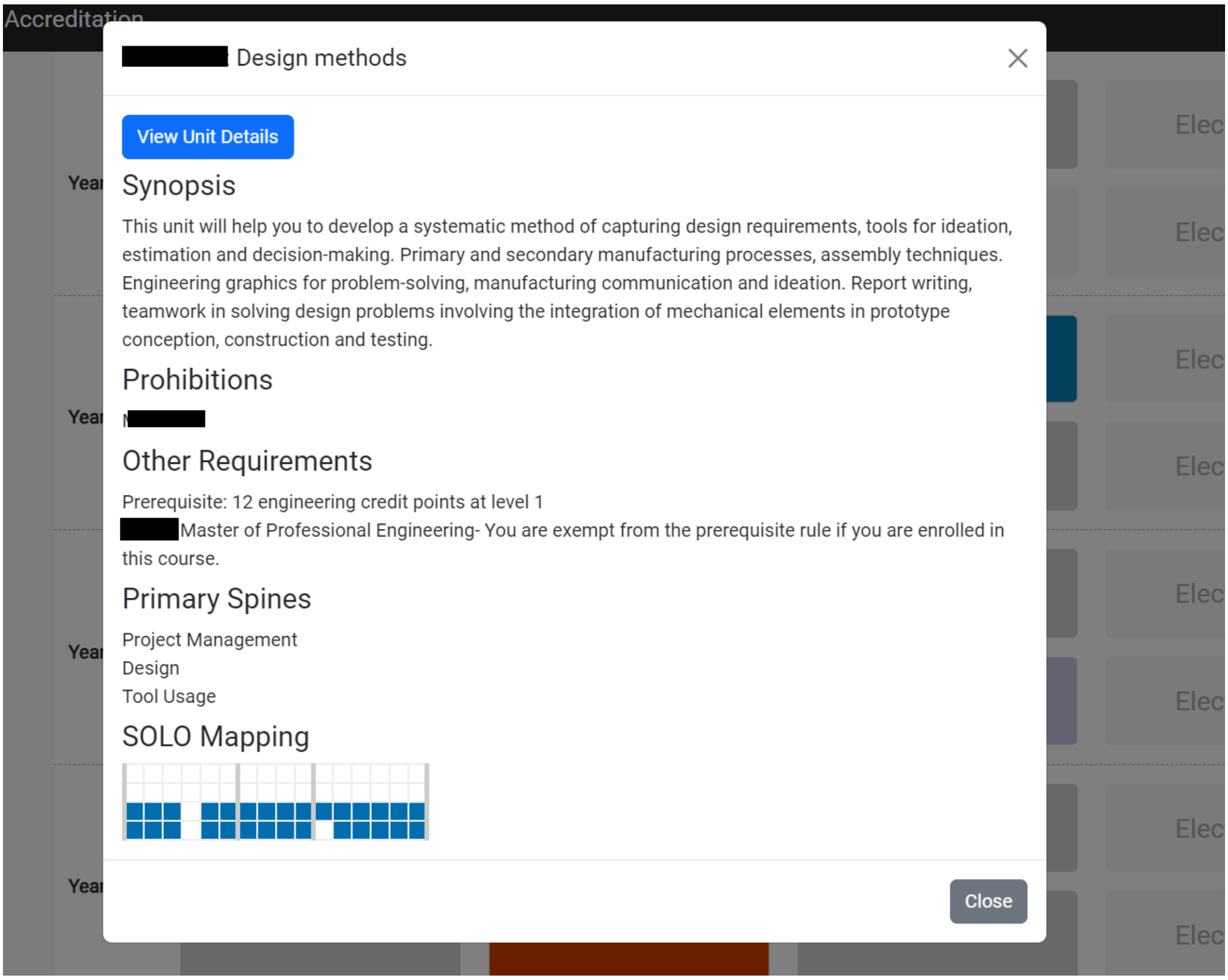

Figure 4: Pop-up unit information

Error Detection and Prevention

Assuring competency attainment throughout a program of study rests on the core premise that multiple methods assess each Program Learning Outcome (PLO) multiple times and at varied levels. Level can refer to Bloom's Taxonomy of Learning level, Structure of Observed Learning Outcomes (SOLO) level, or another similar taxonomy. Ergo, unit learning outcomes are composed with verbs that have institutionally approved levels; an example is that true "design" should be a top-level action by students and is conducted in the latter years of study and only after progressing through lower level activities. Despite this expectation, even first-year units which involve aspects of design are often said to assess design skills.

Documenting mapping of assessments to learning outcomes allows for a layer of validation associated with the level at which students will document their competency. Relating the SOLO or blooms level directly to the outcome language and cross-referencing against the year level of the unit of study allows automated detection of learning outcome misrepresentation and overambitious leveling in real time. This reduces the need for human intervention and improves efficiency.

Overmapping

Another area for improvement with previous versions of learning outcome mapping was the tendency of academic staff to identify all possible competencies which students may demonstrate or draw upon in a given unit. This has, in some instances, led to units mapping more than 60 (of a possible 69) indicators of attainment (as outlined by Engineers Australia in the Stage 1 Competency Standard) (Engineers Australia 2019). Part of the source of this problem was a lack of clarity in the mapping process, so a fundamental shift has been incorporated in the newly implemented application.

At the beginning of the mapping process, staff are asked which of the PLOs are taught, which are practised (having been taught in previous units), and which are explicitly assessed. This step of data collection then restricts the response space as further details are collected. Instead of allowing all indicators of attainment to be mapped to learning outcomes, a question of which indicators of attainment (correlating to student action) are demonstrated in each assessment is asked. Then the (SOLO or Bloom's) level is mapped by associating assessments with their learning outcomes. While adding steps to the process, the overall number of mouse clicks is reduced even for a given volume of mappings, and the process is aimed at reducing this volume to the core intentions of a given unit.

Versioning and Approval

Previous systems of competency mapping used a single spreadsheet per unit to simplify the process of semesterly repeated documentation. While cloud-based spreadsheets do have an edit history, semester breakpoints are not readily visible, and the approval of the documentation process was not clearly recorded. The newly implemented application provides a data structure that records each instance (delivery) of a unit and its approval status.

While many of the benefits of version control and approval records will be immediately apparent to many, the long-term aims of program review warrant mention. Specifically, the non-immediate nature of benefits from unit restructuring means that educators require clear documentation, over several years, of the incremental and substantial changes made to unit design. Compound this with the mandated reviews associated with low Student Evaluation of Teaching and Units (SETU) scores or high-failure rates, and a “paper trail” to track the various changes becomes critical to implementing departmental, faculty, and institutional aims.

Intra-organisational Cross-checking

International campuses with co-delivered units and undifferentiated deliveries mean multiple accreditation standards and a requirement to demonstrate equivalence between them. While Engineers Australia accredits both the Australian and offshore programs, the offshore program is also accredited by a separate body, also under the Washington Accord, in addition to a national tertiary accreditation body. Offshore coordinating staff create documentation primarily for the offshore accreditor, which necessitates a complex system of comparison tables to translate mappings from one standard the other. This translation is too complex to be done by individual teaching teams, so the application is built with this in mind and appropriate guidance embedded.

Original mapping efforts mapped both campuses in isolation against their relevant standards, and the initial version of the application incorporated a summary of the degree of alignment between these two mappings (Australian and offshore). Given that these mappings were conducted without clear visibility of the translation, disparities were common at this stage, but this allowed the identification of the size of the problem. In the current application implementation, disparities are identified in real-time and documented for authors and approvers. While teaching staff and their supervisors ultimately have the freedom to approve mappings that differ when translated, the current system clearly outlines matches and mismatches, enabling a discussion about the real engineering competencies gained from a particular unit of study. For an example of this comparison, see figure 5.

Description	Clayton	Malaysia
Certification Stage	CE CERTIFIED	CE CERTIFIED
Offering Period	S2-01, 2023	S2-01, 2023
Assessed Themes	**Clayton**	**Malaysia**
Engineering Knowledge	✓	✓
Problem Analysis	✓	✓
Design/Development of solutions	✓	✓
Investigation		
Modern tool usage	✓	✓
Engineer and society		
Environment and sustainability		
Ethics		
⚠ Mismatch in Mapping Communication	✓	
Individual and team work	✓	✓
Lifelong learning		
Project management and finance		

Figure 5: Cross-campus comparison

Technological Solution

The software application uses a three-tier architecture (IBM, 2023) with the following tiers:

- Presentation Tier: Responsible for dealing with user interaction and display of the data. The main languages used in this tier were HTML, CSS, JavaScript and ASP.NET Core.
- Logic Tier: Using APIs to control database interactions as well as authorisation to sections of the database based on a per user basis. This tier uses ASP.NET Core at its core.
- Data Tier: A MYSQL database server houses all the data for CourseLode.

A primary benefit of this architecture is modularity; common resources and data can be shared between multiple applications, allowing further development and diversification of services. Another is security; passing of data between tiers allows further validation at each pass.

The software application communicates with the institution’s Single Sign On system to authenticate different users. This enables assignment of roles and responsibilities for specific units and the implementation of a more formal and transparent approval structure.

Having the application stand alone without the need to interact with any existing cloud-based data provides autonomy of visualisations, and renders it the single point of access to all stored records.

Outcomes

A previously suspected high degree of mismatch between Australian and offshore mappings has been confirmed and made visible as a result of this application. The process of aligning the two campuses has now begun and is facilitated and documented through the application. Reporting is available to course directors and other executive staff, but the degree of misalignment is also provided immediately to those generating and approving the documentation. While details are new at the time of writing, the available information is expected to encourage discussion and subsequent improvement by teaching staff.

Overmapping has been improved in the initial implementation. Following an initial data collection, a 43% reduction in mapping, measured by the total volume of mapped indicators of attainment per unit learning outcome, was achieved. This is achieved by a combination of error and warning detection (approximately one third of the reduction) and, more significantly, philosophical changes associated with identifying practised vs assessed skills and the associated narrowing of the selection space.

This achievement is in keeping with the overall project aims, which include simplifying and focusing mapping to a state where individual units report only their most crucial and certainly attained competencies, with peripheral achievements left out of primary reporting structures.

Future Development

The most immediate development requirement at the time of writing is the advancement of the application as an integral step in the unit amendment proposal process. Many unit amendments, small and large, are made on a regular basis, including changes to competency mapping. These changes are adjudicated and approved (or denied) by a committee of academic staff based on, generally, a report and defence by the coordinating academic staff member. Gradual migration of the program via these incremental changes is not measured relative to the accreditation or competency attainment framework.

To address this shortfall, the application will be modified to include a ‘prototype’ or ‘proposed’ program function. When proposing a unit amendment (or group of unit amendments, as is commonly done), the coordinating academic will create a new program based on the existing program within which their unit sits. Proposed mappings are documented and a new report will be created to show the changes between the existing program and the proposed.

The described report will allow judgement of unit changes against whole-of-program goals and, if and when approved, expedite the mapping documentation process. This approach leverages the version control function, allowing the coordinating staff member to propose changes for any future unit delivery.

Another key future development is the integration of program targets, to be generated by program directors, and reporting against these specific targets. This will include specification of theme (spine) structures, sequencing and timing of specific competency assessment, targeting assessment type and weighting by program semester, focusing on teamwork activities, and others. The aim is to, over time, provide the framework for complete, top-down target setting and continual reporting against the provided targets. For example, the previously described unit amendment reporting could include not just a comparison of competency mapping from the previous year, but also with reference to all targets.

Summary

Significant improvements have been achieved through the implementation of the new course mapping and visualisation tool, including:

- Improved validity and reliability of mapping data through cross validation of input for multiple accreditation schemes
- Reduction of overmapped competencies, by limiting aggregation of data to assessed competencies only

- Improved usability for academic staff, course directors and accrediting panels
- More robust version control, including the future ability to propose new course versions

This success has been affirmed both by internal testing with academic staff and the commendation received from Engineers Australia's accreditation panel during the accreditation of the institution's engineering degree in 2023.

Developments continue with the aim of improving the unit amendment process, as do refinements to the processes previously established.

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