Dynamic Modelling, Validating and Fine-tuning of Engineering Curriculum

Fazel Naghdy

School of Electrical, Computer and Telecommunications Engineering, University of Wollongong, Australia

fazel@uow.edu.au

Abstract: *The undergraduate Engineering schools in Australia are required to embed and assess the Competency Standards defined by the Engineers Australia in their curriculum. At the same time, embedding graduate attributes in the curriculum has become an important element in the quality assurance processes of universities. The embedding and mapping are only the first step in a long term process. The mapping should be validated empirically and reviewed in a repeating cycle towards an effective and optimal curriculum. This will require a rigorous action learning process for creating and cyclic validation of a living curriculum. The conceptual development and early stages of work on building a computer-based tool for dynamic modelling, validating and fine-tuning of engineering curriculum is reported. The developed system represents an integrated environment through which the mapping of graduate attributes as well as quality assurance and auditing associated with the curriculum can be carried out holistically and interactively.*

Introduction

The undergraduate Engineering schools in Australia are required to embed and assess the Stage 1 Generic Competency Standards defined by the Engineers Australia (Engineers Australia Accreditation Board) in their curriculum. At the same time, embedding graduate attributes in the curriculum has become an important element in the quality assurance processes of universities since the introduction of the concept to the higher education sector by the West Review (DETYA, 1998) in 1998. Though, a number of universities have been identifying and developing graduate attributes since the early 1990's.

The graduate attributes are "the qualities, skills and understandings that a university community expects its students to develop during their time at the institution and consequently, shape the contribution they are able to make to their profession and as a citizen" (Australian Technology Network, 2000).

In this background, embedding and mapping of the graduate attributes and Generic Competency Standards in the Engineering Curriculum have become a priority in engineering schools. This was specifically addressed in a project called "Engineering graduate capabilities continuum: a continuum of learning outcomes", carried out in the Faculty of Engineering, University of Wollongong (UOW) (Nightingale, 2008). In this project, the curricula of different majors have been mapped simultaneously on Generic Competency Standards, University of Wollongong Graduate Attributes and engineering graduates defined by the Faculty.

In order to comply with the requirements of Engineers Australia and the university, the graduate attributes were mapped Dynto the Materials Engineering curriculum at University of Queensland (Bath, et al, 2004). The contribution of each subject to the university graduate attributes was determined according to four different competency levels. Similar activities can be observed in other universities.

The mapping of the curriculum is only the first step in a long term process. The mapping should be validated by measuring the degree of its realisation in students, reviewing the mapping in light of the outcomes, and repeating the cycle towards converging to an effective and optimal curriculum empirically validated to produce the expected graduate attributes. As highlighted by Bath et. al., this will require a rigorous action learning process to maintain a validated and living curriculum.

This paper reports of the conceptual development and early stages of work on a computer-based tool for dynamic modelling, validating and fine-tuning of engineering curriculum based on graduate attributes. The system is an integrated environment through which the mapping of graduate attributes as well as quality assurance and auditing associated with the curriculum can be carried out holistically and interactively.

The structure of the paper is organised as follows. After the introduction, the approach deployed to build the curriculum model is explained. The subject parameters are defined and the method of populating the curriculum-model database is described. In the next section, different stages of action learning process envisioned for fine tuning of the curriculum using the curriculum model will be explained. It will be shown that the developed tools can be used to assist other activities associated with curriculum quality assurance such as automatic generation of subject outlines. The paper is concluded by highlighting the progress made and drawing some conclusions.

Modeling of Curriculum

In this study, the curriculum for Bachelor of Engineering in Electrical, Computer and Telecommunications Engineering is deployed as a vehicle to pilot and validate the developed system.

In a bottom-up approach, the curriculum is modeled by mapping the parameters of every subject taught in the curriculum on to the engineering graduate competencies defined in (Nightingale, 2008) as shown in Figure 1. These attributes are mapped on both the University of Wollongong graduate attributes (Column 1) and the the Stage 1 Generic Competency Standards defined by the Engineers Australia (Column 3). The UOW engineering graduate competencies are shown in column 2.

The parameters of a subject are illustrated in Figure 2 and are defined as:
- **Learning objectives**: For every subject, the learning objectives are what a student will learn, understand, or will be able to do as the result of completing the subject.
- **Activities:** The content of the subjects are delivered and mastered through various teaching and learning activities such as lecture, tutorials, practical, e-learning forums, etc.
- **Assessment:** The methods through which the competency of a student in learning objectives is evaluated.
- **Resources:** The various resources required for the delivery of the subject and conducting its activities.
- **Competency Level:** The degree of competency associated with every learning objective that student can achieve by completing the subject. This is defined based on Bloom taxonomy (Bloom, 1956) which identifies six hierarchical levels of learning that can be achieved during a cognitive process; knowledge, comprehension, application, analysis, synthesis, and evaluation (Figure 3). At knowledge level, student recalls or reconigses information, ideas and principles that have been learned. In comprehension, student translates, comprehends, or interprets information based on prior learning. During application, student selects, transfers, and uses data and principles to complete a problem or task. In analysis, student distinguishes, classifies, and relates the assumptions, hypotheses, evidence, or structure of a statement or question. Synthesis represents creation of new ideas, products or plans by integrating and combining ideas. Evaluation is the highest level competency in which student appraises, assesses, or critiques on a basis of specific standards and criteria.

The subject parameters are stored in a SQL database. The database is populated partly from the Subject Database which is updated every session as part of the subject maintenance across the university. The parameters which depend on the delivery of the subject by a particular academic such as assessment are populated manually by the subject coordinator every session.

Action Learning Process

The developed curriculum model will be the core element in an action learning process which is illustrated in Figure 4. The students' competencies will be measured through assessment procedures and also customized developed surveys. This information combined with the cyclic review of the curriculum and subjects highlight the changes that should be made to the curriculum model. This process will proceed through regular cycles.
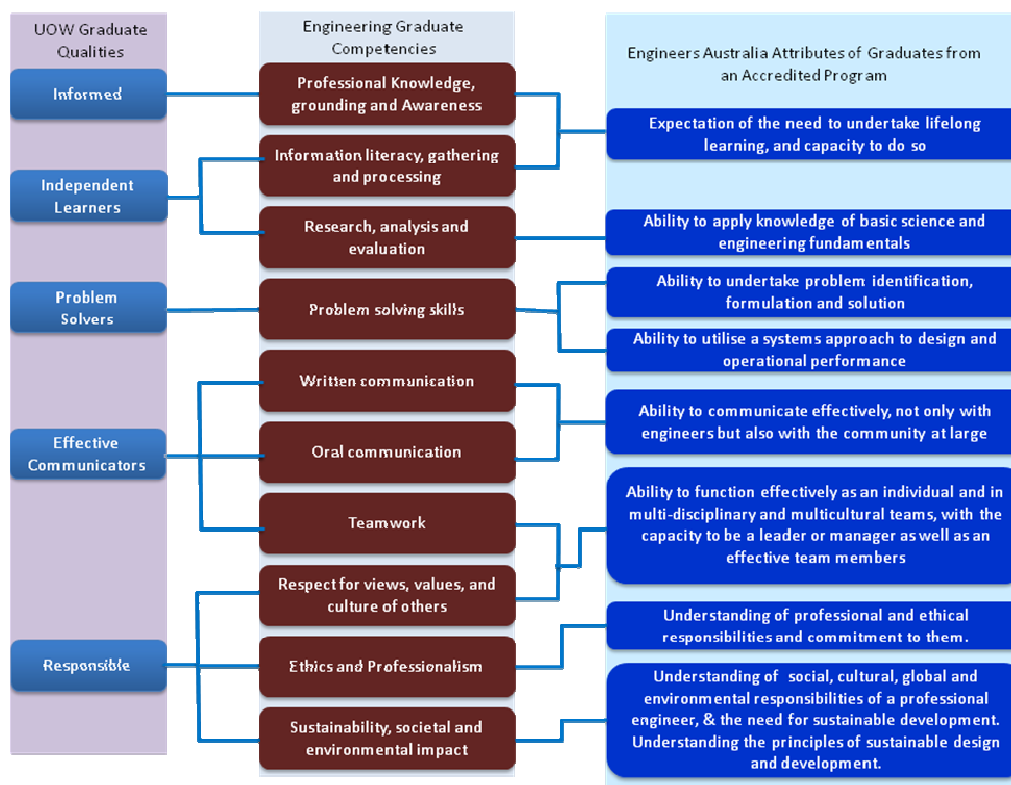

Figure 1 - Mapping between UOW Graduates Qualities, UOW Engineering Graduate Competencies and Engineers Australia Core Competencies (Nightingale, 2008)
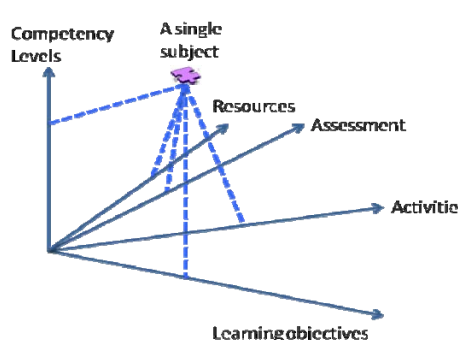

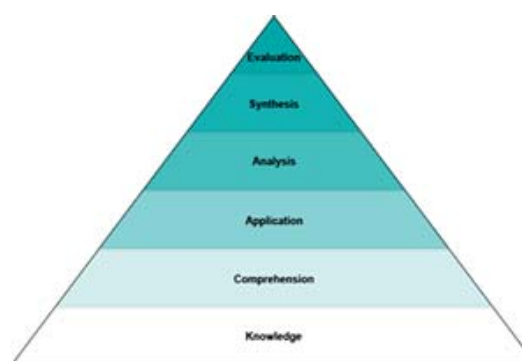**Figure 2 – The parameters of a subject**

Figure 3 – Bloom Taxonomy (Bloom, 1956)

Since the major part of the database driving the model is populated through the subject database, the curriculum model will not drift from the formal definition of subjects as appears in the on line resources and Calendar of the university. Different stages of the action learning process will be embedded in the agenda of the School Education Committee and will be integrated with the quality assurance measures associated with subjects and the degree.

In the next stage of the project, the relationship between the responses received from the subject and course surveys and curriculum parameters will be formalized and built into the system. This will require a better understanding of the implemented model and how it realizes the engineering competencies in the graduating students.

The curriculum model will be also a powerful tool for on demand and dynamic generation of various print and electronic documents associated with the curriculum and its quality assurance such as:

- Dynamic reporting on the overall structure of the curriculum
- Automatic and dynamic generation of subject outlines for print and on-line publication
- Dynamic reporting on the subjects contributing to a particular competency and the level of their contribution
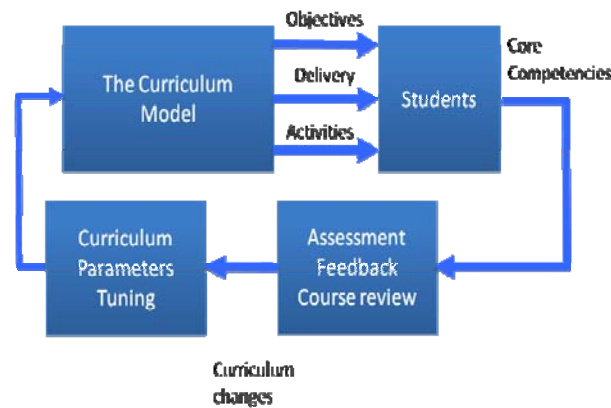- Dynamic reporting of the resources required to deliver the curriculum or a particular subject

Figure 4- The action learning process for fine tuning of the curriculum

Progress so far

In the first stage of the project, a suitable computing platform is designed to implement the curriculum model and other associated modules. The MySQL open source database (http://dev.mysql.com/) is selected as the database driving the modules written in PHP scripting language (http://php.net/index.php) and executed within Drupal (http://drupal.org/) content management platform.

Through careful analysis of the project requirements and its future development, the structure of the database supporting the curriculum is designed. In addition to subject parameters, the database keeps an up to date record of subject coordinators in each session. The delivery of each subject as well as its highlights and shortcomings are reviewed by every subject coordinator at the end of each session through a special questionnaire. This information is also integrated into the database as they will be important in the review of the curriculum.

In addition, the system is designed to provide the necessary workflow for approval of subject outlines in every session by the subject assessor and the Head of School.

The work of populating the database with details of different subjects is in progress.

Conclusion

The conceptual development and early stages of work on a computer-based tool for dynamic modelling, validating and fine-tuning of the engineering curriculum based on a set of engineering competencies derived from Engineers Australia Stage 1 Generic Competency Standards was reported. The developed system represents an integrated environment through which the mapping of graduate attributes as well as quality assurance and auditing associated with the curriculum can be carried out holistically and interactively.

The conceptual design and development of the system is complete. The database supporting the curriculum model is designed and the task of populating the database is in progress.

The developed curriculum model will be the core element in an action learning process for sustained cyclic review and fine tuning of the curriculum.

References

Bloom, B.S. (Ed.) (1956). "Taxonomy of educational objectives: The classification of educational goals," *Handbook 1, Cognitive Domain*, New York; Toronto, Longmans, Green.

Nightingale, S. (2008), *Mapping Learning and Assessment of UOW Graduate Capabilities in Engineering and Physics*, final report on 2007 ESDF Grant, internal document.

Engineers Australia Accreditation Board, Accreditation Management System- Education programs at the level of Professional Engineer, cited at http://www.engineersaustralia.org.au/shadomx/apps/fms/fmsdownload.cfm?file_uuid=5EDFBDF5-B8D8-FB15-66DA-23E7F8E58C58&siteName=ieaust

DETYA (1998). *Learning for Life: Review of higher education financing and policy*, Higher Education Financing and Policy Reviewing Committee, known as the West Review, Department of Education, Science, Training and Youth Affairs, Canberra.

Australian Technology Network (2000). *Generic Capabilities of ATN University Graduates*, cited at http://www.clt.uts.edu.au/ATN.grad.cap.project.index.html.

Bath, D., Smith, C., Steain, S., and Swann, R. (2004). "Beyond mapping and embedding graduate attributes: bring together quality assurance and action learning to create a validated and living curriculum", *Higher Education Research and Development*, 23:3, 313-328.

Copyright statement