Using CDIO to Meet Accreditation Expectations at The University of Sydney

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ABSTRACT

This paper discusses our experience in the School of Electrical and Information Engineering (EIE) at the University of Sydney in successfully using the CDIO framework to help meet Accreditation expectations in preparation for our 2009 accreditation visit. We review the generic graduate attributes and the competency standards of the Australian accreditation body, Engineers Australia (EA), and discuss how we mapped them to the CDIO framework. We analyse the recommendations from the 2004 accreditation visit and compare the 2004 and 2009 visit outcomes, with the 2009 visit report noting that the adoption of CDIO had resulted in a more holistic approach to our program educational design and better quality control over them.

KEYWORDS

Program design, accreditation, quality control, CDIO standards.

INTRODUCTION

This paper addresses a key issue of direct concern to the CDIO constituency, namely the relationship between CDIO and accreditation, and discusses our experience in the School of Electrical and Information Engineering (EIE) at the University of Sydney (USyd) in successfully using the CDIO framework to help meet Australian Accreditation expectations in preparation for our 2009 accreditation visit.

The previous accreditation visit in 2004 raised particular issues regarding the teaching of design, project management, business and management, broad context problem solving, systematic re-enforcement of generic capabilities throughout the curriculum and quality control of the programs. The 2004 visit team strongly advocated that the School take a more holistic approach to educational design.

Over the five years between the 2004 and 2009 accreditation visits, the School of EIE adopted the CDIO framework as the context for its education. The programs were extensively revised using the CDIO standards and syllabus as guides. A careful mapping was carried out between the CDIO standards and syllabus, the EA generic graduate attributes and competency standards and the University of Sydney’s graduate attributes. This mapping provided a foundation for the submission for the 2009 visit. This paper discusses in detail how the issues raised during the 2004 visit were dealt with.

The outcomes of the 2009 visit were far more satisfactory than the 2004 visit, with plaudits from the visit team for the way in which the School had adopted CDIO and used it to renovate its programs.

IDENTIFYING THE NEED

Before adopting CDIO as the context within which the School of EIE would renovate its curricula, we had to clearly identify the need to do so along with the expected benefits, in order to motivate the senior management (the Dean) as well as the academic staff of the School that the undertaking was worthwhile.

In 2004, the School offered a set of five programs, namely Computer, Electrical, Power, Software and Telecommunications Engineering. All are standard four-year engineering programs, share common core subjects, and all could be combined with Commerce, Science, Arts, Medical Science or Law programs, which would earn the student two degrees in 5 years (6 for Law). This resulted in a flexible set of programs, with over 30 electives, offering students a wide choice and the ability to shape their programs to their personal taste.

The goals of the programs were to produce graduates that are equipped with the generic skills we expect of all our graduates, and to provide

- Fundamentals of sciences, technologies and engineering.
- Fundamentals of technical area plus some specialisation
- Opportunities to specialise or generalise through a wide choice of electives
- Complete a major thesis project

At Sydney, in common with many Universities, student surveys of the programs are carried out every semester, both for individual courses (Unit of Study Evaluation, or USE) and surveys of recent graduates to assess their overall satisfaction with the programs (Course Experience Questionnaire (CEQ), since 2010 incorporated into the Australian Graduate Survey (AGS)). Unfortunately, in 2004, our survey scores were falling. Analysis of the freeform comments in surveys found that the problems were

- Conventional curriculum
- Lots of Maths, Physics, programming, but little engineering in first 2 years
- Little overview of the disciplines
- Little experience of what it “means to be an Engineer”
- Not enough design or project work
- Little experience of industry or of manufacturing process
- Unexciting and uninspiring, not attractive

Essentially, we were losing the interest and excitement of the students in the first two years of the programs.

2004 ACCREDITATION VISIT

The 2004 Accreditation visit to our School helped us to crystallise our views of the need to renovate our programs. The visit team report identified the need for

- An holistic approach to curriculum design
- An improved program quality system
- Imparting the full range of generic attributes to our students
- Creating a “forward looking approach” to teaching
- Developing better, more consistent approaches to team project work
- Renovating our laboratories to better support team project work.
- Developing better assessment practices

- A stronger approach to design
- Introducing a first year introduction to engineering unit

In order to respond effectively to these requirements, a search was undertaken to evaluate learning and teaching frameworks in engineering which led to CDIO, which appeared to offer all of the above in a framework of international best practice in engineering education. Prof E Crawley was then invited to visit the School and present a case for the merits of adopting CDIO, which the School then did in 2006.

PREPARING FOR ACCREDITATION

In preparing to use the CDIO framework for the 2009 Accreditation Visit, we identified the need to:

- Map CDIO attributes, USyd GAs to EA GAs
- Map USyd unit and program outcomes to CDIO syllabus and EA Competencies
- Show consistent, holistic program design
- Show a high level of involvement with Industry
- Show first rate design and team project work
- Show effective quality control
- Develop strong involvement and enthusiasm of staff and students

The Accreditation Body for Engineering in Australia is Engineers Australia (EA) visits each accredited institution every five years. At the time of the 2009 visit, EA's published criteria for accreditation were the National Generic Competency Standards (NGCS) [1]. Accredited bodies were expected to show that they met these standards. The standards feature three main domains of competency, namely;

- Knowledge Base, which relates to all the fundamental and technical knowledge;
- Engineering Ability, which addresses problem solving techniques, responsibilities of engineers, project design issues and business principles; and
- Professional Attitudes, which includes elements of effective communication, team work, ethical responsibilities and other professional attitudes.

Each domain articulates to several sub-domains and these are similar in content and meaning to the CDIO syllabus, but there are also instances where the two differ.

Most Universities also have their own graduate attributes (GAs) as does the University of Sydney. While for accreditation EA's NGCS was critical, for our program design we wished to show correspondence between the CDIO syllabus, USyd's GAs and the NGCS. To achieve this, a complete mapping was carried out and is shown in summary form in Appendix A. Further details can be found in [3]. Each teaching module (Unit of Study (UoS) in USyd's parlance) was checked against this map and a fully detailed evaluation of the curriculum was carried out so that we could be sure that requirements of the NGCS were satisfied. The objective was to show convincingly to the visit team that the School graduates engineers who are skilled in their chosen area of technology while having a high level of personal and interpersonal skills, are capable of working effectively individually and in teams to conceive, design and implement modern engineering artefacts and systems.

The use of the CDIO reference syllabus also provides benchmarking against other Universities internationally allowing us to show that our programs meet the targeted graduate capabilities and in particular, address the projected levels of technical competence, enabling knowledge and skills, engineering application skills as well as personal and professional skills that EA requires we instil in our graduates. In EIE, we achieve these outcomes by applying the engineering problem solving paradigm, by first developing a sound understanding of the fundamental skills needed by contemporary engineer in order to be able to develop complex artefacts and systems. This is accompanied by a focus on the personal and professional skills central to engineering practice. We follow this by honing those skills in the 3rd and 4th year through industry-relevant team projects, carried out in the context of the specialist units of study and culminating with the capstone thesis project. Throughout, our curricula seek to endow our students with a mastery of the fundamentals of the appropriate technical knowledge and reasoning by continuously strengthening their knowledge in the context of their team project work. In order to work effectively in teams, students must develop the interpersonal skills of teamwork and communications. Finally, the curricula, by emphasizing team-based projects, give the students confidence in their ability to create products and systems. At all times the relevance to industry practice is emphasized, through industry involvement in projects and use of external lecturers and supervisors. Further detail on recent work regarding the teaching Engineering Design in Australia, carried out for the Australian Learning and Teaching Council and which recognises the impact of CDIO may be found in [5].

Our laboratories were extensively renovated, using the CDIO standards and experience from MIT, Linköping and Liverpool as guides, with thanks for their assistance. The Laboratories were refocused on Active Learning, supporting a variety of learning modes through flexible spaces to enhance interactive and group learning. The new integrated learning spaces were the first of their kind in the University. The Power Engineering laboratory in particular enables students to work on standard industrial equipment as opposed to computer simulations, thereby closing the gap between theory and real world practice, providing a combination of a professional engineering environment and curriculum, integrating advanced methods of teaching and learning activities that resemble professional industrial practices and involves considerable input from industry at every step. The lab was developed by Prof V Agilides [2] and follows a similar design implemented by him at Murdoch University. We are very fortunate at the University of Sydney to have many industrial partners supporting this vision. Selected labs are open for extended hours during the semester to allow students to work on their projects at hours convenient to themselves.

The revised programs and mappings were presented to Engineers Australia in the submission for the 2009 visit.

OUTCOMES OF THE 2009 VISIT

The visit panel reported that it was “pleased to note the many actions that had been initiated in response to the recommendations of the 2004 panel” and further noted the School’s improved quality management system, the redevelopment of laboratories to provide a more collaborative, project based learning experience and that “the CDIO initiative will drive a strong project based learning focus and maintain an emphasis on tracking engineering design capability development”. The board further noted that “generic capabilities development is a mandated component of the CDIO standard and this will provide the framework for a more systematic approach” and that the new first year ‘Professional Engineering and IT’ unit provides a “foundation awareness and commitment to aspects of sustainability and professional ethics, and also builds a foundation understanding of professional engineering practice”.

The panel noted with approval that the detailed mapping table demonstrates how the graduate attributes map to the Engineers Australia Generic Attributes and to the NGCS and further noted that the adoption of the CDIO framework and the School’s involvement as a collaborating institution within the CDIO Consortium significantly influenced improvements in the quality of the School’s teaching programs. The panel commended the School’s engagement with the CDIO Consortium as “worthy of consideration from a Faculty wide perspective”.

CONCLUSIONS

The School of EIE's adoption of CDIO has led to the strengthening of the School's programs and improvements in the assessment of the School at the most recent accreditation visit. Considerable effort was required to map the requirements of the accreditation body, the CDIO syllabus and the School's programs. This was undertaken as part of the program revision, and proved valuable in presenting the School's position in a coherent and holistic way to the Accreditation Panel.

It is also worth noting that the increasing takeup of CDIO in Australia, with 12 Universities now using CDIO to some degree, has had an influence on the Accreditation body. A recent review of engineering education in Australia by King [4], undertaken on behalf of the Australian Council of Engineering Deans, along with the experience gleaned from many accreditation visits, has led Engineers Australia to revise the NGCS [6]. The CDIO standards are currently also being updated. As a result of these dynamics, we will soon revise our mappings in order to stay current and be up to date at the next accreditation visit in 2014.

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Biographical Information

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Appendix A: Graduate Attribute and Engineers Australia Competency Standards Mappings

Graduate Attributes Comparison				Competency Standards Comparison		
USYD graduate attributes	ENG-IT graduate attributes (Aug 08)	EA graduate attributes (generic)	EA program structure elements	EA Stage 1 Competency Standards – Level 2	CDIO Standards - Level 2	CDIO Standards – Level 1
Personal & Intellectual Autonomy	Discipline Expertise	⇒ In-depth technical competence in at least one engineering discipline.	Engineering discipline specialisation	PE1.2 In-depth technical competence in at least one engineering discipline PE1.3 Techniques and resources	1.2 Core engineering fundamental knowledge. // PE 1.2 – R 3 1.3 Advanced engineering fundamental knowledge. // Unique PE 1.2 2.1 Engineering reasoning and problem solving. // PE 1.3 2.2 Experimentation and knowledge discovery. // PE 1.3 – R 5 2.5 Professional skills and attitudes. // PE 1.2 4.3 Conceiving and engineering systems. // PE 1.3	1 – TECHNICAL KNOWLEDGE AND REASONING. // R 2 2 - PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES. // R 3 4 - CONCEIVING, DESIGNING, IMPLEMENTING, AND OPERATING SYSTEMS IN THE ENTERPRISE, SOCIETAL AND NATURAL CONTEXT. // R 1
	Science & Engineering Fundamentals	⇒ Ability to apply knowledge of science and engineering fundamentals.	Mathematics, science, engineering principles, skills & tools (inc. computing, experimentation).	PE1.1 Knowledge of science and engineering fundamentals	1.1 Knowledge of underlying sciences. // PE 1.1 – R 2	1 - TECHNICAL KNOWLEDGE AND REASONING. // UNIQUE R 1
Information Literacy	Information Skills	⇒ Expectation of the need to undertake lifelong learning and the capacity to do so.	Mathematics, science, engineering principles, skills & tools (inc. computing, experimentation).	PE3.2 Ability to manage information and documentation PE3.6 Capacity for lifelong learning and professional development	2.2 Experimentation and knowledge discovery. // PE 3.2 2.4 Creative and critical thinking, educating and aesthetics. // PE 3.6 – R 2 2.5 Professional skills and attitudes. // PE 3.6 3.1 Teamwork. // PE 3.6 3.2 Structured communications. // PE 3.2 – R 3	2 - PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES. // R 3 3 - INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION. // R 2
Communication	Communication	⇒ Ability to communicate effectively, with the engineering team and with the community at large		PE3.1 Ability to communicate effectively, with the engineering team and with the community at large	3.1 Teamwork. // PE 3.1 – R 2 3.2 Structured communications. // PE 3.1 – R 4	3 - INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION. // R 2

Graduate Attributes Comparison				Competency Standards Comparison		
USYD graduate attributes	ENG-IT graduate attributes (Aug 08)	EA graduate attributes (generic)	EA program structure elements	EA Stage 1 Competency Standards – Level 2	CDIO Standards - Level 2	CDIO Standards – Level 1
Research & Inquiry	Design & Problem Solving	⇒ Ability to undertake problem identification, formulation, and solution ⇒ Ability to utilise a systems approach to design and operational performance	Engineering design & projects	PE2.1 Ability to undertake problem identification, formulation, and solution PE2.3 Ability to utilise a systems approach to complex problems and to design and operational performance PE2.4 Proficiency in engineering design PE3.3 Capacity for creativity and innovatio006E	2.1 Engineering reasoning and problem solving. // PE 2.1, PE 2.4 – R 2 2.2 Experimentation and knowledge discovery. // PE 3.3 2.3 System thinking. // PE 2.1, PE 2.3 – R 2 2.4 Creative and critical thinking. // PE 2.3, PE 3.3 – R2 2.5 Professional skills and attributes. // PE 2.4 2.6 Leadership: character and core personal values. // PE 3.3 4.1 External, societal and natural context and environment. // PE 2.4 4.3 Conceiving and engineering systems. // PE 2.4 – R 4 4.4 Designing. // PE 2.4 – R 6, PE 2.3 – R 2 4.6 Operating. // PE 2.3 – R 3 4.7 Engineering entrepreneurship. // PE 2.4 4.8 Leading engineering endeavours. // PE 3.3 – R 2	2 - PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES. // R 6 4 - CONCEIVING, DESIGNING, IMPLEMENTING, AND OPERATING SYSTEMS IN THE ENTERPRISE, SOCIETAL AND NATURAL CONTEXT. // R 6
	Teamwork & Project Management	⇒ Ability to function effectively as an individual and in multidisciplinary and multicultural teams, as a team leader or manager as well as an effective team member	Engineering design & projects	PE2.5 Ability to conduct an engineering project PE3.5 Ability to function effectively as an individual and in multidisciplinary and multicultural teams, as a team leader or manager as well as an effective team member	2.5 Professional skills and attitudes. PE 3.5 2.6 Leadership: character and core personal values. // PE 3.5 – R 2 3.1 Teamwork. // PE 3.5 – R 4 3.2 Structured communication. // PE 2.5 3.4 Leadership: relating to others. // Unique PE 3.5 4.3 Conceiving and engineering systems. // PE 2.5 – R 2 4.8 Leading engineering endeavours. // PE 2.5 – R 2	2 - PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES. // R 2 3 – INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION. // R 3 4 - CONCEIVING, DESIGNING, IMPLEMENTING, AND OPERATING SYSTEMS IN THE ENTERPRISE, SOCIETAL AND NATURAL CONTEXT. // R 2

Graduate Attributes Comparison				Competency Standards Comparison		
USYD graduate attributes	ENG-IT graduate attributes (Aug 08)	EA graduate attributes (generic)	EA program structure elements	EA Stage 1 Competency Standards – Level 2	CDIO Standards - Level 2	CDIO Standards – Level 1
Ethical, Social & Professional Understanding	Professional Practice	⇒ Understanding of the social, cultural, global, and environmental responsibilities of the professional engineer and the need for sustainable development ⇒ Understanding of the principles of sustainable design & development ⇒ Understanding of professional and ethical responsibilities, and commitment to them	Exposure to Professional Practice	PE1.4 General Knowledge PE2.2 Understanding of social, cultural, global, and environmental responsibilities and the need to employ principles of sustainable development PE2.6 Understanding of the business environment PE3.4 Understanding of professional and ethical responsibilities, and commitment to them PE3.7 Professional Attitudes	2.1 Engineering reasoning and problem solving. // PE 2.6 + PE 3.7 2.2 Experimentation and knowledge discovery. PE 1.4 2.4 Creative and critical thinking, educating and aesthetics. PE 3.7 2.5 Professional skills and attitudes. PE 3.7 2.6 Leadership: character and core personal values. // PE 2.2 + PE 3.4 + PE 3.7 4.1 External, societal, and natural context and environment. // PE 2.2 – R 3, PE 3.4 – R 2 4.2 Enterprise and business context and environment. // PE 2.6 – R 2 4.3 Conceiving and engineering systems. // PE 2.6 – R 2 4.4 Designing. // PE 2.2 – R 2 4.7 Engineering entrepreneurship. PE 2.6 4.8 Leading engineering endeavours. PE 3.7	2 - PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES. // R 5 4 - CONCEIVING, DESIGNING, IMPLEMENTING, AND OPERATING SYSTEMS IN THE ENTERPRISE, SOCIETAL AND NATURAL CONTEXT. // R 6
Col 1	*Col 2*	*Col 3*	*Col4:* Accreditation Manual Doc. P02 Item 5.2	*Col 5:* Accreditation Manual Doc. P05 Item 4	*Col 6:* CDIO Level 2 mapping column based on mapping work done by Alci Popp. Done second pass and added unique link weighting consideration.	*Col 7:* CDIO Level 1 based on mapping work done by Alci Popp. Ranking based on CDIO Level X.X in this document.

Notes:
1. For column 6, items which are written in grey colour are considered to have less weigh with respect to the mapping developed. Information posted after the '//' double forward slash indicates explicitly the items being mapped. The 'R - #' indicates the rank. The higher the rank the stronger the link. Unique results are given a higher weight in the ranking.
2. Column 7 is the corresponding level 1 items based on aggregation counts from the level 2 items.