TOWARD INTERNATIONALIZED ENGINEERING CURRICULUM AND STUDENT MOBILITY

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ABSTRACT

There is a growing need for international transparency of engineering qualifications, and mechanisms to support and facilitate student mobility. In response, there are a number of global initiatives attempting to address these needs, particularly in Europe, North America and Australia. The Conceive-Design-Implement-Operate (CDIO) Initiative has a set of standards, competencies, and proficiency levels developed through a global community of practice. It is a well-structured framework in which best-practice internationalization and student mobility can be embedded. However, the current 12 CDIO Standards do not address international qualifications or student mobility. Based on an environmental scan of global activities, the underpinning principles of best practice are identified and form the basis of the proposed 13th CDIO Standard – "Internationalization and Mobility".

KEYWORDS

CDIO, engineering education, internationalization, student mobility

INTRODUCTION

Graduate engineers of the future will increasingly need to be international in their outlook and experience, and be prepared to operate globally. Businesses have to compete and collaborate on a global scale, and operate across national and international borders with organisational environments being increasingly complex, dynamic and with more interdependencies. Our challenge as educational institutions is to aid our students to prepare for this global environment.

CDIO is a global initiative beginning with collaboration between a consortium of Swedish Universities, Massachusetts Institute of Technology (MIT), and the US Naval Academy, funded originally by the Knut and Alice Wallenberg Foundation. Based on the broad engineering principles of product and system design, CDIO is reflective of the product and system design principles of **C**onceive, **D**esign, **I**mplement and **O**perate. It has grown into a global community of practice with more than 40 engineering schools in the U.S., Europe, Canada, U.K., Africa, Asia, Australia and New Zealand.

CDIO has adopted 12 Standards as guiding principles for program reform and evaluation. The 12 CDIO Standards address program philosophy, curriculum development, design-build experiences and workspaces, new methods of teaching and learning, faculty/academic development, and assessment and evaluation (Crawley et al, 2009) [1]. However, at present, the Standards do not explicitly address international qualifications or student mobility. In response,

the first author of this paper (Duncan Campbell) has drafted the 13th CDIO Standard, Internationalization and Mobility. This paper presents the underpinning case for the formulation of the draft Standard and process for its potential adoption.

BACKGROUND

A shortage of students willing to study abroad is causing international embarrassment for Australian universities, which stand accused of being more interested in export dollars than educational exchanges (Rout, 2007) [2].

The benefits of and growing need for international transparency in engineering qualifications, simple cross-credit processes, international dual awards and mechanisms to encourage student mobility are receiving much attention around the world at present. In response, there are a number of global initiatives now examining how these issues may be addressed, particularly in Europe, North America and Australia. A number of these are discussed later in this paper.

The challenge for educational institutions is to assist students to prepare for this interdependent global environment. The Stratégé Study found that worldwide, there is a requirement to increase the internationalization of engineering programs, content and context, as well as support the mobility of engineering students and scholars [3]. Indeed, employers have expressed the need for undergraduates to have global competence to enable them to function in the corporate environment (Dolby, 2008 [4], Grandin and Hirleman, 2009 [5]). Not only will engineers need technical competence, but will also need to have an understanding of global conditions, and be aware of and sensitive to differences in cultural environment and work ethic (Abanteriba, 2006) [6]. Mobility and international experience give students the opportunity to be immersed in other cultures, with exposure to different and unfamiliar situations and different approaches to problem solving (Department of Education, Employment and Workplace Relations (DEEWR)) [7]. Other benefits include “the promise of returning with an enhanced understanding of the world and its intricate web of political, economic, social and cultural relationships” (Dolby, 2008) [4]. The Queensland Education and Training International (QETI) & International Education Association of Australia (IEAA) study of the attitudes and perceptions of Australian employers claims that 61 percent of employers view international study experiences as unique and a competitive addition to a resume, while 81 percent of employers believe that graduates who undertake an overseas experience return to Australia with enhanced skills that are applicable to the workplace [8].

Global experience for students, as part of their degree, is supported by (but not limited to) governments of Australia, the EU, the USA, the engineering profession and employers. While the trend for student mobility increases annually, study abroad demands the mutual understanding and recognition of others’ educational systems (Buisson and Jensen, 2009) [3].

INTERNATIONALIZATION AND MOBILITY AGENDA

International study experience has been on the educational agenda for at least a decade (Pasfield, Taylor and Harris, 2009) [9], with employers, governments and educational institutions driving student mobility changes that will ensure graduates are equipped to face a globalised workplace. Most agree on the individual, social, educational, cultural and national benefits derived from broad exposure to international experience, and the intellectual benefits from global collaboration. Specifically, companies need culturally-sensitive workers, prepared to accept the challenges and benefits of working in a different environment, and who can be mobilised to suit their strategic needs.

The Newport Declaration (2008) [10] calls on engineering educators, engineering administrators, and engineering policy leaders to "take deliberate and immediate steps to **integrate global education into the engineering curriculum to impact all students,** recognizing global competency as one of the highest priorities for their graduates".

Student mobility, both inbound and outbound, has well-documented benefits for students and employers that are broadly acknowledged across the globe. However, the impediments to student mobility including costs, language difficulties, timing (of the mobility window), and especially academic recognition, have significantly limited the potential for students to study abroad.

The *International Student Mobility Study* undertaken by the Universities of Sussex and Dundee (UK), states that around 1.8 million students were studying outside their country of origin in 2000, a figure that is expected to rise to 7.2 million by 2025 (DEEWR) [7]. An estimated 200,000 American students studied abroad in 2006 (Rexeisen, Anderson, Lawton and Hubbard, 2008) [11]; or 8.5% pa in 2007, and 2.2% of Canadian college and university students also studied abroad (DEEWR) [7].

Inbound Mobility

In a speech on 26 May 2009, The Hon Julia Gillard MP stated: "International education has made a significant contribution to Australia. It has grown to now be our third-largest source of overseas earnings, generating $15.5 billion in 2008 and supporting more than 125,000 jobs. In 2008, nearly half a million students came to Australia. It is the lead sector in terms of export earnings in Victoria and the second largest in New South Wales". Indeed, inbound mobility students studying in Australia in 2008 numbered more than 543,000, injecting $14.2 billion into the Australian economy (DEEWR) [7].

Outbound Mobility

There is no real tradition of studying abroad for Australian students as there has been for European students. However, the trend for overseas study in the past five years indicates a ten percent growth in this area (DEEWR) [7]. The Australian Universities International Directors' Forum (AUIDF) Report (2008) reveals that in 2007, 8354 undergraduate students, or 5.8% of completing students, from 37 Australian universities undertook international study [12]. Of this number, 5.6% were engineering students. The corresponding proportion of mobile engineering students for the UK is 1.2% and 0.3% for the USA (Australian Education International (AEI), 2009) [13]. UNESCO data indicates that the top host countries for Australian students in 2006 were the USA, New Zealand, the UK, Canada, Germany and Japan (AEI, 2009) [13].

The majority of international study experiences of all types were funded by the university or by government; 60% were supported by university funds, 4% from Australian Government programs such as University Mobility in Asia and the Pacific (UMAP), 5% by a combination of university funds and Government programs, 13% by OS HELP ($14 million in student loans in 2009. [AEI 2009] [13]), and 5% supported privately or by other Australian foundations (AUIDF, 2008) [12].

Impediments to Student Mobility

The process of cross-credit is problematic where knowledge of the worth of study programs is questionable or unknown. Recognition, curricula rigidity and credit are identified by several

studies as obstacles to student mobility, along with the potential of prolonged study and the lack of recognition by the home university (Buisson and Jensen, 2008) [3]; Grandin and Hirleman, 2009 [5]). Resolving these issues contributes to realizing the potential of trans-national cross-accreditation and the prospect of students owning their own eportfolio of transferable attributes and credentials.

In a report to the National Summit Meeting on the Globalisation of Engineering Education, The IFEES (International Federation of Engineering Education Societies) Secretariat identified obstacles and hurdles to international academic opportunities, with which Australia might also identify, summarised as follows (Grandin and Hirleman, 2009) [5]:

1. **Curricular rigidity:** The engineering curriculum is very full and lock-step.
2. **Lack of tradition:** Study abroad has always been considered the prerogative of students in the humanities. Even though engineers are far more likely to have to work abroad or work together with colleagues from other nations, there has been no tradition of sending engineers to study or work abroad. This leaves a void of experience among engineering faculty and administrators, at a time when we now find it critically important to prepare engineering students for eventual work in the global sphere.
3. **Lack of support from study abroad professionals.**
4. **Lack of support for cross-disciplinary activities.**
5. **Lack of support by departments, colleges of engineering or faculty:** Engineering programs often do not have advisors who are knowledgeable about study abroad opportunities
6. **American monolingualism:** Americans, as native speakers of English, have always felt that language learning is for others.
7. **Academic rewards system:** Building successful international programs for engineering students is labor intensive and requires substantial time commitments from faculty and administrators. Since faculty are promoted and tenured by traditional teaching, publication, grantsmanship, etc. and not by sending students abroad, there is little incentive for faculty to work in this area.
8. **University financial restrictions:** Building program opportunities for engineering students abroad is labor intensive and expensive.
9. **Student financial restrictions:** Programs abroad are often arranged for summer when students need to work for precious tuition dollars.
10. **Difficulty in transferring credit:** Credit systems vary around the world.
11. **Negative perception of study abroad:** Study abroad experiences are not uniformly regarded as worthwhile by either parents or recruiters.
12. **Disconnect in the corporate world between CEO and HR:** While CEO's often speak of the importance of global education, the message often does not reach the human resource departments. The message does not reach the recruiters who interact with students and do the hiring.
13. **Private vs. university-based programs:** Study abroad is now a big business and many private companies organize international educational experiences.
14. **Lack of emphasis on total immersion for a significant length of time:** Evidence collected by IIE indicates that study abroad experiences are becoming shorter and

sometimes have little cultural immersion. Students often seem to gravitate to these programs to "check a box" on their resumes. Universities also tend to boast about total number of students who have gone abroad and not student-months abroad.

15. **Difficulty in recruiting:** Students do not necessarily value the experience abroad or are hesitant about taking the risk.
16. **Lack of cultural preparation:** Engineering students are often ill-prepared to accept the norms of another culture.

Transportability of Qualifications

The transportability of qualifications has long been an issue perceived by students. However, means of improving the mobility of students between the EU and Australia have been identified by Buisson and Jensen (2008), who claim that transportability of qualifications will be critical in the future not only for academic credit but potentially for accreditation under the Washington Accord or under the EUR-ACE (EUROpean Accredited Engineer), accreditation being developed in Europe. [13]

European students are well catered for through programs such as the following, but many of these may not be applicable for non-European students studying abroad:

- **IFEES** - Through the collaboration of its member societies, IFEES works to establish effective engineering education processes of high quality around the world to assure a global supply of well-prepared engineering graduates. IFEES also enhances the ability of engineering faculty, students and practitioners to understand the varied cultures of the world and work effectively in them.
- **International Cotutelle** - The international Cotutelle program, involving a number of Australian Universities, is a French national initiative that offers jointly supervised PhD qualifications leading to a doctoral degree that is recognized by the two participating countries.
- **Erasmus Mundus** (2009-2013) is a cooperation and mobility program that supports joint postgraduate programs, researchers and university staff as well as joint projects to enhance European higher education worldwide. Recognised courses are hosted from a consortium of higher education institutions from across Europe, and other Northern hemisphere regions.
- **EUR-ACE** - The European engineering accrediting agency, has proposed a European system of accreditation of engineering educational programs (ENAEE, 2009) [15]. This system raises the potential for mutual recognition of accreditation in collaboration with Engineers Australia (Buisson and Jensen, 2009) [3].

Other frameworks for the recognition of qualifications do exist, but are limited for, or totally preclude, Australian outbound students. These include:

- **European Credit Transfer and Accumulation System (ECTS**) - ECTS guarantees academic recognition of studies abroad. "With ECTS, higher education institutions preserve their autonomy and responsibility for all decisions concerning students' achievements, without amending existing course structures and assessment methods: all courses and assessments are those which are normally taken by regular students at the host institution". The ECTS standard allows comparison of study attainment and performance of EU higher education students and other collaborating European countries. [16]

- **SEFI - Société Européenne pour la Formation des Ingénieurs** - Europe's largest network of higher engineering institutions, was founded in 1973 for the purpose of contributing to the development and the improvement of engineering education in Europe [17].
- **The European Qualifications Framework (EQF)** - The European Qualifications Framework for Life Long Learning is a common reference framework which enables European countries to link their qualifications systems to one another. Its key aim is to contribute to creating a truly mobile and flexible European workforce. [17]
- **National Coordination Point (NCP) -** The National Coordination Point, established by the European Commission, is intended as a means of relating each Member State's qualifications systems to the EQF. It is tasked with referencing levels of national qualifications systems to the EQF, promoting quality assurance principles while maintaining transparency of the methodology. [18]
- **World Federation of Engineering Organisations (WFEO)** –A working group of the WFEO Committee on Education and Training has been tasked to prepare a policy on the mobility of professional engineers, "WFEO Policy on Accreditation of Courses and Mobility of Engineering Professionals" [19]. The policy is currently draft with the intention of having it adopted later in 2009.

DRAFT CDIO STANDARD (13) – INTERNATIONALIZATION AND MOBILITY

The CDIO Initiative has a number of syllabus topics around internationalization expressed through:- 3.3 *Communications in Foreign Languages*; 2.5.2 *Professional Behavior*; 2.5.4 *Staying Current on World of Engineer*; and 4.1.6 *Developing a Global Perspective* (Crawley et al, 2007) [1]. There is a current revision taking place of the CDIO Syllabus and is likely that greater emphasis on internationalization will be made. Oosthuizen (2009) also writes about the need for greater internationally based experiences within the curriculum [20].

The 12 CDIO Standards act as guiding principles for program reform and evaluation. They are listed below.

Standard 1 -- CDIO as Context*
Adoption of the principle that product and system lifecycle development and deployment -- Conceiving, Designing, Implementing and Operating -- are the context for engineering education

Standard 2 -- CDIO Syllabus Outcomes*
Specific, detailed learning outcomes for personal, interpersonal, and product and system building skills, consistent with program goals and validated by program stakeholders

Standard 3 -- Integrated Curriculum*
A curriculum designed with mutually supporting disciplinary subjects, with an explicit plan to integrate personal, interpersonal, and product and system building skills

Standard 4 -- Introduction to Engineering
An introductory course that provides the framework for engineering practice in product and system building, and introduces essential personal and interpersonal skills

Standard 5 -- Design-Build Experiences*
A curriculum that includes two or more design-build experiences, including one at a basic level and one at an advanced level

Standard 6 -- CDIO Workspaces
Workspaces and laboratories that support and encourage hands-on learning of product and system building, disciplinary knowledge, and social learning

Standard 7 -- Integrated Learning Experiences*
Integrated learning experiences that lead to the acquisition of disciplinary knowledge, as well as personal, interpersonal, and product and system building skills

Standard 8 -- Active Learning

Teaching and learning based on active experiential learning methods

Standard 9 -- Enhancement of Faculty CDIO Skills*

Actions that enhance faculty competence in personal, interpersonal, and product and system building skills

Standard 10 -- Enhancement of Faculty Teaching Skills

Actions that enhance faculty competence in providing integrated learning experiences, in using active experiential learning methods, and in assessing student learning

Standard 11 -- CDIO Skills Assessment*

Assessment of student learning in personal, interpersonal, and product and system building skills, as well as in disciplinary knowledge

Standard 12 -- CDIO Program Evaluation

A system that evaluates programs against these twelve standards, and provides feedback to students, faculty, and other stakeholders for the purposes of continuous improvement

The CDIO Standards however, do not make explicit mention of internationalization or mobility. There is little guidance or environmental consideration around internationalization, and enablers of mobility for CDIO programs. It is therefore proposed that the CDIO Initiative responds through: (i) more explicit recognition of international issues and multi-cultural curriculum through the CDIO Syllabus, (ii) that collaboration and resource sharing be facilitated in this domain, and (iii) that a new CDIO Standard be adopted on "Internationalization and Mobility". The draft Standard (extract below), authored by the first author of this paper (Duncan Campbell) is intended to provide guidance and key attributes based on current best practice and recommendations summarized in this paper.

Standard 13 (October Draft) - CDIO Internationalization and Mobility

Programs and organizational commitment which exposes students to foreign cultures, and promotes and enables transportability of curriculum, portability of qualifications, joint awards, transparent recognition and international mobility.

Description: CDIO Program Internationalization and Mobility encourages and recognizes organizational commitment which prepares engineers for a global environment and to expose them to a rich set of international experiences and contexts during their studies. It represents the exposure, promotion, facilitation, opportunity and scholarship of an internationalized curriculum, qualifications and international mobility of students.

Rationale: Graduate engineers of the future will increasingly need to be international in their outlook and experience, and be prepared to operate globally. Businesses have to compete and collaborate on a global scale, and operate across national and international borders with organizational environments being increasingly complex, dynamic and with more interdependencies. Our challenge as educational institutions is to aid our students to prepare for this global environment.

Evidence may include, non-exclusively, one or more of the following:

- The embedding of authentic cultural awareness and experiences within the curriculum, or social activities
- Opportunities be made available for students to learn second languages
- Programs which encourage and recognize study abroad, and other international experiences (including internships, exchanges) for credit
- Establishment of a mobility window within programs and curriculum
- An ePortfolio facility which links student learning outcomes with artifacts, and graduate attributes and competencies which are recognized through international accords
- A demonstrable and tangible institutional commitment to internationalization and student mobility
- Complimentary partnerships between international universities
- Transparent expectations of student learning outcomes from an international experience
- International benchmarking of programs
- Active involvement in international engineering education scholarly activities
- Program accreditation with international cross-accreditations (eg. Washington accord, …)
- Transparency in intuitional cross-credit for study aboard

- Partnerships with international corporations/industry with offices co-located with partnering institutions
- Professional development programs (including sabbatical leave) on internationalization and mobility for faculty
- Dual award programs involving two or more countries
- Participation in international global mobility networks

Consultative Process

The first draft proposal was tabled at the 2009 CDIO Conference in Singapore for initial debate. The proposed Standard was subsequently circulated around the global CDIO community for comment over a three month period. Further discussion occurred at the 2009 October CDIO Collaborators' meeting in Turku (Finland).

In summary, the CDIO Council meeting in Finland concluded that:-

1. There is overall agreement in the principles of internationalization and student mobility.
2. There is some concern about the potential of a multitude of new Standards being introduced.
3. There is some concern about perceived expectations and potential exploitation of some of the "evidence" of best practice.

In response to these meeting conclusions, an international CDIO working party has been established to respond to the concerns and suggestions with a view of presenting such at the 2010 CDIO Conference in Montreal.

CONCLUSION

The benefits and growing need for international transparency in engineering qualifications, simple cross-credit processes, international dual awards and mechanisms to encourage student mobility are recognised. A number of impediments to mobility, and trans-national curriculum and qualification compatibility are identified, however there are now several global initiatives examining how these issues may be addressed, particularly in Europe, North America and Australia.

The CDIO Initiative has a well-established global community of practice, organizational affiliations, and institutional collaborations. It brings a network of relationships beyond regional bounds and jurisdictions. In many ways, CDIO already embraces and practices the key characteristics which positively contribute to internationalization and mobility. This paper encapsulates the underpinning argument to adopt a new CDIO Standard:- Standard 13 (Draft) – "CDIO Internationalization and Mobility" with the view of bringing an extra and unique dimension to establishing a global culture and practice of internationalization and mobility.

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