MAPPING THE RELATIONSHIP BETWEEN THE CDIO SYLLABUS AND THE 2008 CEAB GRADUATE ATTRIBUTES

Guy Cloutier

École Polytechnique de Montréal

Ronald Hugo

University of Calgary

Rick Sellens

Queen’s University at Kingston

ABSTRACT

The recently introduced Canadian Engineering Accreditation (CEAB) requirements for Graduate Attributes [1] require demonstrated learning outcomes for the first time. CDIO has required outcomes and benchmarking for more than a decade, and the CDIO Syllabus [2] has provided a detailed and proven framework within which to organize the topics covered by those outcomes. The latest revision of the syllabus informs many of our programs, and can provide the detail on how we can document a set of outcomes that meet the more general requirements of the CEAB Graduate Attributes. This paper provides a framework for Canadian engineering programs to satisfy CEAB requirements through a mapping of the CDIO Syllabus Version 2.10 topics to the CEAB Attributes, and verification of the completeness of that list. An engineering program can meet all of the CEAB Graduate Attribute requirements by addressing a subset of the CDIO Syllabus, however a CEAB accredited program may not meet all of the requirements of CDIO.

KEYWORDS

CEAB, Graduate Attributes, curriculum mapping, program assessment

INTRODUCTION

CDIO Standard 2 stipulates learning outcomes based on a syllabus that has been validated by program stakeholders and most CDIO programs are using the CDIO Syllabus (version 1) [2] as the basis for developing their own outcomes. Version 2 of the Syllabus is in development and expected to be presented at the 2010 CDIO International Conference. In this comparison we have used a draft (v2.10 October 2009) that was circulated for discussion among the CDIO Council Members.

CDIO is not the only initiative in engineering education developing outcomes based approaches and most national and international accreditation organizations are moving towards approaches that are compatible with the CDIO Syllabus. The Canadian Engineering Accreditation Board published new guidelines in 2008 [1], including a set of attributes specifying general program outcomes for the first time, while still retaining criteria based on instructional hours and content. Section 3.1 of the document specifies a set of twelve "Graduate Attributes" that all students should have on completion of an accredited program in engineering. They are:

3.1.1 A knowledge base for engineering
3.1.2 Problem analysis
3.1.3 Investigation
3.1.4 Design
3.1.5 Use of engineering tools
3.1.6 Individual and team work
3.1.7 Communication Skills
3.1.8 Professionalism
3.1.9 Impact of engineering on society and the environment
3.1.10 Ethics and equity
3.1.11 Economics and project management
3.1.12 Life-long learning

All of them elaborate on "demonstrated competence," "an ability," or "an understanding" without detailing the level to be attained in each particular aspect. This leaves room for individual institutions to establish their own priorities among the attributes as long as all are adequately addressed, usually within the context of complex problems.

Under the International Engineering Alliance (IEA), various international agreements govern mutual recognition of engineering qualifications and professional competence, by the recognition of substantial equivalence in the accreditation of qualifications : the *Washington Accord* (1989) in professional engineering, co-signed by Engineers Canada; the *Sydney Accord* (2001) in engineering technology and the *Dublin Accord* (2002) in technician engineering, both co-signed by the Canadian Council of Technicians and Technologists. In June 2009, the Japanese Accreditation Board for Engineering Education and the Institution of Engineers Japan hosted the Kyoto meeting. The ensuing meeting paper [3] describes graduate attributes and professional competencies. It also formally defines terms like *complex problem* and *simple* to *complex activities* used in the CEAB documents. The IEA paper details 12 *graduate attributes*: “components indicative of the graduate's potential to acquire competence to practise at the appropriate level,” which the CEAB uses explicitly to honour their commitment to the Washington Accord. The paper also defines 13 professional competencies require for one to “demonstrate that he/she is able to practice competently in his/her practice area to the standard expected of a reasonable Professional Engineer.”

OBJECTIVES

There is broad consensus on directions in engineering education that are consistent with CDIO objectives. This comparison aims to show that the new CEAB Graduate Attributes are consistent with and complementary to the CDIO Syllabus.

In this era of accountability, most engineering departments face multiple tests against different standards to verify program quality on various bases. We would all benefit if the process of documentation could be streamlined. The very practical objective of this work is to show how a properly documented CDIO program can meet all of the new CEAB graduate attribute requirements; that CDIO is a superset of those requirements.

PROCESS

The authors met and discussed at length the correlation between the 12 attributes and 14 topics, sometimes with reference to background at lower levels of detail. This process convinced us there was merit in the idea and resulted in the table of correlations shown in figure 1. Although satisfying, this table does not go beyond summarizing apparent correlations between areas. At this level of detail it is not possible to validate requirements in either direction.

The CEAB attributes are sufficiently general that it is not possible to map them directly to individual level 3 or 4 CDIO syllabus topics. A graduate might have the CEAB attribute "3.1.12 Life-long learning: An ability to identify and to address their own educational needs in a changing world, sufficiently to maintain their competence and contribute to the advancement of knowledge" without addressing CDIO topic "2.5.3 Proactively Planning for One's Career." Yet, addressing topic 2.5.3 is certainly a contribution towards meeting attribute 3.1.12.

The practical objective of showing a CDIO program meets CEAB attributes requires a mapping of syllabus topics to attributes, recognizing that while many topics may contribute to an attribute, only some will be absolutely essential to that attribute. Accordingly, we reviewed each of the topics for potential contributions to the attributes, and ranked them with values from 0 (very little contribution) to 1 (very strong contribution). The basis for the rankings was our expectation that a deliverable or an activity associated with a particular syllabus topic would contain evidence of a student's possession of a particular attribute. These values are indications of where one should look for evidence of performance in auditing individual students or a program.

In completing this assessment, we recognized that some elements are essential in the demonstration of many of the attributes. For example, it is hard to imagine how one would demonstrate engineering problem solving in the absence of an engineering knowledge base. Rather than link a particular topic to many or all attributes, we only linked those topics that would provide additional evidence for a particular attribute that may not have been relevant to an earlier numbered attribute.

We then tested our list for completeness, assessing which of those syllabus topics were required as part of a particular attribute, and whether that list of required topics was sufficient to cover all aspects of an attribute. The standard for inclusion was "Must all graduates of an engineering program address this topic to show they have this attribute?" These *must have* topics are identified in the tables in a larger font and bold type.

No attempt was made to define the level of proficiency needed in each topic area, as this aspect requires extensive input from stakeholders. We also felt that assessment of whether the collection of deliverables and activities met the requirements of the attributes for "complexity" could only be addressed in the context of an overall program, rather than topic by topic.

RESULTS

The 12 by 14 matrix in table 1 provides a summary that clearly shows the correlation between the CDIO Syllabus and the CEAB Graduate Attributes. This strong agreement in general terms is born out by the detailed analysis.

Table 2 provides a more detailed look at how the over 80 topics in the CDIO Syllabus at the third level of detail can combine to satisfy the CEAB Attributes. The CDIO Syllabus also contains a fourth level of detail with hundreds of individual topics identified. Level four topics are of great value in selecting assessment activities once the level of proficiency is chosen. The matching of topics is detailed attribute by attribute in the paragraphs that follow, with some reference to the fourth level of CDIO detail where required. The quoted text is the full description of each attribute from the CEAB document.

One outcome that arises is the identification of some critical elements that are implicit in the CEAB Attributes while being explicitly identified in the CDIO Syllabus. System Thinking and Critical Thinking show up as syllabus topics that should be in evidence to adequately address many of the attributes. Likewise there are several attributes, Engineering Tools, Impact on Society, and Economics, that include elements identified explicitly in multiple different subsections of the syllabus.

Table 1
Overview of correlations between the CDIO Syllabus and CEAB Graduate Attributes

	CDIO Syllabus v2.10 (UNESCO four pillars) [ABET a-k]	3.1.1	3.1.2	3.1.3	3.1.4	3.1.5	3.1.6	3.1.7	3.1.8	3.1.9	3.1.10	3.1.11	3.1.12
	Matrix entries are between 0 and 1 for the extent that a given CDIO syllabus element may contribute to satisfying requirements for a given CEAB attribute.	A knowledge base for engineering	Problem Analysis	Investigation	Design	Use of engineering tools	Individual and team work	Communication skills	Professionalism	Impact of engineering on society	Ethics and equity	Economics and project management	Life-long learning
	Large, bold entries indicate topics required to meet an attribute												
1.1	KNOWLEDGE OF UNDERLYING MATHEMATICS AND SCIENCES [a]	1											
1.2	CORE ENGINEERING FUNDAMENTAL KNOWLEDGE [a]	1											
1.3	ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE, METHODS AND TOOLS [k]	0.5				1							
2.1	ANALYTICAL REASONING AND PROBLEM SOLVING [e]		1			0.25						0.5	
2.2	EXPERIMENTATION, INVESTIGATION AND KNOWLEDGE DISCOVERY [b]			1		0.25		0.5					
2.3	SYSTEM THINKING		0.5		0.5	0.25				0.5		0.25	
2.4	ATTITUDES, THOUGHT AND LEARNING		1	1	1	1	0.5			0.25		0.25	1
2.5	ETHICS, RESPONSIBILITY, EQUITY, AND CORE PERSONAL VALUES						0.25		1	0.25	1		0.5
3.1	TEAMWORK [d]						1						
3.2	COMMUNICATIONS [g]						0.25	1					0.25
3.3	COMMUNICATIONS IN A FOREIGN LANGUAGE							0.25					
4.1	EXTERNAL, SOCIETAL, ECONOMIC AND ENVIRONMENTAL CONTEXT [h]								1	1	0.5		0.25
4.2	ENTERPRISE AND BUSINESS CONTEXT					0.25	0.5					1	
4.3	CONCEIVING, SYSTEMS ENGINEERING AND MANAGEMENT [c]				1	0.25				0.5		0.5	
4.4	DESIGNING [c]				1	0.25				0.5		0.25	
4.5	IMPLEMENTING [c]				0.5	0.5				0.5		0.5	
4.6	OPERATING [c]				0.5	0.5	0.25			0.5		0.25	

"**3.1.1 A knowledge base for engineering:** Demonstrated competence in university level mathematics, natural sciences, engineering fundamentals, and specialized engineering knowledge appropriate to the program."

A knowledge base is clearly to be understood as a *working* knowledge base at the course level. Without wandering into subtle discussions about what deserves to be called a "problem," we understood attribute 3.1.1 dealt more with working knowledge at the applied-knowledge-acquisition "exercise" levels, whereas attribute 3.1.2 introduced "problems" and complexity.

Underlying mathematics and science is the natural mandatory stepping stone of applied knowledge. Note this has no bearing on the pedagogical approach used, and bears no implicit conclusion about a "theory first, applications later" preference.

CDIO 1.2 "Core Engineering *Fundamentals"* — however we detail them — are the essence of a knowledge base for engineering "appropriate to the program." Topic 1.3 "Advanced Engineering Fundamental Knowledge Methods and Tools" has to be an essential complement, even if there is a rationale to associate it also to the CEAB 3.1.5 attribute, as illustrated within the list following.

As CDIO 2 and 3 cover skills, and all CDIO 4 sub-topics dealt with increased complexity and open-ended problems with multiple criteria, it was felt only the CDIO 1.x topics suitably matched the CEAB 3.1.1 attribute at the knowledge acquisition "exercise" level.

"**3.1.2 Problem analysis:** An ability to use appropriate knowledge and skills to identify, formulate, analyze, and solve complex engineering problems in order to reach substantiated conclusions."

Table 2 (a)
Detailed mapping of CDIO Syllabus topics 1.X.X – 3.X.X contributions to meeting the CEAB Graduate Attribute requirements

	CDIO Syllabus v2.10 (UNESCO four pillars) [ABET a-k]	3.1.1	3.1.2	3.1.3	3.1.4	3.1.5	3.1.6	3.1.7	3.1.8	3.1.9	3.1.10	3.1.11	3.1.12
	Matrix entries are between 0 and 1 for the extent that a given CDIO syllabus element may contribute to satisfying requirements for a given CEAB attribute.	A knowledge base for engineering	Problem Analysis	Investigation	Design	Use of engineering tools	Individual and team work	Communication skills	Professionalism	Impact of engineering on society	Ethics and equity	Economics and project management	Life-long learning
	Large, bold entries indicate topics required to meet an attribute												
1	**DISCIPLINARY KNOWLEDGE AND REASONING (Learning to know)**												
1.1	**KNOWLEDGE OF UNDERLYING MATHEMATICS AND SCIENCES [a]**	**1**											
1.2	**CORE ENGINEERING FUNDAMENTAL KNOWLEDGE [a]**	**1**											
1.3	**ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE, METHODS AND TOOLS [k]**	**0.5**				**1**							
2	**PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES (Learning to be)**												
2.1	**ANALYTICAL REASONING AND PROBLEM SOLVING [e]**		**1**			*0.25*						**0.5**	
2.1.1	Problem Identification and Formulation		**1**										
2.1.2	Modeling		**1**			*0.5*							
2.1.3	Estimation and Qualitative Analysis		**1**										
2.1.4	Analysis With Uncertainty		**1**									**0.5**	
2.1.5	Solution and Recommendation		**1**			*0.5*							
2.2	**EXPERIMENTATION, INVESTIGATION AND KNOWLEDGE DISCOVERY [b]**			**1**		*0.25*		**0.5**					
2.2.1	Hypothesis Formulation			**1**									
2.2.2	Survey of Print and Electronic Literature			**1**				**0.5**					
2.2.3	Experimental Inquiry			**1**		*0.5*							
2.2.4	Hypothesis Test, and Defense			**1**									
2.3	**SYSTEM THINKING**		*0.5*		*0.5*	*0.25*				*0.5*		*0.25*	
2.3.1	Thinking Holistically		*0.5*		*0.5*	*0.25*				*0.5*		*0.25*	
2.3.2	Emergence and Interactions in Systems		*0.5*		*0.5*	*0.25*				*0.5*			
2.3.3	Prioritization and Focus		*0.5*		*0.5*	*0.25*				*0.5*		*0.25*	
2.3.4	Trade-offs, Judgment and Balance in Resolution		*0.5*		*0.5*	*0.25*				*0.5*		*0.25*	
2.4	**ATTITUDES, THOUGHT AND LEARNING**		**1**	**1**	**1**	**1**	*0.5*			*0.25*		*0.25*	**1**
2.4.1	Initiative and the Willingness to Make Decisions in the Face of Uncertainty						*0.25*			*0.5*		*0.25*	
2.4.2	Perseverance, resourcefulness, flexibility, responsibility, and will and urgency to deliver						*0.5*					*0.25*	
2.4.3	Creative Thinking				**1**								
2.4.4	Critical Thinking		**1**	**1**	**1**	**1**						*0.25*	
2.4.5	Self-awareness, Meta-cognition and Knowledge Integration						*0.5*						**1**
2.4.6	Lifelong Learning and Educating Others [i]						*0.25*						**1**
2.4.7	Time and Resource Management						*1*					*0.25*	
2.5	**ETHICS, RESPONSIBILITY, EQUITY, AND CORE PERSONAL VALUES**						*0.25*		**1**	*0.25*	**1**		**0.5**
2.5.1	Ethics, Integrity and Social Responsibility [f]								**1**		**1**		
2.5.2	Professional Behavior and Responsibility [f]						*0.5*		*0.5*		**1**		
2.5.3	Proactively Planning for One's Career												*0.5*
2.5.4	Staying Current on the World of Engineering												**0.5**
2.5.5	Equity and Diversity									*0.5*	**1**		
2.5.6	Trust and Loyalty						*0.5*				*0.5*		
2.5.7	Vision and Intention in Life												*0.5*
3	**INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION (Learning to live together)**												
3.1	**TEAMWORK [d]**						**1**						
3.1.1	Forming Effective Teams						**1**						
3.1.2	Team Operation						**1**						
3.1.3	Team Growth and Evolution						*1*						
3.1.4	Team Leadership						**1**						
3.1.5	Technical and Multi-disciplinary Teaming						*1*						
3.2	**COMMUNICATIONS [g]**						*0.25*	**1**					*0.25*
3.2.1	Communications Strategy							**1**					
3.2.2	Communications Structure							**1**					
3.2.3	Written Communication							**1**					
3.2.4	Electronic/Multimedia Communication							**1**					
3.2.5	Graphical Communication							**1**					
3.2.6	Oral Presentation							**1**					
3.2.7	Inquiry, Listening and Dialog						*0.25*	**1**					
3.2.8	Negotiation, Compromise and Conflict Resolution						*0.25*	*0.25*					
3.2.9	Advocacy						*0.25*	*0.25*					
3.2.10	Establishing Diverse Connections, networking						*0.25*	*0.25*					*0.25*
3.3	**COMMUNICATIONS IN A FOREIGN LANGUAGE**							*0.25*					
3.3.1	Communications in English							*0.25*					
3.3.2	Communications in languages of regional industrial nations							*0.25*					
3.3.3	Communications in other languages							*0.25*					

Problem analysis incorporates the production of conclusions, but not necessarily of "solutions" in the sense a design would. CDIO 2.1 "Analytical Reasoning and Problem Solving" is a natural match, down to detail levels 3 and 4 of the topics, bearing in mind the two level 4 sub-topics Problem solution and Summary recommendations are understood as "conclusions" rather than as a “design to successfully address the problem.” Sufficient complexity must be provided. Complexity modulation is achieved by a combination of conflicting requirements, depth of analysis, (un)familiarity of issues, consequences, and system interdependence. It is thus natural for CDIO 2.3 “System Thinking” to contribute and 2.4.4 “Critical Thinking” to be absolutely necessary to reach (and present) “substantiated conclusions.”

Table 2 (b)
Detailed mapping of CDIO Syllabus topics 4.X.X contributions to meeting the CEAB Graduate Attribute requirements

	CDIO Syllabus v2.10 (UNESCO four pillars) [ABET a-k]	3.1.1	3.1.2	3.1.3	3.1.4	3.1.5	3.1.6	3.1.7	3.1.8	3.1.9	3.1.10	3.1.11	3.1.12
	Matrix entries are between 0 and 1 for the extent that a given CDIO syllabus element may contribute to satisfying requirements for a given CEAB attribute.	A knowledge base for engineering	Problem Analysis	Investigation	Design	Use of engineering tools	Individual and team work	Communication skills	Professionalism	Impact of engineering on society	Ethics and equity	Economics and project management	Life-long learning
	Large, bold entries indicate topics required to meet an attribute												
4	**CONCEIVING, DESIGNING, IMPLEMENTING, AND OPERATING SYSTEMS IN THE ENTERPRISE, SOCIETAL AND ENVIRONMENTAL CONTEXT – INNOVATION (Learning to do)**												
4.1	**EXTERNAL, SOCIETAL, ECONOMIC AND ENVIRONMENTAL CONTEXT [h]**								**1**	**1**	0.5		0.25
4.1.1	Roles and Responsibility of Engineers								**1**	1	0.5		
4.1.2	The Impact of Engineering on Society and the Environment								0.25	**1**			
4.1.3	Society's Regulation of Engineering								**1**	1	0.5		
4.1.4	The Historical and Cultural Context								0.25	**1**			
4.1.5	Contemporary Issues and Values [j]								0.25	**0.5**	0.5		
4.1.6	Developing a Global Perspective								0.25	**0.5**			0.5
4.1.7	Sustainability and the need for sustainable development								0.25	**0.5**			
4.2	**ENTERPRISE AND BUSINESS CONTEXT**					0.25	0.5					**1**	
4.2.1	Appreciating Different Enterprise Cultures						0.25					0.5	
4.2.2	Enterprise Stakeholders, Strategy and Goals						0.25					0.5	
4.2.3	Technical Entrepreneurship											0.5	
4.2.4	Working in Organizations						1						
4.2.5	Engineering Project Finance and Economics					0.25						**1**	
4.2.6	New Technology Development, Assessment and Infusion												
4.2.7	Working in international organizations						0.25						
4.3	**CONCEIVING, SYSTEMS ENGINEERING AND MANAGEMENT [c]**				**1**	0.25				**0.5**		**0.5**	
4.3.1	Understanding Needs and Setting Goals				**1**					**0.5**		0.5	
4.3.2	Defining Function, Concept and Architecture				**1**								
4.3.3	Modeling of System and Insuring Goals Can Be Met				**1**	0.25						0.5	
4.3.4	System Engineering and Development Project Management						0.25					**0.5**	
4.4	**DESIGNING [c]**				**1**	0.25				0.5		0.25	
4.4.1	The Design Process				**1**								
4.4.2	The Design Process Phasing and Approaches				**1**								
4.4.3	Utilization of Knowledge in Design				**1**	0.25							
4.4.4	Disciplinary Design				**1**	0.25							
4.4.5	Multidisciplinary Design				0.5	0.25							
4.4.6	Design for Sustainability, Safety, Operability, Aesthetics and other Objectives				0.5					1		0.25	
4.5	**IMPLEMENTING [c]**				0.5	0.5				0.5		0.5	
4.5.1	Designing a Sustainable Implementation Process				0.5					1		0.5	
4.5.2	Hardware Manufacturing Process					0.25							
4.5.3	Software Implementing Process					0.25							
4.5.4	Hardware Software Integration												
4.5.5	Test, Verification, Validation, and Certification					0.5						0.5	
4.5.6	Implementation Management						0.25					0.5	
4.6	**OPERATING [c]**				**0.5**	0.5	0.25			0.5		0.25	
4.6.1	Designing and Optimizing Sustainable and Safe Operations				**0.5**					1			
4.6.2	Training and Operations				0.5		0.25			0.5			
4.6.3	Supporting the System Lifecycle					0.25				1		0.25	
4.6.4	System Improvement and Evolution				0.5	0.25							
4.6.5	Disposal and Life-End Issues				0.5					0.5			
4.6.6	Operations Management				0.5	0.25	0.25						

“**3.1.3 Investigation:** An ability to conduct investigations of complex problems by methods that include appropriate experiments, analysis and interpretation of data, and synthesis of information in order to reach valid conclusions.”

Investigation requires experiments, analysis of data, and synthesis of information. CDIO 2.1.3 and 2.1.4 are obvious *must have* matches which are presumed by satisfying CEAB 3.1.2. CDIO 2.4.4 “Critical Thinking” is explicitly required to address new aspects not evident in 3.1.2. All of the topics of CDIO 2.2 are *must have* on the basis of a direct match.

“**3.1.4 Design:** An ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, and economic, environmental, cultural and societal considerations.”

This attribute requires a broad base in system, creative, and critical thinking skills, all necessary but insufficient without their application within the level 4 elements of CDIO 4.4.3 “Utilization of Knowledge in Design”.

Bearing in mind the responsibilities of engineers towards safe operation of their work, CDIO 4.6.1 is an essential element across all engineering specialties.

The first three elements of CDIO 4.3 directly address CEAB 3.1.4. It was felt CDIO 4.3.4 dealt more with the design project management, and that the characteristics of “economic, environmental, cultural and societal considerations” were the ones more relevant to the design itself under CEAB 3.1.4. It is thus within the design goals, criteria and constraints definition within disciplinary design that a program will address these concerns. Although CDIO 4.4.5 and 4.4.6 are strong contributors, they are not essential elements in all engineering specialties, however each program should provide contributions from some of the CDIO level 4 topics as part of its distinctive character.

“**3.1.5 Use of engineering tools:** An ability to create, select, apply, and extend appropriate techniques, resources, and modern engineering tools to a range of engineering activities, from simple to complex, with an understanding of the associated limitations.”

CDIO 1.3 "Advanced Engineering Fundamental Knowledge, Methods and Tools" is a natural fit as *must have*, especially as it pertains to the methods and tools component. The statement “with an understanding of the associated limitations” also requires CDIO 2.4.4 "Critical Thinking," a topic that is ubiquitous to many of the CEAB attributes. Although CDIO 2.1.2 "Modeling" does fit within this attribute, it has already been met with CEAB 3.1.2 and consequently it is a contributor, but not a *must have* and there are numerous topic areas where tools may be used.

“**3.1.6 Individual and team work:** An ability to work effectively as a member and leader in teams, preferably in a multi-disciplinary setting.”

The *must have* topics are under CDIO 3.1 "Teamwork," specifically CDIO 3.1.1 "Forming Effective Teams," 3.1.2 "Team Operation," and 3.1.4 "Team Leadership." The latter topic on team leadership was included given that CEAB Attribute 3.1.6 explicitly mentions “work effectively as a ... leader.” Contributions could also be evident in 3.1.3 "Team Growth and Evolution" which is good to see within a team environment, but not strictly required for functioning. CEAB mentions a preference for multidisciplinary teams, but not a requirement, thus 3.1.5 "Technical and Multi-disciplinary Teaming" could be a strong contributor without being a *must have.*

“**3.1.7 Communication skills:** An ability to communicate complex engineering concepts within the profession and with society at large. Such ability includes reading, writing, speaking and listening, and the ability to comprehend and write effective reports and design documentation, and to give and effectively respond to clear instructions.”

CDIO 2.2.2. "Survey of Print and Electronic Literature" is viewed as a *must have* given the constantly increasing volume of on-line information and the importance of being able to process this information properly. Seven of the topics under CDIO 3.2 "Communications" were also included (3.2.1 - 3.2.7) as essential subject matter that is closely aligned to this CEAB attribute. Some additional components of CDIO 3.2 make contributions that are not explicitly required by CEAB, covering things like negotiating, networking, and communication in a foreign language. Although Canada is a bilingual nation, communication in more than one language is not explicitly required by the CEAB attributes.

"3.1.8 Professionalism: An understanding of the roles and responsibilities of the professional engineer in society, especially the primary role of protection of the public and the public interest."

CDIO 2.5.1 "Ethics, Integrity, and Social Responsibility" is an essential aspect due to the social responsibility component. CDIO 4.1.1 "Roles and Responsibilities of Engineers" and CDIO 4.1.3 "Society's Regulation of Engineering" are also *must have* components for this attribute. Other items that could contribute include CDIO 2.5.2 "Professional Behavior and Responsibility" and the impact of engineering on society (CDIO 4.1.2, CDIO 4.1.4-4.1.7). These latter topics, although related to Professionalism, fit more appropriately under CEAB Attribute 3.1.9 and consequently they are only listed as a *could have*.

"**3.1.9 Impact of engineering on society and the environment:** An ability to analyse social and environmental aspects of engineering activities. Such abilities include an understanding of the interactions that engineering has with the economic, social, health, safety, legal, and cultural aspects of society; the uncertainties in the prediction of such interactions; and the concepts of sustainable design and development and environmental stewardship."

The direct mapping to topics under CDIO 4.1 is expected, and all aspects of 4.1 are *must have* topics either here or under Professionalism. CDIO 4.3.1 "Setting goals and requirements" is also essential as it brings in "ethical, social, environmental, legal and regulatory influences," and the "probability of change" at the fourth level. Numerous other CDIO topics have the potential to contribute societal context, depending on how they are presented and system thinking will be invaluable in assessing the bigger picture, as it is throughout.

"**3.1.10 Ethics and equity:** An ability to apply professional ethics, accountability, and equity."

The mapping to CDIO 2.5 is direct. CDIO 4.1 also provides contributions related to the societal context. Note the distinction made between ethics and regulation, which are often addressed together in a curriculum.

"**3.1.11 Economics and project management:** An ability to appropriately incorporate economics and business practices including project, risk and change management into the practice of engineering, and to understand their limitations."

CDIO 4.2.5 must be combined with 2.1.4 to incorporate economics in a framework of uncertainty to manage risk. 4.3.4 explicitly addresses project management while many other topics have the potential to contribute experience of the limitations through a context of practice.

"**3.1.12 Life-long learning:** An ability to identify and to address their own educational needs in a changing world, sufficiently to maintain their competence and contribute to the advancement of knowledge."

CDIO 2.4.5 addresses the self-awareness to identify needs, and integrate new general knowledge learned through 2.4.6 and current developments in engineering under 2.5.4, all *must have* topics.

APPLICATION

The global mapping in table 1 shows clear correlation between the CDIO and CEAB approaches that is not surprising. Its primary utility is in convincing administrators that we are on the right track in a single presentation slide. It is inadequate for detailed assessment, which requires at least the depth provided by table 2.

Even non-CDIO engineering programs can benefit from this analysis as a basis for validation of their curriculum through having a well thought out list of topic areas that can contribute to satisfying the CEAB attributes. Still, the largest benefit will be to CDIO programs whose curricula are already mapped to CDIO topics. They can validate their programs to the new CEAB requirements by demonstrating they have already addressed the relevant CDIO topics at an adequate level of complexity, as confirmed by their stakeholder surveys. Thus CDIO benchmarking and development documentation provides the direct support for accreditation through a rigorous forward mapping of CDIO topics to CEAB attributes.

Program audits are a part of CEAB accreditation and should also be part of ongoing program development under CDIO. The matrix of table 2 provides a back mapping of CEAB attributes to the topic areas where evidence for the existence of those attributes may be found, and through those topics back to course activities and deliverables that may be assessed directly.

CDIO Standards 2 and 12 require continuous curriculum development based on stakeholder input, and CEAB 3.1 requires "processes in place that demonstrate that program outcomes are being assessed in the context of these attributes, and that the results are applied to the further development of the program." The mapping in table 2 allows stakeholder input based on either the 12 CEAB Attributes or the 14 CDIO Topics to be used to inform program development in both contexts.

CEAB Attributes are based on students at the point of graduation, thus assessment of these attributes will be concentrated towards the end of the program. We don't expect students to have these attributes earlier in their development. However, we can follow that development by linking the final attributes to syllabus topics that will be visited and revisited repeatedly throughout the program. That process can be tracked by an Introduce-Teach-Utilize curriculum analysis as part of the CDIO benchmarking process [2,4,5].

CONCLUSION

A program demonstrated to meet a reasonable collection of CDIO Syllabus Topics with outcomes at appropriate levels meets the CEAB Graduate Attributes requirements. The only exception is in the technical knowledge base where both standards lack detail that must be validated for each discipline or program separately.

A subset of the CDIO Syllabus has been identified as *must have* items for each CEAB attribute. That should not be interpreted to mean that addressing only those topics is sufficient to meet that attribute. There must also be sufficient integration to demonstrate the attributes within the larger context of engineering practice, represented in part by the multiple additional topics expected to provide contributions to each CEAB attribute.

This unidirectional mapping shows how a subset of topics from the third level of the CDIO Syllabus can adequately address the new CEAB requirements for Graduate Attributes, however it does not support the inverse mapping. A program that meets the CEAB Attributes does not necessarily meet CDIO standards. It must also be emphasized that this is not **the** subset of topics, but simply **a** subset that is adequate, and that some substitution could produce different flavours of CDIO programs that would also meet CEAB requirements.

REFERENCES

[1] Engineers Canada / Ingénieurs Canada, Canadian Engineering Accreditation Board: Accreditation Criteria and Procedures / Bureau canadien d'agrément des programmes de génie: Normes et procédures d'agrément, 2008. (Latest edition: http://www.engineerscanada.ca/e/files/Accreditation_Criteria_Procedures_2009.pdf)

[2] Crawley, E.F.; Malmqvist, J.; Östlund, S.; Brodeur, D.R., Rethinking Engineering Education: The CDIO Approach, Springer, New York, 2007.

[3] International Engineering Alliance, "Graduate Attributes and Professional Competencies - Version 2," Kyoto IEA meetings, 15-19 June 2009. [Online]. Available: www.washingtonaccord.org/IEA-Grad-Attr-Prof-Competencies-v2.pdf. [Consulted on 2010-03-01].

[4] Bankel, J.; Berggren, K.F.; Engström, M.; Wiklund, I.; Crawley, E.F.; Soderholm, D.; El Gaidi, K.; Östlund, S., Benchmarking Engineering Curricula with the CDIO Syllabus, *Int. J. Engng Ed.,* Vol. 21, 121-133, 2005.

[5] CDIO Syllabus and other materials online: http://www.cdio.org/

Biographical Information

Guy Cloutier is an Associate Professor and program coordinator in the Department of Mechanical Engineering at École Polytechnique de Montréal. His research interests are in the areas of metrology, process simulation and engineering education.

Ronald Hugo is an Associate Professor and Head of Mechanical and Manufacturing Engineering at the University of Calgary. His research interests are in the areas of experimental fluid dynamics, energy systems and engineering education.

Rick Sellens is an Associate Professor in the Department of Mechanical and Materials Engineering at Queen's University. His research background is in Fluid Mechanics and more recently in Biomechanics and he has been actively involved in facilities development to support active learning, including the recently completed Integrated Learning Centre at Queen's.

Corresponding author

Dr. Rick Sellens
Mechanical and Materials Engineering
Queen's University
Kingston, Ontario
Canada K7L 3N6
613 533 6760
rick.sellens@queensu.ca