CDIO AS A CROSS-DISCIPLINE ACADEMIC MODEL

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ABSTRACT

The purpose of this paper is to examine the broader applicability of the Conceive Design Implement Operate (CDIO) curricular model (Crawley, Malmqvist, Ostlund, Brodeur, & Edstrom, 2014) across academic disciplines adjacent to and outside of engineering.

To study this, we examined a sample of five selected undergraduate degree programs developed at Sheridan College Institute of Technology and Advanced Learning as case studies. Housed in four different academic Faculties, each program has varying proximity to technology education. We used one additional CDIO-based program, Bachelor of Engineering – Mechanical, in the Faculty of Applied Science and Technology (Mechanical), as the control group to assess how an engineering program might appear in our findings.

To test our questions, using a series of matrices, we mapped discipline-specific program learning outcomes (PLOs) and characteristics onto the CDIO framework and UNESCO framework (Delors, et al., 2013), assessing compatibility / incompatibility.

We discovered that we were able to successfully map non-engineering discipline curricula to the CDIO model when terminology was modified to be discipline-specific. Non-engineering programs mapped closely at the first level (X) where the CDIO model merges with UNESCO standards, and at the CDIO Standards level, where all studied programs rated highly. Some discipline-specific modifications were required to achieve a mapping to the second level (X.X) of CDIO Syllabus. Additionally, our observations of the mapping to the second level of CDIO Syllabus revealed significant variation in curricular emphasis by program.

KEYWORDS

Universal model, Non-engineering disciplines, Mapping, UNESCO, CDIO Syllabus, CDIO Standards: 1 - 12

INTRODUCTION

The purpose of this paper is to examine the broader applicability of the Conceive Design Implement Operate (CDIO) curricular model (Crawley E. F., Malmqvist, Ostlund, Brodeur, & Edstrom, 2014) across academic disciplines adjacent to and outside of engineering. Our inspiration to undertake this investigation is rooted in the dynamic growth of our home institution, Sheridan College Institute of Technology and Advanced Learning (Sheridan). As such, a brief institutional history is provided as background context for undertaking this research.

Sheridan is a post-secondary institution on three campuses in adjacent cities of the Greater Toronto Area, in Ontario, Canada. Sheridan serves approximately 20,000 full-time students and 35,000 continuation education students. Founded in 1967 as a College of Applied Arts and Technology, it initially offered 1-year (certificate), 2-year (diploma) and 3-year (advanced diploma) credentials. In 2003, Sheridan changed designation along with 4 other regional institutions, and became an Institute of Technology and Advanced Learning (ITAL), analogous to becoming a polytechnic. This provided the institution with access to develop and offer 4-year undergraduate degrees. Since then, Sheridan has experienced a dynamic curriculum growth, developing and offering 20 new 4-year undergraduate degrees, with a number of additional degrees in various stages of development and application. In 2012, president Dr. Jeff Zabudsky announced the “Sheridan Journey,” with the vision, “to become Sheridan University, celebrated as a global leader in undergraduate professional education” (Sheridan). While established as a prolific research institution among Canadian large colleges – ranked first in formal research projects completed, 2015 (Research Infosource Inc., 2015) – focus remains on educating students, with a strategic goal to, “inspire creative, innovative teaching and learning” (Sheridan, 2013).

One such degree in the development and application process is the Bachelor of Engineering – Mechanical. The authors of this program, lead by Dr. Farzad Rayegani, selected the CDIO curriculum model along with Canadian Engineering Accreditation Board (CEAB) requirements to drive curriculum development. They appreciated the CDIO philosophy of positioning graduates to be successful in their discipline by combining theory and practice in a way unique in engineering education. To summarize, the initiative was developed to ensure engineering students receive a rational, complete and generalizable universal education that prepares them to be leaders and in some cases entrepreneurs (Crawley E. , Malmqvist, Lucas, & Brodeur).

During development there was an engaged discussion about the CDIO curriculum model across disciplines and Faculties at Sheridan, especially as CDIO’s emphasis on creativity and experiential learning aligns well with our institutional values. These conversations included one of the authors of this paper, Dave Wackerlin, who at the time was co-authoring a Bachelor of Architectural Studies degree development. The cross-institutional prolific development of new degree programs, that extended conversation, and this author’s reflection upon how CDIO might inform development of Architectural Studies curricula, inspired this research paper.

The current CDIO initiative is geared specifically to engineering, but given its success, the topic this paper investigates is CDIO’s broader applicability across disciplines. **Can the CDIO philosophy be generalized to create a more universal model that includes other academic disciplines?** Our literature review indicates that no academic institution has adopted this model for programs outside of engineering and engineering related sciences (such as Engineering Technology and programs of Applied Science), which is intuitive, considering the engineering directed terminology used in the model. However, our own personal experience with the CDIO model suggests that it resonates outside the focused disciplines of engineering. To explore this topic, we asked three sets of questions.

First, **could we effectively map other discipline specific curriculum onto the CDIO Standards and Syllabus structure by varying the engineering specific terminology?** If so, **would that create at an effective curricular variant that preserves the CDIO values and strengths?** Preliminary findings with a technology-related program suggested so, and we elected to broaden the investigation to other programs to find if there is a boundary of effective mapping as disciplines become less technical in nature.

Our second research question is, **how does mapping each program to the CDIO model inform future iterations of syllabus revision undertaken by that program?** Each of the five programs studied is mandated to undertake comprehensive program review at maximum span of 7-year intervals. Observations from our research could potentially identify opportunities the program might explore for implementation in their curriculum.

Our last research question informs CDIO curriculum and those who implement CDIO curricula at their institutions. **How can the study of the mapping of non-engineering disciplines to CDIO, and in particular how portions of the syllabus are emphasized differently by non-engineering disciplines, inform future iterations of the CDIO syllabus and particulars of its implementation?**

METHOD

Participants

To study our questions, we used a sample of selected undergraduate degree programs developed at Sheridan College as case studies. Housed in four different academic Faculties, each program has varying proximity to technology education. The programs and Faculties studied are:

- Bachelor of Applied Information Sciences – Information Systems Security in the Faculty of Applied Science and Technology (Computing),
- Bachelor of Health Sciences – Kinesiology and Health Promotion in the Faculty of Applied Health & Community Studies (Health Sciences),
- Bachelor of Architectural Studies in the Faculty of Applied Science and Technology (Architecture),
- Bachelor of Illustration in the Faculty of Animation, Arts & Design (Illustration),
- Bachelor of Business Administration – Accounting in the Pilon School of Business (Accounting).

Additionally, we used a CDIO-based program, Bachelor of Engineering – Mechanical in the Faculty of Applied Science and Technology (Mechanical), as control group to asses how an engineering program might appear in our findings.

Design

To test our questions, we mapped discipline specific program learning outcomes (PLOs) and characteristics onto the CDIO framework and UNESCO (Delors, et al., 2013) framework, assessing compatibility / incompatibility.

Our data sources were formal degree application / renewal documents that had been submitted to our provincial government, provided by each of the individual programs. These documents were:

- Computing; Application for Ministerial Renewal 2012 (Sheridan, 2012)
- Health Sciences; Program Review 2012 (Sheridan, 2012)
- Architecture; Application for Ministerial Consent 2014 (Sheridan, 2014)
- Illustration; Application for Ministerial Renewal 2012 (Sheridan, 2012)
- Accounting; Application for Ministerial Consent 2012 (Sheridan, 2012)
- Mechanical; Application for Ministerial Consent 2014 (Sheridan, 2014)

To ensure that our comparator curricula was sufficiently robust for this study, we established that all of the programs participating met benchmarks for quality through a review of the degree application / renewal documents. We found that all five degree programs:

- Were developed or renewed within the last 4 years of this study, suggesting modern curriculum theory and practice had been implemented,
- Were designed internally by professional academics who as a team possessed expertise in their fields, industrial experience, and teaching / learning expertise,
- Were designed following an institutionally mandated internal process and receiving multi-stage approvals to ensure quality,
- Where applicable, were designed in alignment with established professional standards
- Employed Program Advisory Councils (PACs) in both development and delivery upon operation.

Our review of these quality assurance measures validated that the programs studied use curricula of quality sufficient to study.

We also performed a review of the CDIO model to confirm its suitability for consideration in this study. Notable literature included the works of Crawley et al, (Crawley E. F., Malmqvist, Ostlund, Brodeur, & Edstrom, 2014) (Crawley E. , Malmqvist, Lucas, & Brodeur) which detail the CDIO model, and review of the UNESCO Know – Do – Live – Be pedagogical model (Delors, et al., 2013). One author also attended the 2014 10th annual CDIO conference in Barcelona, Spain, and observed paper presentations by CDIO participant institutions. Our review validated that CDIO curriculum is suitable for study as curricular exemplar.

When comparing these programs to the CDIO model, we separated our observations into three categories. We considered the top level (X) of the CDIO syllabus, which Crawley identifies as mapping to the UNESCO Know – Do – Live – Be model, (Delors, et al., 2013), the second level (X.X) of the CDIO Syllabus with more detailed description, and the CDIO Standards.

Setting and Procedure

Stage 1 – Study of the “detailed program map” for each program.

Each detailed program map was reviewed and studied in detail. Containing a compressed version of course outlines, complete with course description, critical performance statements, course learning outcomes and evaluation plans, detailed program maps revealed the details of courses that made up the curriculum, in addition to specific detailed administrative information such as delivery method and credit hours, etc.

Stage 2 – Study of “PLO’s and the “PLO matrix” for each program.

Each of the PLO’s were reviewed to understand the topics and level of learning that the program was delivering. The outcomes had been assembled in a matrix by program authors to illustrate the correlation between them and the individual courses that make up the programs. Authors of this study reviewed those matrices to understand depth and breadth of individual PLO integration into the curriculum.

Stage 3 – Development of UNESCO and CDIO Mapping Matrices.

Applying Stage 1 and 2 findings, three mapping matrices were developed to assess the data.

Matrix 1: UNESCO / Program Comparison. Using the four pillars of learning (know – do - live - be) defined by UNESCO as categories, we compared the UNESCO model to the PLOs of each program. In addition, a fifth category, titled “Additional” was introduced with the purpose to harmonize the UNESCO and CDIO models (see Table 1). Findings were established based on a literature review of the detailed program map and learning outcomes, and verified by each author for consistency. The matrix was designed with the x-axis representing the 4+1 categories of UNESCO / Additional and the y-axis representing each of the six programs. A numeric rating scale from 1 to 5 was used to assess the correlation, with 1 being least correlated and 5 being most correlated.

Matrix 2 – CDIO Syllabus / PLO Comparison. Using the five categories of the CDIO Syllabus level 1 (X) and level 2 (X.X), a matrix was developed to compare the CDIO syllabus to each of the PLO’s for the six programs studied. The matrix was designed with the CDIO Syllabus categories on the x-axis and the PLO’s on the y-axis. Using a colour coding technique each of the cells were highlighted according to the PLO’s proximal relationship to CDIO Syllabus item. To express this relationship three categories were established; engineering application relationship to CDIO (white); non-engineering application relationship to CDIO (grey); and no relationship (black).

Findings from our analysis comparing PLO’s to CDIO Syllabus Level 2 (X.X) are organized into three categories to answer each of our study questions; observations, impact for program, and impact for CDIO. ‘Patterns’, which are groupings of the colour coded cells read vertically in the matrix and identified by an outline in the figures, are described in the observations associated to that program.

Matrix 3 – CDIO Standards / Program Comparison. Using the 12 Standards outlined in the CDIO Standards, a matrix was developed to compare with each of the six programs studied.

The matrix was designed with the 12 Standards on the x-axis, and the each of the six programs on the y-axis. We applied the rubric criteria defined by the CDIO, from 0 to 5. Each of the cells were rated based on their relationship to the CDIO Standards.

Stage 4 – Collaboration with Program Specific Experts. Throughout the mapping of the data, discussions were had with each Associate Dean representing the six programs to clarify or provide additional information required. Following matrices development, we met with the Associate Dean from each program to discuss our research methodology and findings. Their intimate knowledge of each program aided in achieving valid and reliable findings. There were a few instances where changes were suggested. When this occurred, a thorough explanation was given to ensure changes were accurately made and to ensure everyone was informed. Interviewing experts from each of the programs also reduced potential bias as it equalized our depth of knowledge of individual programs used to examine results.

Addressing Potential Sources of Bias

This study relies on coding of documents and interpretation of language to establish findings. As such, there are several potential sources of bias that we have addressed.

A potential source of bias, that PLO's were not written with CDIO in mind, and therefore direct interpretation to CDIO can be discretionary, was addressed by thorough review of course outlines, course learning outcomes, and collaborative interviews with program leaders to ensure accurate mapping.

Another source of bias we considered was observer bias in the form of interpretative differentiation between coders (the authors) in assigning colour coding to the cells. The two authors addressed this by each author validating all matrices drafted by the other, and through collaborative interviews with program leaders.

We discovered that reading the matrices horizontally versus vertically when colour coding had some influence on results. To address this, we double coded each matrix (both horizontally and vertically), and validated each other authors coding.

REPORT/FINDINGS (RESULTS)

Matrix 1 - UNESCO / Program Comparison

As illustrated in Table 1 below, despite some variation in emphasis between the curricula examined, it is evident there is a strong correlation between all six of the programs and UNESCO Standards. While there is some variation in total scores of individual programs, we did not find evidence suggesting that this is indicative of quality difference between the curricula. Rather, it suggests their proximal relationship to UNESCO, which is close in all cases. This analysis revealed a stronger relationship between the 6 programs and UNESCO than to the CDIO Syllabus at level 2 (X.X). We attribute this to several factors. First, UNESCO is multi-disciplinary curriculum design model, and therefore was designed with a multi-disciplinary lens, where the CDIO Syllabus was designed with a focus on the disciplines of engineering. Secondly, it can be expected that all programs in our study have a strong emphasis on the 'know' and 'do' categories as this aligns with Sheridan's core value of preparing industry ready graduates. Lastly, the UNESCO standards are higher level and less detailed than CDIO Syllabus Level 2, so there are fewer and less defined categories to compare to. More varying responses are found in categories 'live', 'be', and 'additional'. We consider that this variation is indicative of variation between discipline foci rather than quality of curriculum. For example, Accounting is the only program to achieve a 5 in the 'Additional' category, which could be anticipated given the business focus of the program.

Table 1. Matrix 1: UNESCO / Program Comparison

UNESCO Mapping					
Scale 1 - 5	**Know**	**Do**	**Live**	**Be**	**Additional**
	DISCIPLINARY KNOWLEDGE AND REASONING	PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES	INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION	THE INNOVATION PROCESS	LEADERSHIP AND ENTREPRENEURSHIP
Bachelor of Engineering - Mechanical	5	4	3	5	4
Bachelor of Applied Info Sciences – Info Systems Security	5	5	3	4	3
Bachelor of Health Sciences	5	5	4	3	4
Bachelor of Architectural Studies	5	5	4	4	4
Bachelor of Illustration	5	4	4	4	3
Bachelor of Business Administration - Accounting	5	4	4	4	5

Matrices 2 – CDIO Syllabus / PLO Comparison

This study surfaced a number of interesting observations regarding individual programs, which are detailed below. There are also some findings that are generalizable across all of the programs; there was a high degree of non-engineering (grey) mapping, and certain terms that might commonly be considering engineering related (math, science, design, experiment, implement, operate) were found regularly throughout the non-engineering PLO's. Our findings supported our primary research question, as we were able to map all programs to the CDIO standard successfully. Pattern comments identify areas of interest in observations, but do not attempt to address all features of the matrix. Further research could have increased detailed observations for individual programs and follow-up on pattern observations.

Bachelor of Engineering – Mechanical

Table 2. Bachelor of Engineering – Mechanical: CDIO Syllabus / PLO

Bachelor of Engineering - Mechanical	1 DISCIPLINARY KNOWLEDGE AND REASONING			2 PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES					3 INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION			4 CONCEIVING, **DESIGNING, IMPLEMENTING,** AND OPERATING SYSTEMS IN THE ENTERPRISE, SOCIETAL AND ENVIRONMENTAL CONTEXT – THE INNOVATION PROCESS						CONDENSED EXTENDED CDIO SYLLABUS: LEADERSHIP AND ENTREPRENEURSHIP	
	1.1 KNOWLEDGE OF UNDERLYING MATHEMATICS AND SCIENCES	1.2 CORE ENGINEERING FUNDAMENTAL KNOWLEDGE	1.3 ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE, METHODS AND TOOLS	2.1 ANALYTICAL REASONING AND PROBLEM SOLVING	2.2 EXPERIMENTATION, INVESTIGATION AND KNOWLEDGE DISCOVERY	2.3 SYSTEM THINKING	2.4 ATTITUDES, THOUGHT AND LEARNING	2.5 ETHICS, EQUITY AND OTHER RESPONSIBILITIES	3.1 TEAMWORK	3.2 COMMUNICATIONS	3.3 COMMUNICATIONS IN FOREIGN LANGUAGES	4.1 EXTERNAL, SOCIETAL, AND ENVIRONMENTAL CONTEXT	4.2 ENTERPRISE AND BUSINESS CONTEXT	4.3 CONCEIVING, SYSTEMS ENGINEERING AND MANAGEMENT	4.4 **DESIGNING**	4.5 **IMPLEMENTING**	4.6 OPERATING	4.7 LEADING ENGINEERING ENDEAVORS	4.8 ENTREPRENEURSHIP
Degree Program Level Learning Outcomes																			
1 Create sustainable engineering solutions through applications of mathematical, scientific and fundamental engineering concepts, methods and techniques.																			
2 Create sustainable engineering solutions that are based on feasibility, technology, environmental impact, and economic assessments.																			
3 Validate conclusions through investigations of complex engineering problems that include relevant experimentation, data collection, analysis, interpretation and synthesis.																			
4 Design a system, component, or process that meets regulatory and industry standards and considers, health and safety risks, economic, environmental, cultural and social impacts																			
5 Demonstrate proficiency in the techniques, skills, and tools necessary for mechanical engineering practice with an understanding of the associated limitations.																			
6 Perform as an effective team member and leader in collaborative, multidisciplinary settings.																			
7 Communicate technical concepts and issues effectively with both technical and non-technical audiences.																			
8 Explain the roles and responsibilities of the professional engineer in society.																			
9 Analyze the impact of engineering solutions in a global, economic, societal and environmental context.																			
10 Demonstrate ethical conduct, accountability and equity consistent with the requirement of the profession.																			
11 Incorporate business practices, including project management tools & techniques, into practices of engineering.																			
12 Develop self-leadership strategies to enhance personal and professional effectiveness that is responsive to a rapidly changing world.																			
Pattern #		1									2			3				4	

direct relationship to engeineering
yes but discipline specific
absent, no relationship

Pattern #1 - An even distribution of learning in disciplinary knowledge and reasoning that is emphasized in a large number of the learning outcomes. The correlation represents a direct relationship to the CDIO Syllabus, which we expected because it is an engineering discipline.

Pattern #2 – No foreign languages PLO. Several of the studied programs, including Mechanical, did not emphasize foreign language.

- Impact for Program; Opportunity to explore ways of integrating foreign language in the existing curriculum and provide pathway to global employment.
- Impact for CDIO; Opportunity to further focus on the importance of foreign languages and provide recommendations on how it can be successfully integrated into curriculum.

Pattern #3 – There is an equal distribution of conceiving, designing, implementing and operating spread throughout the learning outcomes. This aligns and is a positive example of CDIO implementation intent.

- Impact for Degree; This aligns with the industry standard according to the CDIO mandate and prepares graduates of the program to be industry ready.

Pattern #4 – Low relationship between ‘entrepreneurship’ and the course learning outcomes.

- Impact on Program; Existing engineering programs at Sheridan have extensive industry partnerships that is not reflected in this list, opportunity to formalize in PLO’s.
- Impact on CDIO: Opportunity to Incorporate intrapreneurship overtly into syllabus.

Pattern #5 - Program learning outcomes were written with intent to align to CDIO, which created an observable learning outcome mapping 1:1 relationship emphasis. They were also all engineering aligned. The map views as ‘less dense’, which we interpret as a reflection of this CDIO oriented design compared to the other study participants, whose program addressed CDIO Syllabus in a less targeted, broader (more cells, less engineering) manner.

Bachelor of Applied Information Sciences – Information Systems Security

Table 3. Information Systems Security: CDIO Syllabus / PLO

Bachelor of Applied Information Sciences – (Information Systems Security),	1 DISCIPLINARY KNOWLEDGE AND REASONING			2 PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES					3 INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION			4 CONCEIVING, **DESIGNING, IMPLEMENTING,** AND OPERATING SYSTEMS IN THE ENTERPRISE, SOCIETAL AND ENVIRONMENTAL CONTEXT – THE INNOVATION PROCESS						CONDENSED EXTENDED CDIO SYLLABUS: LEADERSHIP AND ENTREPRENEURSHIP	
	1.1 KNOWLEDGE OF UNDERLYING MATHEMATICS AND SCIENCES	1.2 CORE ENGINEERING FUNDAMENTAL KNOWLEDGE	1.3 ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE, METHODS AND TOOLS	2.1 ANALYTICAL REASONING AND PROBLEM SOLVING	2.2 EXPERIMENTATION, INVESTIGATION AND KNOWLEDGE DISCOVERY	2.3 SYSTEM THINKING	2.4 ATTITUDES, THOUGHT AND LEARNING	2.5 ETHICS, EQUITY AND OTHER RESPONSIBILITIES	3.1 TEAMWORK	3.2 COMMUNICATIONS	3.3 COMMUNICATIONS IN FOREIGN LANGUAGES	4.1 EXTERNAL, SOCIETAL, AND ENVIRONMENTAL CONTEXT	4.2 ENTERPRISE AND BUSINESS CONTEXT	4.3 CONCEIVING, SYSTEMS ENGINEERING AND MANAGEMENT	4.4 **DESIGNING**	4.5 **IMPLEMENTING**	4.6 OPERATING	4.7 LEADING ENGINEERING ENDEAVORS	4.8 ENTREPRENEURSHIP
Degree Program Level Learning Outcomes																			
1 Analyze, **design,** program, **implement**, secure and maintain network applications																			
2 **Design, implement,** test and document object-oriented software systems																			
3 Install, configure, build, troubleshoot, secure, modify and maintain computer system architectures and networks to meet user requirements																			
4 Initiate and undertake critical analysis of security issues to develop and **implement** security policies and to solve problems																			
5 **Design, implement,** program, secure, troubleshoot and administer databases																			
6 Communicate clearly, concisely, and correctly in written, spoken, and visual form that fulfills the purpose and meets the needs of diverse audiences																			
7 Reframe information, ideas, and concepts using the narrative, visual, numerical, and symbolic representations which demonstrate understanding																			
8 Interact with others in groups or teams in ways that contribute to effective working relationships and the achievements of goals																			
9 Identify, evaluate, report on and, understand when, how and where to refer security issues																			
10 Identify and **implement** investigative techniques adhering to legal processes and case law																			
11 Analyze, **design,** and **implement,** security and threat auditing procedures																			
12 Identify, **design,** and **implement** processes and vulnerability assessments to counter corporate, state, and politically sanctioned losses																			
Pattern #				1							2					3		4	

direct relationship to engeineering
yes but discipline specific
absent, no relationship

Pattern #1 – Analytical reasoning and problem solving is a ‘core value’ in the program, and shows as strong mapping on the matrix.

Pattern #2 – Currently there is no learning outcome that addresses communication in foreign languages. See: Bachelor of Engineering - Mechanical.

Pattern #3 – There is an equal distribution of conceiving, designing, implementing and operating spread throughout the learning outcomes. This aligns with the intent of the design of this degree program. Aligns closely with Bachelor of Engineering – Mechanical.

Pattern #4 – Low relationship between ‘entrepreneurship’ and the course learning outcomes. See: Bachelor of Engineering - Mechanical

Bachelor of Health Sciences – Kinesiology and Health Promotion

Table 4. Kinesiology and Health Promotion: CDIO Syllabus / PLO

	Bachelor of Health Sciences – Kinesiology and Health Promotion	1 DISCIPLINARY KNOWLEDGE AND REASONING			2 PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES					3 INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION			4 CONCEIVING, **DESIGNING, IMPLEMENTING,** AND OPERATING SYSTEMS IN THE ENTERPRISE, SOCIETAL AND ENVIRONMENTAL CONTEXT – THE INNOVATION PROCESS						CONDENSED EXTENDED CDIO SYLLABUS: LEADERSHIP AND ENTREPRENEURSHIP	
		1.1 KNOWLEDGE OF UNDERLYING MATHEMATICS AND SCIENCES	1.2 CORE ENGINEERING FUNDAMENTAL KNOWLEDGE	1.3 ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE, METHODS AND TOOLS	2.1 ANALYTICAL REASONING AND PROBLEM SOLVING	2.2 EXPERIMENTATION, INVESTIGATION AND KNOWLEDGE DISCOVERY	2.3 SYSTEM THINKING	2.4 ATTITUDES, THOUGHT AND LEARNING	2.5 ETHICS, EQUITY AND OTHER RESPONSIBILITIES	3.1 TEAMWORK	3.2 COMMUNICATIONS	3.3 COMMUNICATIONS IN FOREIGN LANGUAGES	4.1 EXTERNAL, SOCIETAL, AND ENVIRONMENTAL CONTEXT	4.2 ENTERPRISE AND BUSINESS CONTEXT	4.3 CONCEIVING, SYSTEMS ENGINEERING AND MANAGEMENT	4.4 **DESIGNING**	4.5 **IMPLEMENTING**	4.6 OPERATING	4.7 LEADING ENGINEERING ENDEAVORS	4.8 ENTREPRENEURSHIP
	Degree Program Level Learning Outcomes																			
1	Develop scientficially based, goal directed physical activiy and lifestyle plans specific to individual and/or group needs and abilities																			
2	Provide leadership in the **implementation** of fitness and wellness promotion programs specifically developed for special populations that consider the variables associated with intergenerational programming and cultural diversity																			
3	Integrate research for the purpose of making informed planning decisions on health, fitness and performance-related outcomes in diverse populations																			
4	**Design** health promotion programs, establishing valid and appropriate approaches through application of the scientific method																			
5	Provide leadership in the intergration of health wellness and safety programming into corporte environments																			
6	Establish best treatment practices for populations with special needs within an inter-professional healthcare team environment																			
7	Guide individuals or groups to assist them in reaching their physical health and lifestyle goals																			
8	Manage the financial, legal and human resources necessary to operate a small business or work effectively within a larger corporate business																			
9	Recruit and train volunteers for a variety of health promotion and fitness initiatives in both the corporate and not-for-profit sectors.																			
10	Work in a manner consistent with professional ethics and pratice, and within legal and organization requirements																			
11	Communicate effectively in written, spoken and visual forms.																			
		1		2			3			4						5				6

direct relationship to engeineering
yes but discipline specific
absent, no relationship

Pattern #1 – This program has an emphasis on descriptive sciences, such as anatomy. It also has a focus on social / behavioural science applications of those sciences.

Pattern #2 – A strong emphasis on application of discipline specific knowledge.

Pattern #3 – Emphasis is placed on system thinking throughout the curriculum. This prepares students for the duties they will be required to do in the working field; such as designing health promotion programs for clients, advising clients of best treatment practices, ensuring clients reach fitness goals, etc.

Pattern #4 – Teamwork is a 'core value' of the curriculum and Health industry. Many of the graduates will be integrated with a team of professionals and with clients through services such as personal training.

Pattern #5 – There is an equal distribution of conceiving, designing, implementing and operating spread throughout the learning outcomes. This aligns with CDIO philosophy.

Pattern #6 – Emphasis is placed on leadership and entrepreneurship. Many students will graduate and work independently as entrepreneurs in the health and wellness industry.

Overall – Program matrix reveals an equitable distribution across PLO's and CDIO syllabus.

Bachelor of Architectural Studies

Table 5. Bachelor of Architectural Studies: CDIO Syllabus / PLO

	Bachelor of Architectural Studies	1 DISCIPLINARY KNOWLEDGE AND REASONING			2 PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES					3 INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION			4 CONCEIVING, **DESIGNING, IMPLEMENTING,** AND OPERATING SYSTEMS IN THE ENTERPRISE, SOCIETAL AND ENVIRONMENTAL CONTEXT – THE INNOVATION PROCESS						CONDENSED EXTENDED CDIO SYLLABUS: LEADERSHIP AND ENTREPRENEURSHIP	
		1.1 KNOWLEDGE OF UNDERLYING MATHEMATICS AND SCIENCES	1.2 CORE ENGINEERING FUNDAMENTAL KNOWLEDGE	1.3 ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE, METHODS AND TOOLS	2.1 ANALYTICAL REASONING AND PROBLEM SOLVING	2.2 EXPERIMENTATION, INVESTIGATION AND KNOWLEDGE DISCOVERY	2.3 SYSTEM THINKING	2.4 ATTITUDES, THOUGHT AND LEARNING	2.5 ETHICS, EQUITY AND OTHER RESPONSIBILITIES	3.1 TEAMWORK	3.2 COMMUNICATIONS	3.3 COMMUNICATIONS IN FOREIGN LANGUAGES	4.1 EXTERNAL, SOCIETAL, AND ENVIRONMENTAL CONTEXT	4.2 ENTERPRISE AND BUSINESS CONTEXT	4.3 CONCEIVING, SYSTEMS ENGINEERING AND MANAGEMENT	4.4 **DESIGNING**	4.5 **IMPLEMENTING**	4.6 OPERATING	4.7 LEADING ENGINEERING ENDEAVORS	4.8 ENTREPRENEURSHIP
	Degree Program Level Learning Outcomes																			
1	Recommend **design** choices based on a critical understanding of the relationship between human behaviour, the natural environment and the design of the built environment.																			
2	Analyze information pertaining to the programming, **design** and presentation processes involved in the architectural project. (The steps to conveying an architectural project to a prospective client include the programming of spaces in order to determine usages and adjacencies, the **implementation** of a coherent design that speaks to a concept, and the preparation of a presentation that will include drawings, models, photographs, studies, precedents, etc.)																			
3	Apply organizational, spatial, structural and constructional principles within the process of the conception and development of sites, spaces, building elements and tectonic components that will be used by individuals of varying physical and cognitive abilities.																			
4	Identify the diverse needs, values, behavioural norms and social/spatial patterns that characterize different cultures and individuals, and the implications of this diversity on the societal role and responsibilities of those working in the architectural profession.																			
5	Depict the diverse global and local traditions in architecture, landscape and urban **design,** as well as the factors that have shaped them.																			
6	Incorporate the principles that inform the **design** and selection of life-safety systems into buildings and their subsystems including legislation, building codes, and standards applicable to a given site and building design project.																			
7	Create a comprehensive program for an architectural project that accounts for client and user needs, appropriate precedents, space and equipment requirements, the relevant laws and standards, site selection, context and condition, and **design** assessment criteria, based upon an architectural idea.																			
8	Communicate through appropriate representational media the essential formal elements at each stage of the programming and design process, including technically precise description and documentation of a proposed **design,** for purposes of review and construction.																			
9	Respect the principles of sustainable **design** to produce projects that conserve natural and built resources, provide healthy environments for occupants/users, and reduce the impacts of building construction and operations on future generations.																			
10	Select appropriate combinations of building materials, components and assemblies for **design** details.																			
11	Formulate projects that fully integrate structural systems, environmental systems, life-safety systems, building envelopes and building service systems into building **design.**																			
12	Contribute to the **design** and/or **implementation** of applied research projects within a collaborative context.																			
13	Interpret information related to financing, building economics, construction cost control, life-cycle cost accounting and elements of project delivery that pertain to cost outcomes.																			
14	Describe the different methods of project delivery, the corresponding forms of service contracts, and the types of documentation required to render competent, ethical and responsible professional service.																			
15	Outline the techniques and skills for architects to work collaboratively with allied disciplines, clients, consultants, builders and the public in the building **design** and construction process, and to advocate on environmental, social and aesthetic issues in their communities.																			
16	Describe the profession's responsibility to the client and the public under the laws, codes, regulations and contracts common to the practice of architecture.																			
17	Explain the basic principles and practices applied in an architectural organization, including financial management, business planning, marketing, negotiation, project management and risk mitigation.																			
18	Apply the basic principles utilized in the appropriate selection of construction materials, products, components and assemblies, based on their inherent characteristics and performance.																			
	Pattern #	1		2								3			4				5	

direct relationship to engeineering
yes but discipline specific
absent, no relationship

Pattern #1 – There is less math and science than engineering programs, but direct engineering connection. The engineering connection is a direct translation to the understanding of how buildings are assembled through a series of structural courses.

Pattern #2 – Advanced engineering skills, analytical reasoning, investigating and system thinking are all 'core values' in the realm of architectural thinking. This is the foundation of understanding architecture.

Pattern #3 – There is no direct teaching of foreign languages, but several PLO's identify their importance.

- Impact for Degree: Given the degree program has a travel semester integrated into the curriculum, there is opportunity to broaden the focus on communication in foreign languages. This would also strengthen the understanding of cultural traditions in the field of design.

Pattern #4 – PLO's address conceiving, designing, and implementing. It is difficult to teach students through the making of full scale buildings. Strategies to overcome this are achieved through the making of scaled models.

- Impact for Degree: Find ways to have students work on full scale projects, such as the collaboration with Habitat for Humanity.

Pattern #5 – Learning outcomes emphasize leadership as Architectural practitioners are commonly 'prime consultants' who organize and lead the numerous consultants involved in construction projects. Learning outcomes emphasize entrepreneurship as consultants or partners in small businesses, a common growth outcome for graduates.

Bachelor of Illustration

Table 6. Bachelor of Illustration: CDIO Syllabus / PLO

Bachelor of Illustration	1 DISCIPLINARY KNOWLEDGE AND REASONING			2 PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES					3 INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION			4 CONCEIVING, **DESIGNING, IMPLEMENTING,** AND OPERATING SYSTEMS IN THE ENTERPRISE, SOCIETAL AND ENVIRONMENTAL CONTEXT – THE INNOVATION PROCESS						CONDENSED EXTENDED CDIO SYLLABUS: LEADERSHIP AND ENTREPRENEURSHIP	
	1.1 KNOWLEDGE OF UNDERLYING MATHEMATICS AND SCIENCES	1.2 CORE ENGINEERING FUNDAMENTAL KNOWLEDGE	1.3 ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE, METHODS AND TOOLS	2.1 ANALYTICAL REASONING AND PROBLEM SOLVING	2.2 EXPERIMENTATION, INVESTIGATION AND KNOWLEDGE DISCOVERY	2.3 SYSTEM THINKING	2.4 ATTITUDES, THOUGHT AND LEARNING	2.5 ETHICS, EQUITY AND OTHER RESPONSIBILITIES	3.1 TEAMWORK	3.2 COMMUNICATIONS	3.3 COMMUNICATIONS IN FOREIGN LANGUAGES	4.1 EXTERNAL, SOCIETAL, AND ENVIRONMENTAL CONTEXT	4.2 ENTERPRISE AND BUSINESS CONTEXT	4.3 CONCEIVING, SYSTEMS ENGINEERING AND MANAGEMENT	4.4 **DESIGNING**	4.5 **IMPLEMENTING**	4.6 OPERATING	4.7 LEADING ENGINEERING ENDEAVORS	4.8 ENTREPRENEURSHIP
Degree Program Level Learning Outcomes																			
1 Create illustrations from the development of the original concept to final execution																			
2 Apply theories and principles of **design** and communication to the development of effective illustrations																			
3 Communicate visually using drawing as a means of visual exploration, idea analysis, problem solving and expression of thought																			
4 Use a variety of technologies to create, capture and manipulate illustration elements in producing a final product																			
5 Work in a professional manner, maintaining professional relationships and communicating effectively with clients,coworkers and others																			
6 Apply appropriate and effective business practices when dealing with clients																			
Pattern #	1			2		3				4				5				6	

direct relationship to engeineering
yes but discipline specific
absent, no relationship

Observations

Pattern #1 – Fundamentals of math and science are addressed but not emphasized. We observe the curriculum emphasizes discovery characteristics across the matrix.

Pattern #2 – Analytical and problem solving is a core value and emphasis of the program. These are the fundamental skills in teaching students how to logically understand and solve a problem.

Pattern #3 and 5 – In the creative field of design (illustration) students are taught to be visual artist and use their imagination to understand problems and derive a solution. This systems thinking approach follows the methodology in place by CDIO as conceiving, designing, implementing and operating, one of the core values.

Pattern #4 – Communication is important in expressing attitudes visually and is also a core value.

- Impact on CDIO: Explore emphasis on different types of communication.

Pattern #5 – Emphasis on Design and Implement, which reflects discipline orientation, and the lack of requirement to 'operate' illustration installations.

Pattern #6 – In the field of design illustration we expect a significant number of artists become entrepreneurs.

- Impact for Degree: Opportunity to examine if additional entrepreneurship emphasis is appropriate.

Bachelor of Business Administration – Accounting

Table 7. Accounting: CDIO Syllabus / PLO

Pattern #1 – One of the fundamental skills (core value) of the accounting field is math. We observe a strong relationship to that specific stream in the CDIO Syllabus.

Pattern #2 – Problem solving, knowledge discovery, and system thinking are all 'core values' in the realm of accounting. Students will be working on a range of project types throughout their career that will address these core values; such as, developing strategic and tactile plans for organizations, use critical and creative thinking skills to address organizational opportunities and challenges, evaluating quantitative data and contextualizing it, etc.

Pattern #3 – As our economy and business industries continue to globalize, it is predictable that this program has a strong relationship to that portion of the CDIO syllabus. Globalization is a core value of the business cluster of degree programs.

Pattern #4 – There is an emphasis on conceiving and operating. This is emphasis is predictable as the industry follows the external accounting regulations and practices.

Pattern #5 – Though the field of business has a high rate of entrepreneurs, there is no direct entrepreneurship connection to the CDIO. In follow-up meeting we found that integration and definition of entrepreneurship differs from CDIO.

- Impact for CDIO: Opportunity to consider the ways Accounting defines and integrates entrepreneurship into their curriculum.

Matrix 3 – CDIO Standards / Program Comparison

As illustrated in Table 8 below, all programs studied are valid, strong curricula and are fully compliant to CDIO Standards, resulting in scores of 5/5. We found this result surprising at first examination. However, upon close review of the supporting documentation, we confirmed the reliability of these findings. As explanation, we consider that strong centralized program oversight, both internally within our institution through review processes, and externally by provincially mandated program renewal processes, cause programs to create and maintain robust quality assurance recording mechanisms. All programs are reviewed and revised within a 7-year timeframe to meet ministry standards, with renewal of ability to offer the program contingent upon successful renewal. Programs are often revised to ensure they align with the institutional vision and mission and are up-to-date with industry standards, and with professional advisory committees.

Note that each program was evaluated based on their discipline, not on engineering, which would have much lower applicability in learning outcomes. Where the word “Engineering” was used in Standard 4 and 6, it was replaced to reflect the specific disciple. For example, “Introduction to Engineering” was replaced with “Introduction to Accounting” to reflect the Bachelor of Business Administration program). Similarly, we reviewed documentation to ensure that appropriate discipline specific workspaces were provided in assessing compliance with Standard 6.

Table 8. Matrix 3 – CDIO Standards / Program Comparison

CDIO STANDARDS/RUBRIC	Standard 1 – The Context	Standard 2 – Learning Outcomes	Standard 3 -- Integrated Curriculum	Standard 4 -- Introduction to Engineering	Standard 5 -- Design-Implement Experiences	Standard 6 -- Engineering Workspaces	Standard 7 -- Integrated Learning Experiences	Standard 8 -- Active Learning	Standard 9 -- Enhancement of Faculty Competence	Standard 10 -- Enhancement of Faculty Teaching Competence	Standard 11 -- Learning Assessment	Standard 12 -- Program Evaluation
SHERIDAN DEGREE PROGRAMS												
Bachelor of Engineering - Mechanical	5	5	5	5	5	5	5	5	5	5	5	5
Bachelor of Applied Info Sciences – Info Systems Security	5	5	5	5	5	5	5	5	5	5	5	5
Bachelor of Health Sciences	5	5	5	5	5	5	5	5	5	5	5	5
Bachelor of Architectural Studies	5	5	5	5	5	5	5	5	5	5	5	5
Bachelor of Illustration	5	5	5	5	5	5	5	5	5	5	5	5
Bachelor of Business Administration - Accounting	5	5	5	5	5	5	5	5	5	5	5	5

CONCLUSIONS AND FURTHER RESEARCH

We successfully mapped non-engineering discipline curricula to the CDIO model when terminology was modified to be discipline specific. Non-engineering programs mapped closely at the first level (X) where the CDIO model merges with UNESCO standards, and at the CDIO Standards level, where all studied programs rated highly. Some discipline specific modifications were required to achieve a mapping to the second level (X.X) of CDIO Syllabus. Additionally, our observation of the mapping to the second level of CDIO Syllabus revealed significant variation in curricular emphasis by programs. Sources of these variations include characteristics inherent to the disciplines that vary their applicability to CDIO. For instance, the Illustration degree emphasized communication (3.2) heavily, while the Accounting degree emphasized mathematics (1.1), which makes inductive sense when considering the type of professions graduates enter. Second level variation could also include external influencers, such as professional governing bodies. For example, the Architectural Studies program was designed to align with Canadian Architectural Certification Board (CACB) standards. There was an even distribution of programs that adhered to external professional standards versus those with no such requirement, and we did not observe a general pattern of whether these programs varied more or less from CDIO. Rather, we observed that external governing bodies exert curricular design pressure on programs that may influence them independently (either towards or away from CDIO). Applying the current CDIO curricular model to non-engineering disciplines can inform curriculum development in important ways, but should not be interpreted as a checklist to be implemented without considering the disciplinary context.

Mapping each program to the CDIO Syllabus can inform future iterations of Syllabus revision undertaken by that program. For example, several of the programs studied might examine integrating foreign languages as a pathway towards accessing global employment for graduates.

Mapping these non-engineering programs to the CDIO model can inform future iterations of the CDIO model. For example, study of the Accounting program suggests an alternative way to consider entrepreneurship.

This research provides possibilities further research. Most importantly, there is an opportunity to convene a cross-disciplinary research team to examine the CDIO Syllabus at second level (X.X), develop a generalizable version of the third level (X.X.X), and design an implementation plan to assist curriculum designers. Another interesting direction of further research could be to analyse program and CDIO learning outcomes to Bloom's taxonomy in an effort to assess relative learning levels. While our research used degree renewal and application documents with 'Degree Level' sections to ensure that studied programs meet degree level outcomes, analysing both programs and the CDIO outcomes to Bloom's may have interesting results.

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BIOGRAPHICAL INFORMATION

Jordan Martin joined Sheridan in 2012 to bring his knowledge of the built environment to the classroom. Jordan is an intern architect and designer who has an educational background in architecture and urban design. He has worked extensively on projects related to mixed-use urban infill developments, sustainable urbanism and net-zero energy design strategies.

Dave Wackerlin is an associate dean for Sheridan's School of Architectural Technology. He leads the school teams with a strengths-based philosophy that promotes student, faculty, and curricular excellence by engaging people in professional activities that excite them while supporting organizational goals. Dave's research interests focus on curricular designs and innovative teaching methodology.

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