CONCEIVE DESIGN IMPLEMENT OPERATE™

Reconceptualizing Engineering Education
The CDIO Approach
(*Conceive, Design, Implement, Operate*)

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January 16,Sunday, 2022

Presentation Outline

- Engineering Education, Drives for Change, and Employability.
- The Learning Context for Professionals Practice and the Context of Engineering Education.
- The CDIO Initiative Reforming Engineering Education
- The CDIO Standards
- The CDIO Syllabus
- The Assessment and Levels of Proficiency
- The CDIO Faculty Development Program
- CDIO Academy
- How to Join

Engineering Education

Drives for Change and Employability

"The measure of intelligence is the ability to change."

Albert Einstein

What We Are Doing At Engineering Schools Is **NECESSARY BUT NOT SUFFICIENT**

Schools of Engineering should be engines for **SOCIAL AND ECONOMIC DEVELOMENTS**

The Purpose of Engineering Education

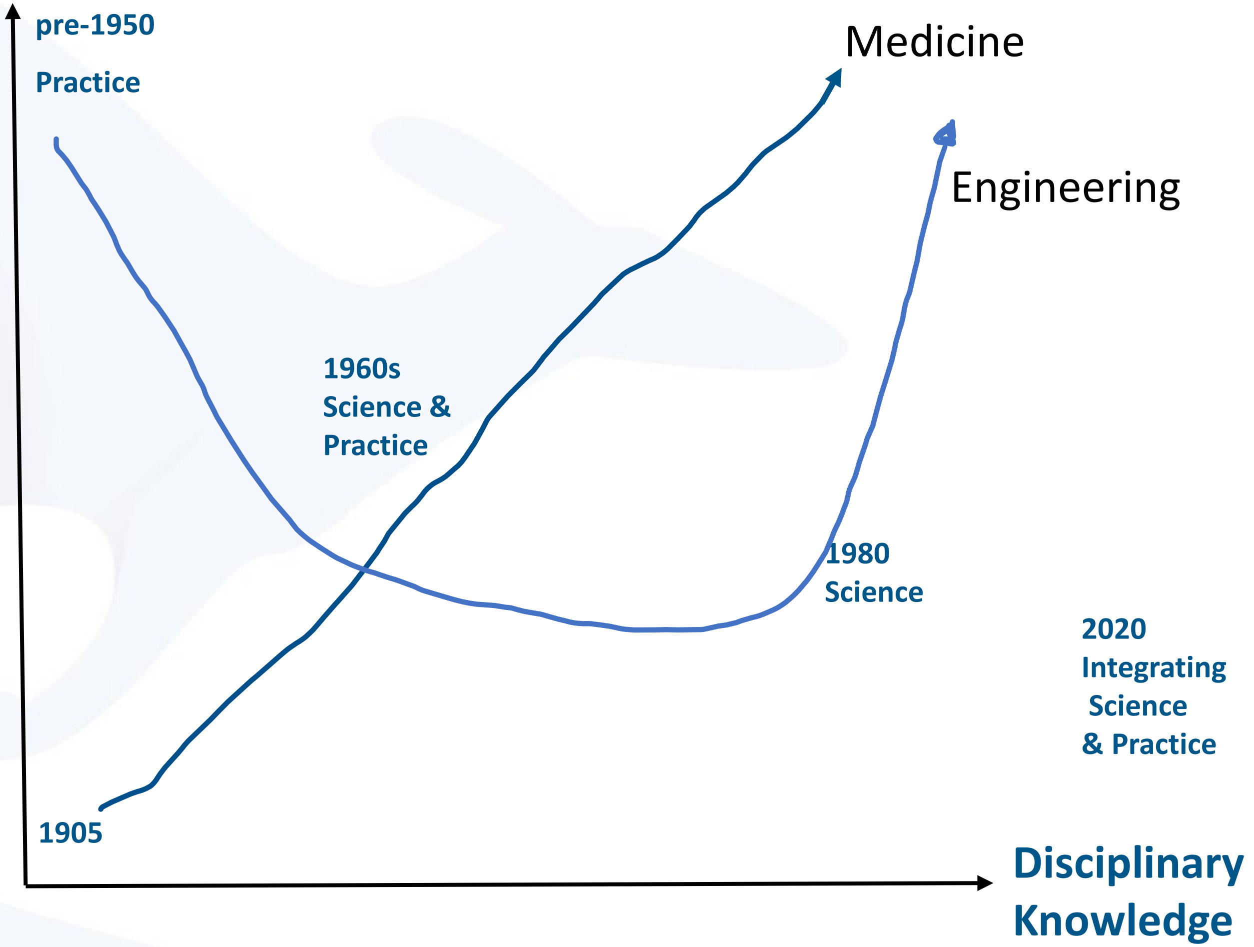
The purpose of engineering education :

- Is to provide the learning required by students to become successful professional engineers.
- To equip the students with the required technical expertise, social awareness with a mindset biased toward innovation and entrepreneurship.
- To train the learners to utilize the combined set of knowledge, skills, and attitudes to strengthening productivity and to enhance the sustainability and the quality of life.
- To prepare the learners for the uncertain environment that is increasingly based on technologically complex products, processes, and systems with a short life cycle.
- To equip the graduands with the research methodology

It is imperative that we improve the quality and nature of undergraduate engineering education

Development of Engineering Education

Personal, Interpersonal, Innovation, System Building, Implementation, Collaboration, Professional Skills & Practice.



Engineering Professionals need both dimensions, and we need to develop education that delivers both

The New England Journal of Medicine

American Medical Education 100 Years after the Flexner Report

MEDICAL EDUCATION
IN THE
UNITED STATES AND CANADA

A REPORT TO
THE CARNEGIE FOUNDATION
FOR THE ADVANCEMENT OF TEACHING

BY
ABRAHAM FLEXNER

WITH AN INTRODUCTION BY
HENRY S. PRITCHETT
PRESIDENT OF THE FOUNDATION

BULLETIN NUMBER FOUR (1910)
(Reproduced in 1960)
(Reproduced in 1972)

437 MADISON AVENUE
NEW YORK CITY 10022

Professional Engineer

- Professional, ENGINEER as one who has attained and continuously enhances technical, communications, and human relations knowledge, skills, and attitudes,

- Professional, ENGINEER contributes effectively to society by theorizing, conceiving, developing, and producing reliable structures, devices, systems and services of practical and economic value.

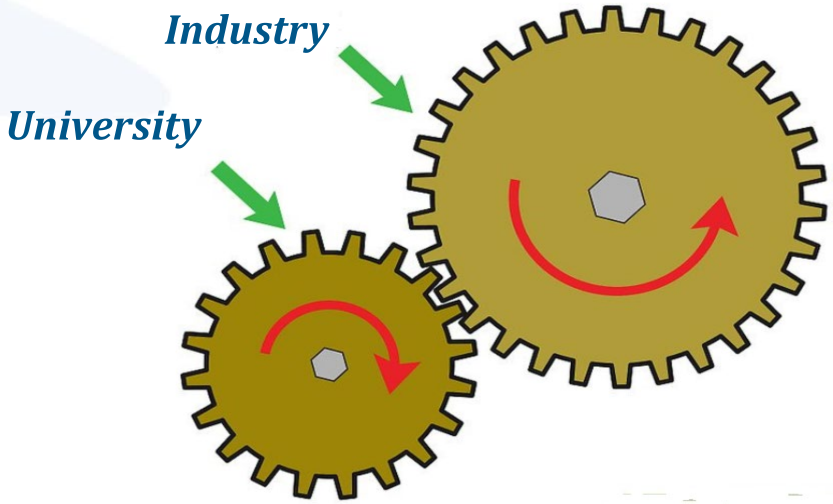
- The industry looking for graduates with a specific set of attributes.

- Critics of engineering education often cite number of inadequacies and complains about the engineering education system (contents and shape)

The Role of Engineering Colleges

- What engineering colleges should do to prepare the graduates to be able to become professional engineers and to have the required attributes?

- The Engineering Education developers should look at the context of engineering profession very closely to perform the required reform



Which one is gearing the other?

Central Questions for Engineering Colleges

Need to Know	What is the professional role and practical context of the profession(al)?
Program Learning Outcomes	What knowledge, skills and attitudes should students possess as they graduate from our programs?
Pedagogy Implementation	How can we do better at ensuring that students learn these skills?(Curriculum. Teaching, learning, workspace, assessment)

We need to ***innovate:***

- The Programs
- The Workplace and Facilities
- The Teaching & Learning Pedagogies
- The Assessment Tools and Methods

We need to **professionally *rehabilitate:***

- The Faculty Members

We need to ***engage:***

- The Students & the Stakeholders

Challenges Facing Engineering Education

Shifting Student Demography

School of Business Facilities

The University Strategy and Governance Model

Pedagogical Approaches

Relevant Academic Research

Bringing Research to Classroom

Faculty Readiness

Facilitators
Mentors
Advisors
Engagement

Importance of Innovative Partnership

University Degrees Vs. Professional Certificates

Big Threat from Agencies

Disruptive Technologies

Forms of Learning

Project Based Learning
Problem Bases Learning
Capstone
Cooperate
Research Base Learning
Flip Classes
Technical Visits
Case Studies
Surveys

Transform the challenges into drivers

Understanding Innovation within the Context of Engineering Education

What is innovation?

Disruptive (new way), Sustaining (better way), Efficiency (doing more for less)

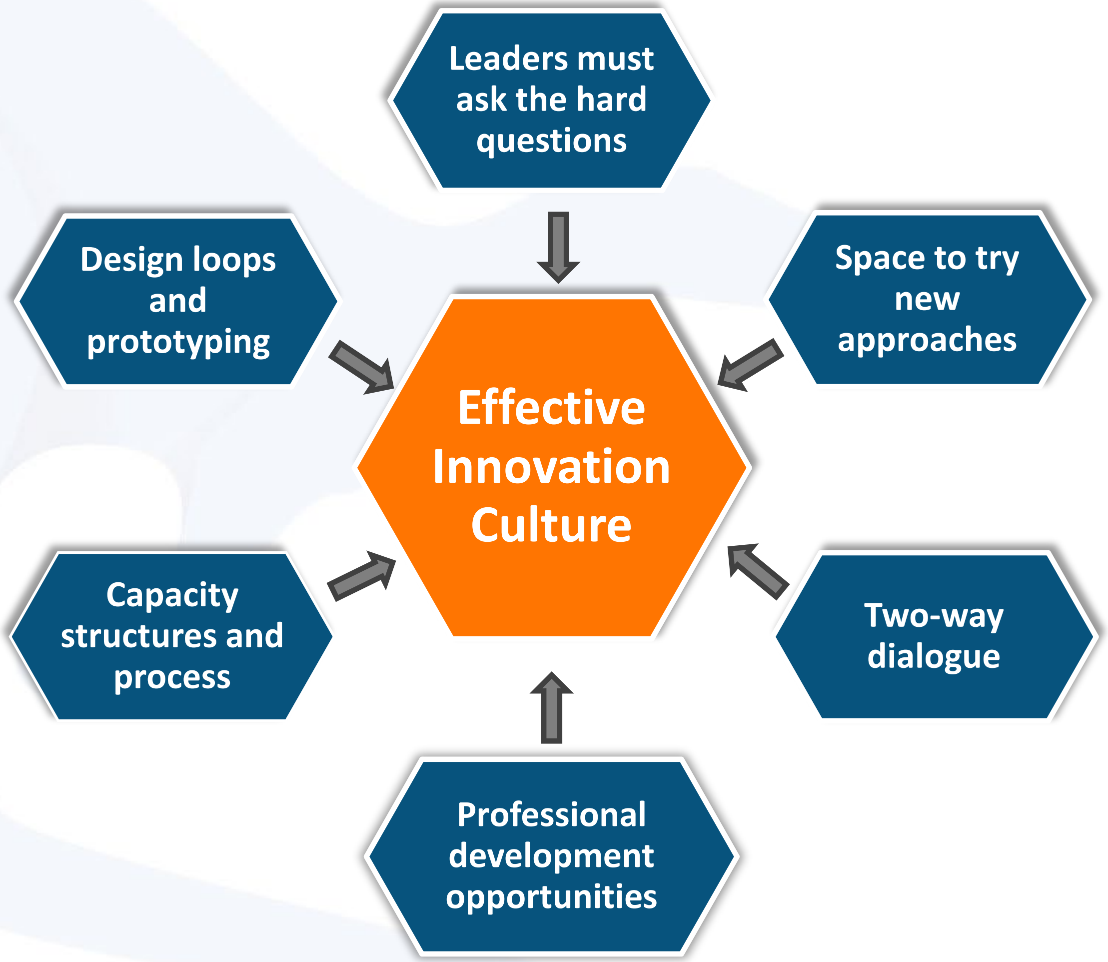
Innovation in engineering education?

A significant change in selected educational practices. It means doing new things and doing existing things better.

Why is it hard?

- Higher education systems are known to be rigid in management
- Universities have been referred to as ‘dinosaurs’ and the staff as ‘men in their ivory towers’
- University personnel are not well trained in innovation practices.

Understanding Innovation Culture within the Context of Engineering Education



Understanding Innovation within the Context of Business Education

Leadership (Not Managers)

University leaders must have a clear vision and ask the hard questions.

Communication Strategy (with stakeholders)

University leaders must be clear and transparent in their communication with clearly defined objectives and outcomes.

They must also champion engagement of stakeholders by two-way dialogues.

Resource Allocation

Universities must invest in professional development opportunities.

Capacity, Structure & Process (Change the Mindset)

Universities should adopt a growth mindset where every member of their community is important for the success of innovation.

Correct structures and processes must be set-up.

Learning Piloting

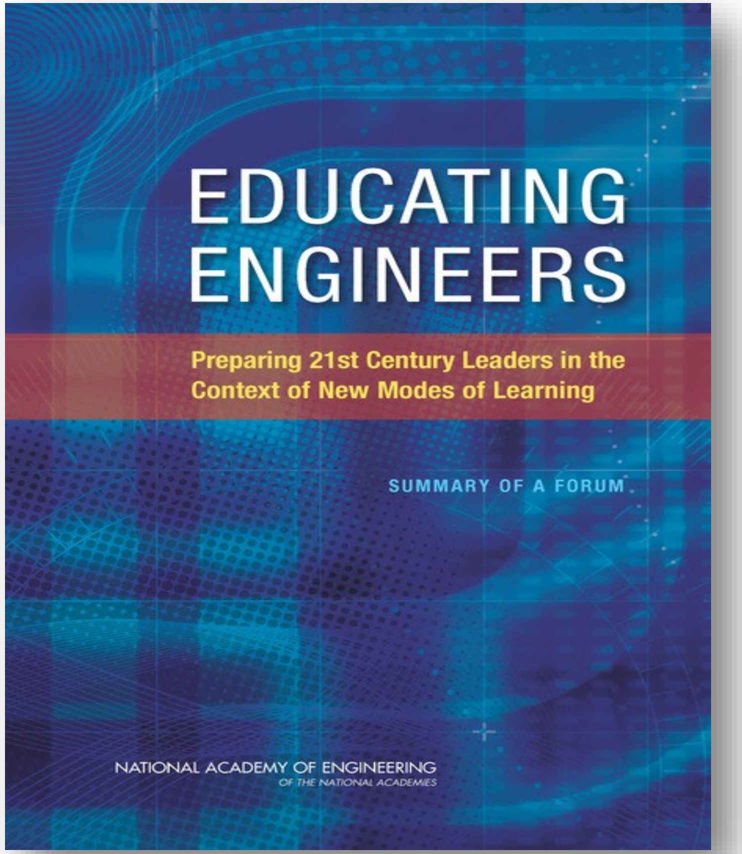
Change leaders should pilot small-scale version of change concepts before moving forward.

Rewards Policy

Leaders should work towards creating a policy environment that promotes and rewards innovative behaviors.

The Context of the Engineering Profession and Engineering Education

To become a leader, you must know the context of your environment



The Context of the Engineering Profession and Engineering Education

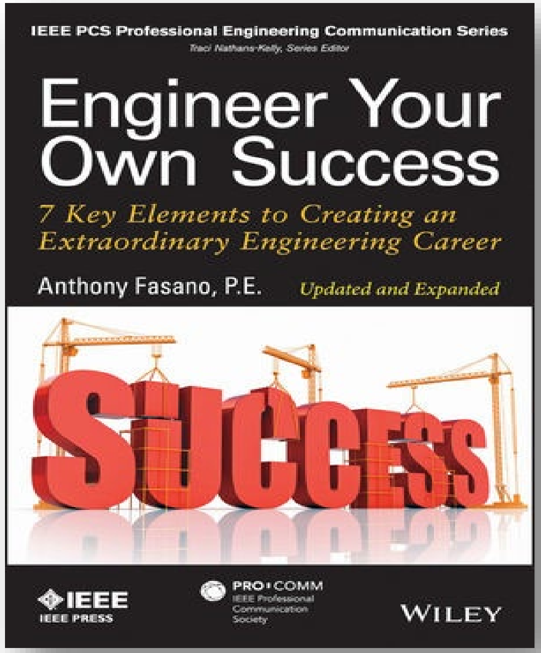
The word ***context.***

- One definition of context is "the circumstances or events that form the environment within which something exists or takes place, and that help in understanding."
- The definition has two parts: that there are surroundings, and that the surroundings help with understanding or the interpretation of meaning.
- An architect might say that to understand a building, one must examine the context of the neighborhood.
- It is this meaning of context—circumstances and surroundings that aid in understanding—that we use.

The Evolution of a Professional Engineering Context

A. The contextual elements that have not materially changed for PE include:

- A focus on the problems of the customer and society.
- The delivery of new products, processes and systems.
- The role of invention and new technology in shaping the future.
- The use of many disciplines to develop the “solution”.
- The need for engineers to work together, to communicate effectively, and to provide leadership in technical endeavors.
- The need to work efficiently, within resources and/or profitably



The Evolution of a Professional Engineering Context

B. Evolvement Seen in the context of engineering Profession

- Sustainability
- Globalization
- Innovation
- Leadership
- Entrepreneurship
- Knowledge Economy
- Demographics
- Technological Change
- Exponentiating technologies,
- Business Plan
- Mobility & Internationalization

PE
PROFESSIONAL ENGINEERING

Critics of engineering education

- Disproportionately low and increasingly poor economic return for the amount of employed engineering resources.
- Limited formal training in, and exposure to, a breadth of basic technical knowledge.
- Inadequate training and orientation to a meaningful depth of engineering skills.
- Inadequate understanding of the importance of precise test and measurement.
- Insufficient competitive drive a perseverance.
- Inadequate communication skills.
- Lack of discipline and control in work habits.
- Fear of taking personal risks.

—B. M. Gordon, Analogic Corporation

Industry Expectations

“Desired Attributes Of An Engineer”

1. A good understanding of engineering science fundamentals
2. A good understanding of design and manufacturing processes
3. A multi-disciplinary systems perspective
4. A basic understanding of the context in which engineering is practiced
5. Good communication skills
6. High ethical standards
7. An ability to think both critically and creatively—independently and operatively
8. Flexibility, i.e., the ability and self-confidence to adapt to rapid or major change
9. Curiosity and a desire to learn for life
10. A profound understanding of the importance of teamwork.

—The Boeing Company

Engineering Education Context Based on the Professional Context

- A focus on the needs of customers, clients, and patients
- Delivery of products, processes, and services
- Incorporation of inventions and new technologies
- Stewardship of the environment
- A focus on solutions, not disciplines
- Working with others and providing leadership in technical endeavors
- Communicating effectively
- Working efficiently, within resources, and/or profitably

Learning Outcomes
To Enhance Graduates Employability

Professional Behaviors

Ability to implement professional behaviors in the workplace.

Communication and Teamwork Skills

Effectively use communication as a tool for negotiating and creating new understanding and interacting with others in a team environment.

Critical Thinking

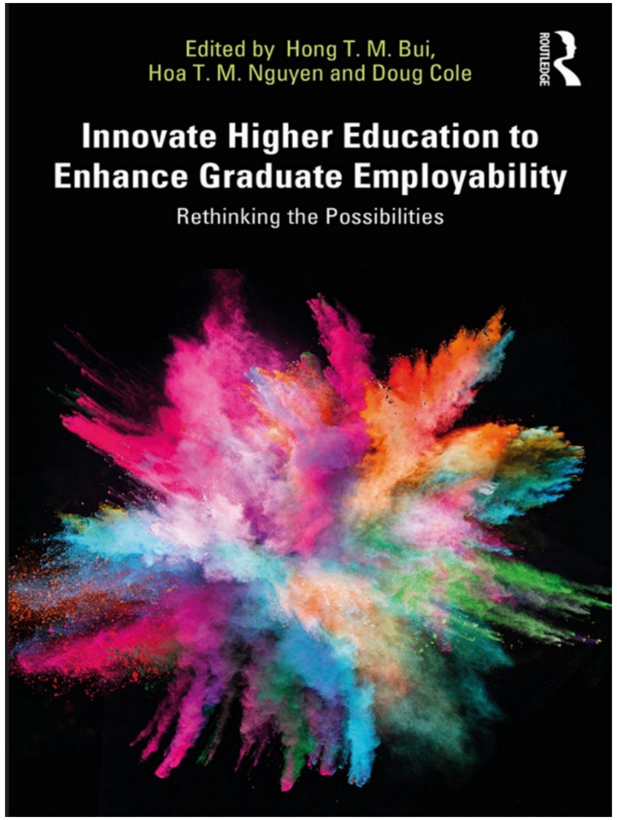
Ability to apply critical thinking and decision-making skills to solve complex and ambiguous problems.

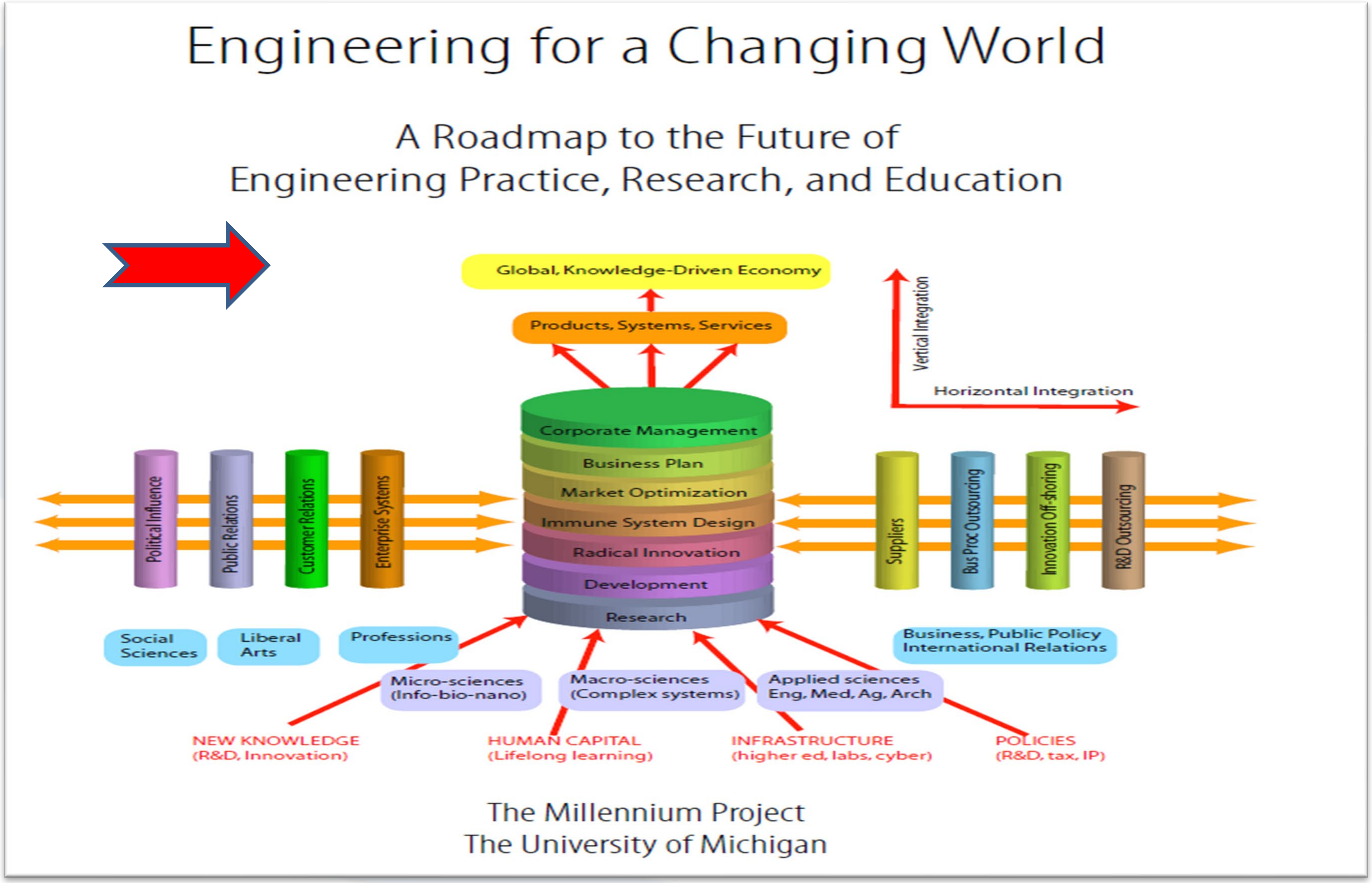
Entrepreneurial Skills

Ability to work effectively in an environment characterized by uncertainty and risk, and a willingness to meet new challenges innovatively and independently.

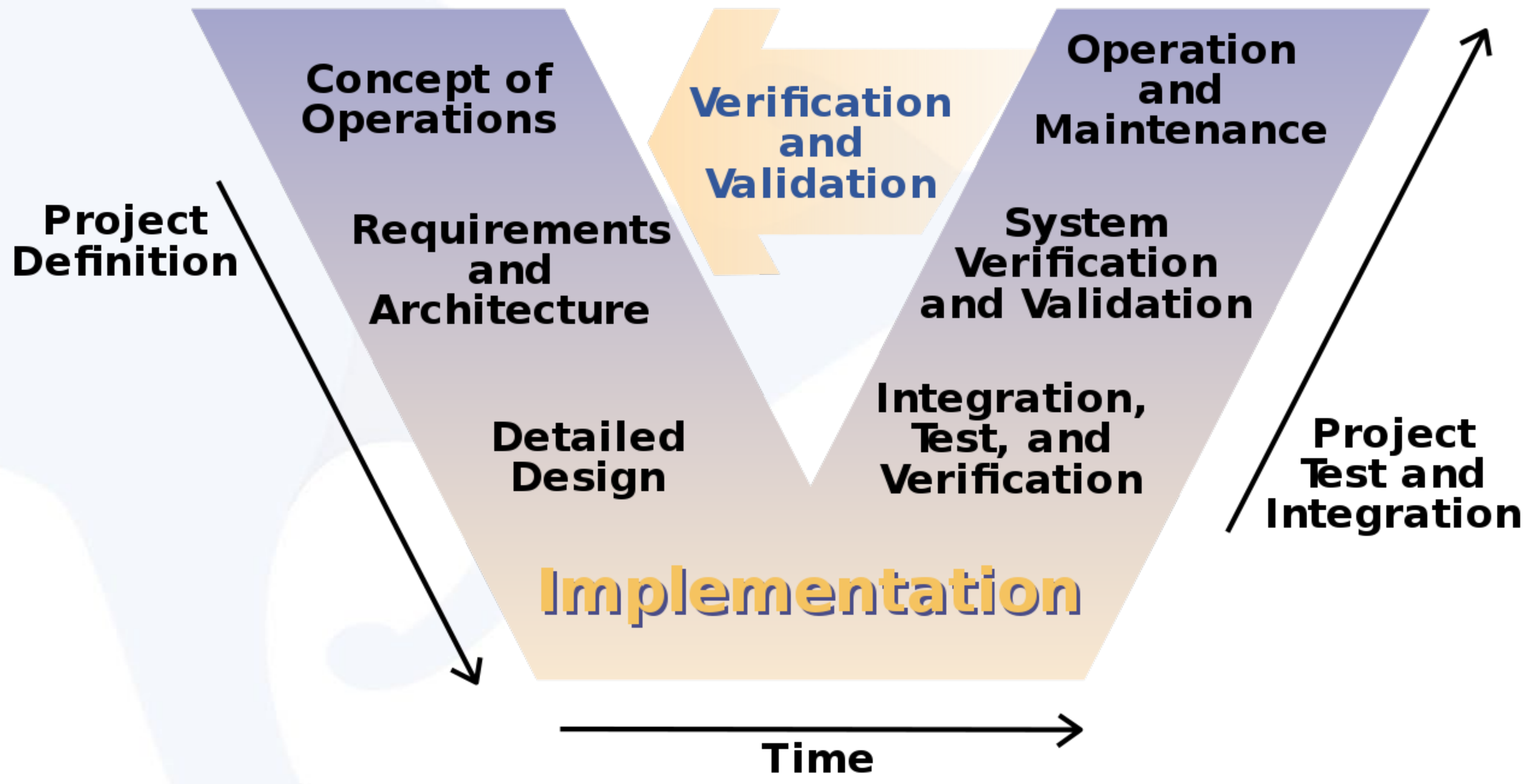
Planning & Organizational Skills

Ability to plan, organize, and control professional projects.




Engineering for a Changing World
A Roadmap to the Future of
Engineering Practice, Research, and Education
Global, Knowledge-Driven Economy
Products, Systems, Services
Vertical Integration
Horizontal Integration
Corporate Management
Business Plan
Market Optimization
Immune System Design
Radical Innovation
Development
Research
Political Influence
Public Relations
Customer Relations
Enterprise Systems
Suppliers
Bus Proc Outsourcing
Innovation Off-shoring
R&D Outsourcing
Social Sciences
Liberal Arts
Professions
Business, Public Policy International Relations
Micro-sciences (Info-bio-nano)
Macro-sciences (Complex systems)
Applied sciences Eng, Med, Ag, Arch
NEW KNOWLEDGE (R&D, Innovation)
HUMAN CAPITAL (Lifelong learning)
INFRASTRUCTURE (higher ed, labs, cyber)
POLICIES (R&D, tax, IP)
The Millennium Project
The University of Michigan

Systems Engineering Process

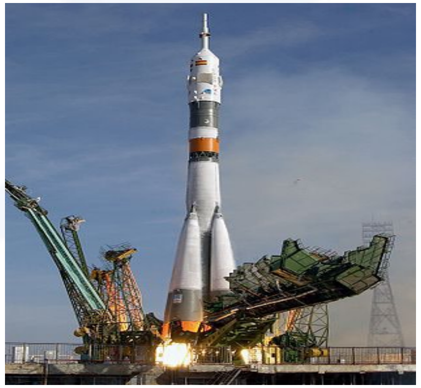


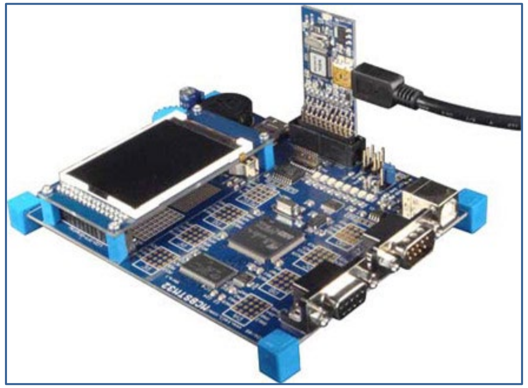
V model of the systems engineering process from:
"Systems Engineering Process II" by Osborne, Brummond et al.

The Professional Role(s) of Engineers

"Engineers **Conceive, Design, Implement**, and **Operate** Complex products and systems in a modern team-based Engineering environment."

Conceive	**Form or devise (a plan or idea) in the mind.** **Form a mental representation of;** **Imagine.** **Become affected by**





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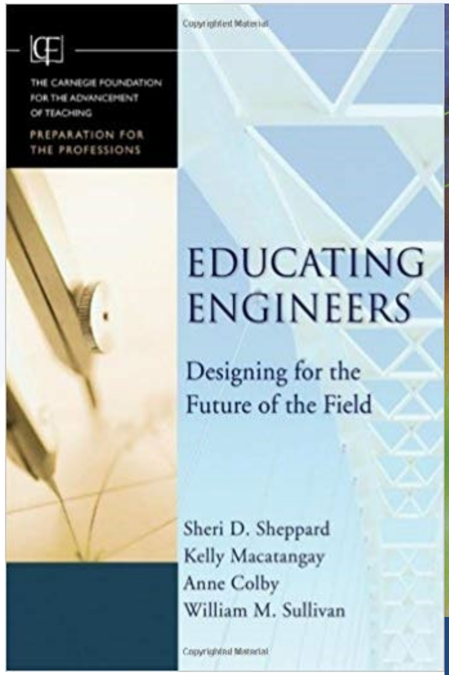
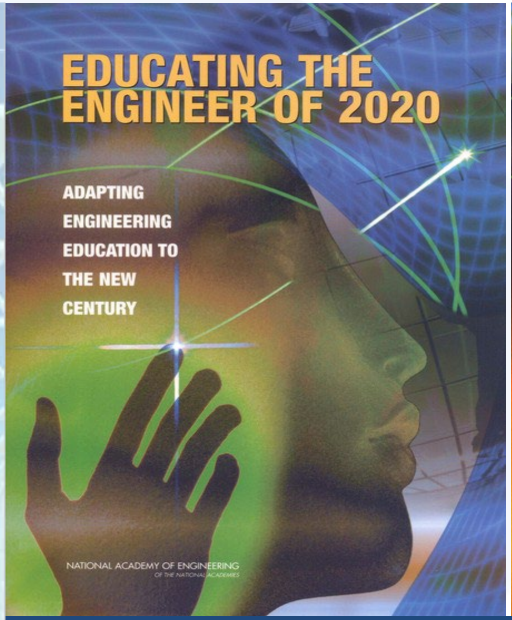
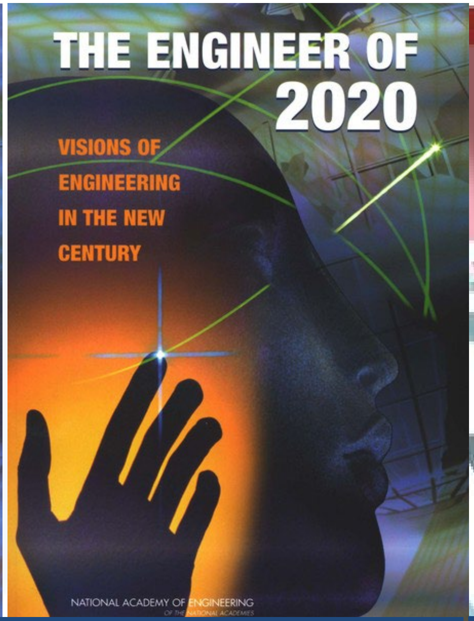
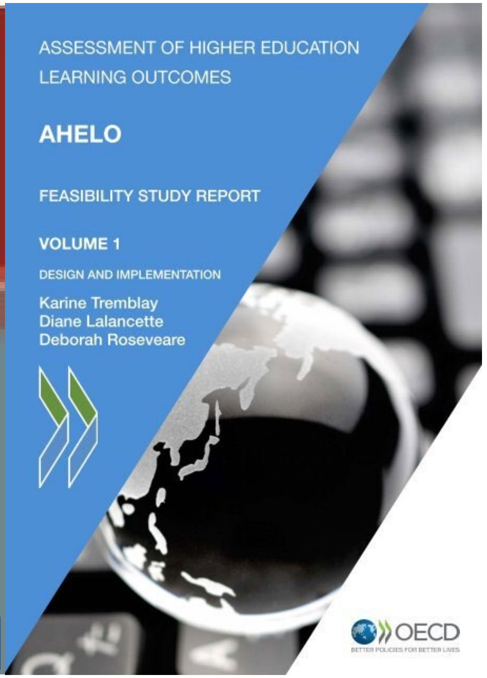




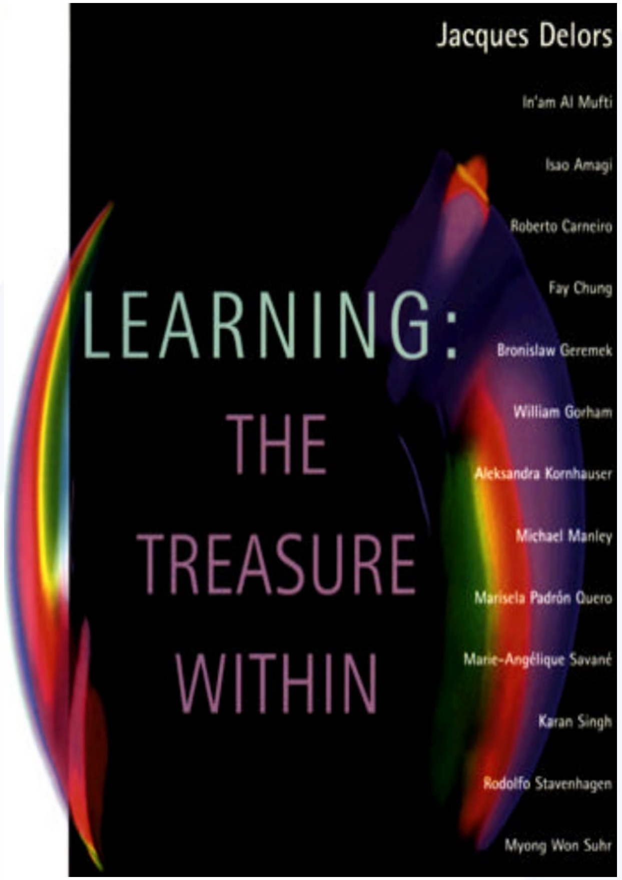


National Academy of Engineering

European Society for Engineering Education



Progress is impossible without change, and those who cannot change their minds cannot change anything

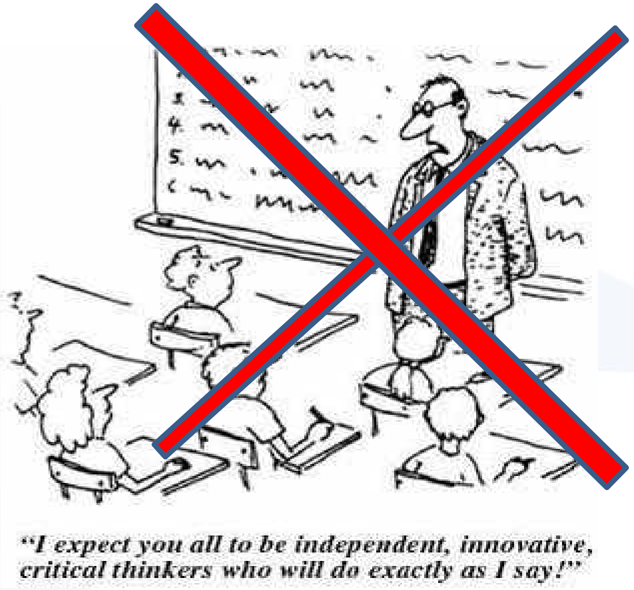


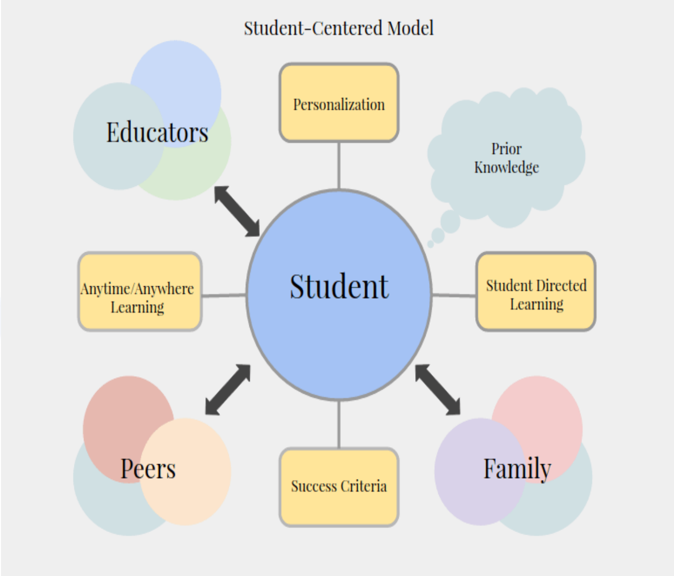
bologna process

World declaration on higher education
For the twenty-first century: vision and action

Change Is Inevitable

- Mission
- Content
- The Purpose
- The Methods of Delivery
- The Environment and the physical space
- The Assessment Methods
- The Roles
- The Culture and the attitude



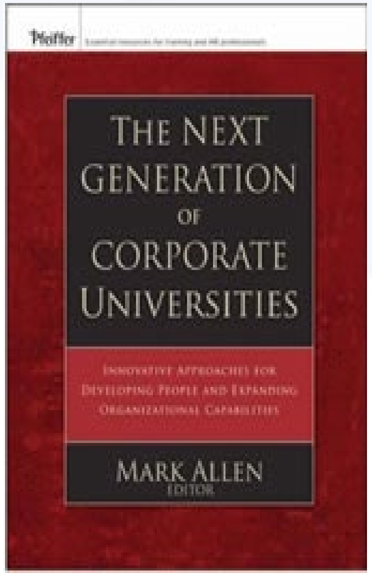


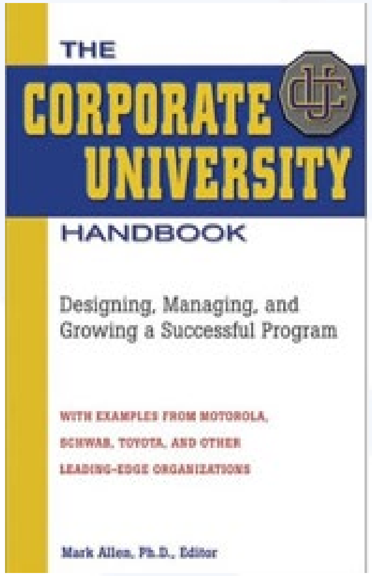
Teaching
Research
Services

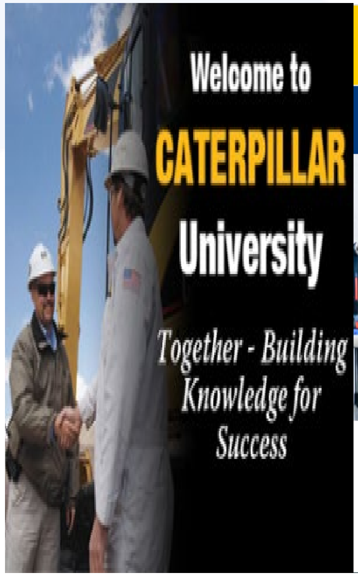
→

Learning
Innovation and Development
Shared Leadership

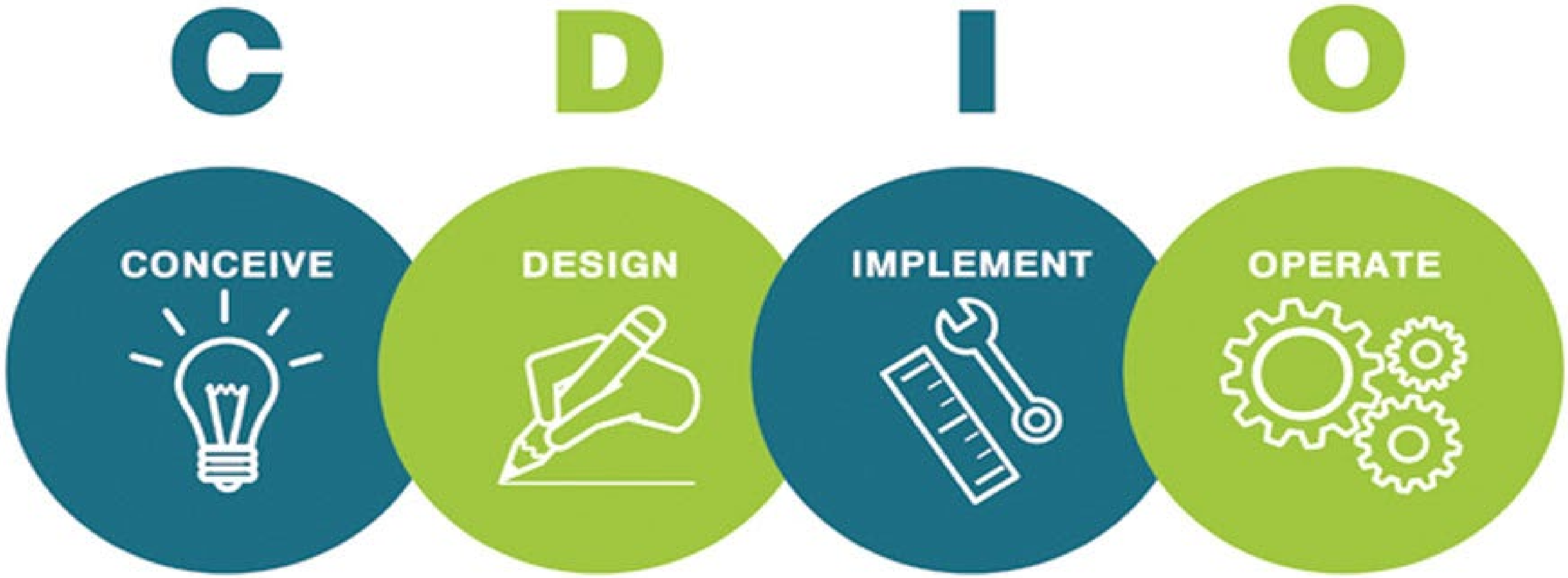
If you don't change
You will be changed







Initiative for Change



The Story Before CDIO: IUGREEE

Industry-university-government roundtable for enhancing engineering education (IUGREEE)

- Eng. Edu. programs throughout much of the 20th century offered students plentiful hands-on practice
- But as the century progressed and scientific and technical knowledge expanded rapidly, Eng. Edu. evolved into the teaching of engineering science.
- Teaching engineering practice was increasingly de-emphasized.
- As a result, industry in recent years has found that graduating students, while technically adept, lack many abilities required in real-world engineering situations. Major companies created lists of abilities they wanted their engineers to possess.

To encourage schools to meet real world needs and rethink their educational strategies, ABET, listed its expectations for graduating engineer Industry-university-government roundtable for enhancing engineering education (IUGREEE)

IUGREEE Composition (1995-1997)

Industry:

ABEWNWL
Aero Vironment
Allied Signal Aerospace
Allison Engine Company
Boeing
Boise Cascade
"Flight & Space" Magazine
GE Aircraft Engines
Hewlett-Packard
Honeywell
Hughes Electronics Company
Kaiser Aerospace
Lockheed Martin
McDonnell Douglas
Northrop Grumman
Parker Bertea Aerospace
Raytheon Aircraft Company
Rockwell International Corp.
Solar Turbines
Sundstrand Aerospace
TRW Space and Electronics Group
United Technologies Corp.
Weyerhauser
Williams International
Xerox Corp.

University:

Brigham Young University
Carnegie Mellon University
Clemson University
Duke University
Georgia Institute of Technology
Iowa State University
Johns Hopkins University
Loyola Marymount University
Massachusetts Institute of Technology
Princeton University
Purdue University
Stanford University
Texas A&M University
United States Air Force Academy
University of Arizona
University of California – Berkley
University of Florida
University of Minnesota
University of Tennessee
University of Washington
Virginia Polytechnic Institute and State University
Washington State University
Wichita State University
Worcester Polytechnic Institute

Government:

National Science Foundation (NSF)
National Aeronautics and Space Administration (NASA)
U.S. Department of Commerce
Sandia National Laboratories

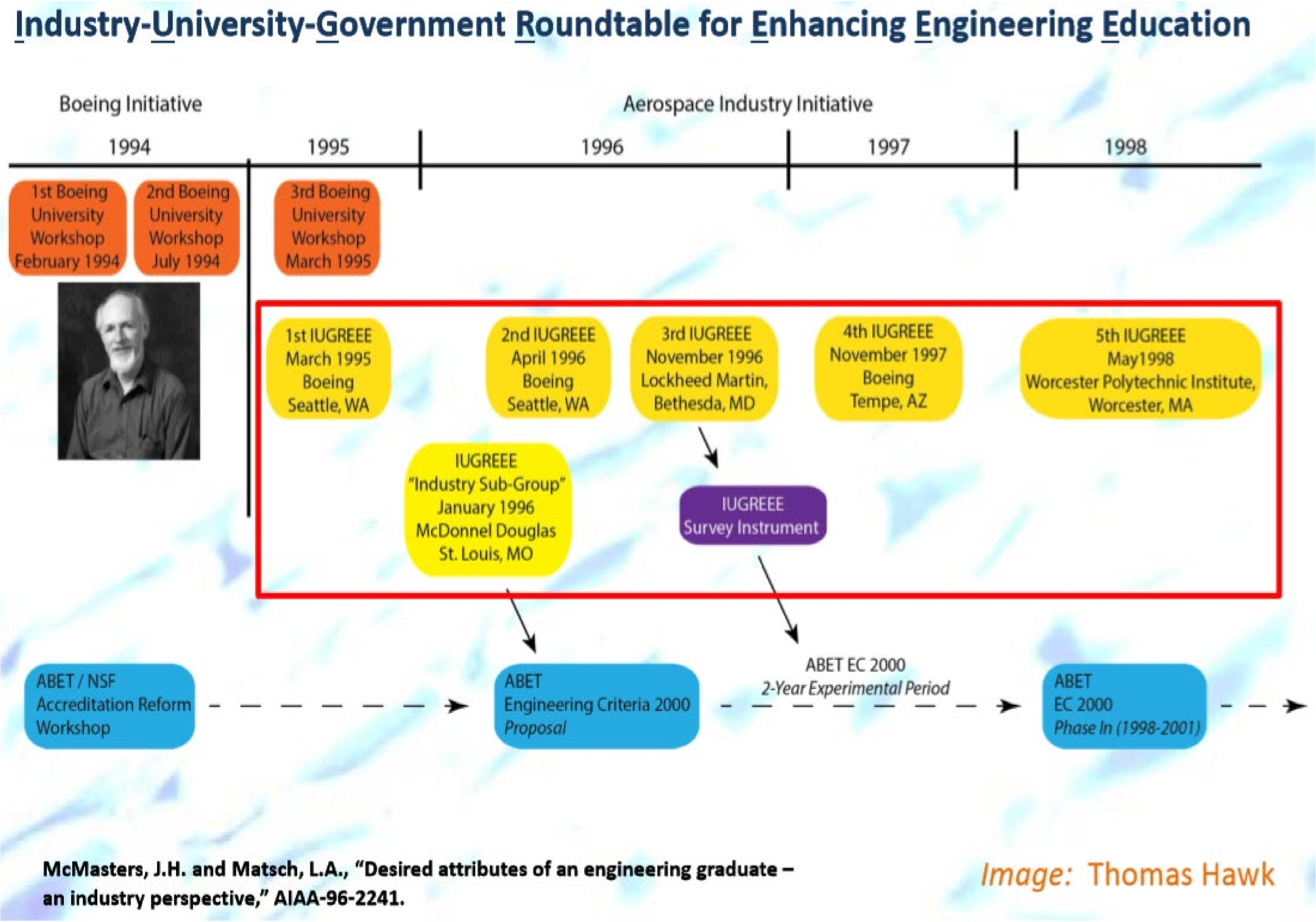
Professional Societies:

Accreditation Board for Engineering and Technology (ABET)
American Institute of Aeronautics and Astronautics (AIAA)
American Society for Engineering Education (ASEE)
American Society of Mechanical Engineers (ASME)
Institute of Electrical and Electronics Engineers (IEEE)
National Academy of Engineering (NAE)
National Academy of Sciences (NAS)
Society of Automotive Engineers (SAE)
Society of Manufacturing Engineers (SME)
Seattle Professional Engineering Employees Association (SPEEA)

Bowman, D., Lang, J., McMasters, J.H., "The Roundtable for Enhancing Engineering Education – An Update," AIAA-97-0844.

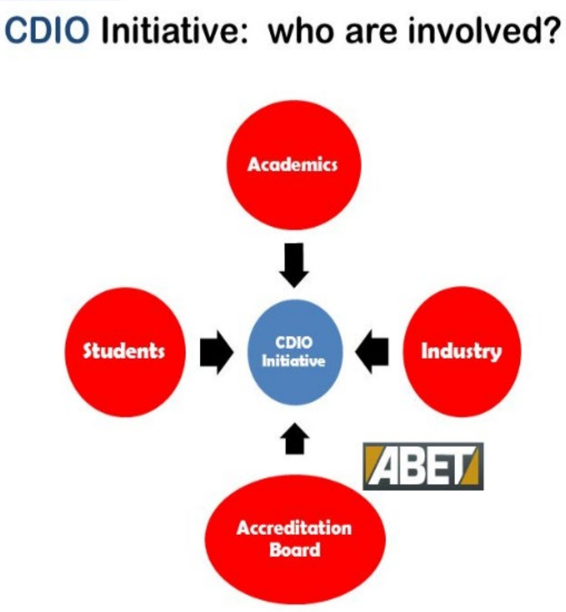
Image: Thomas Hawk

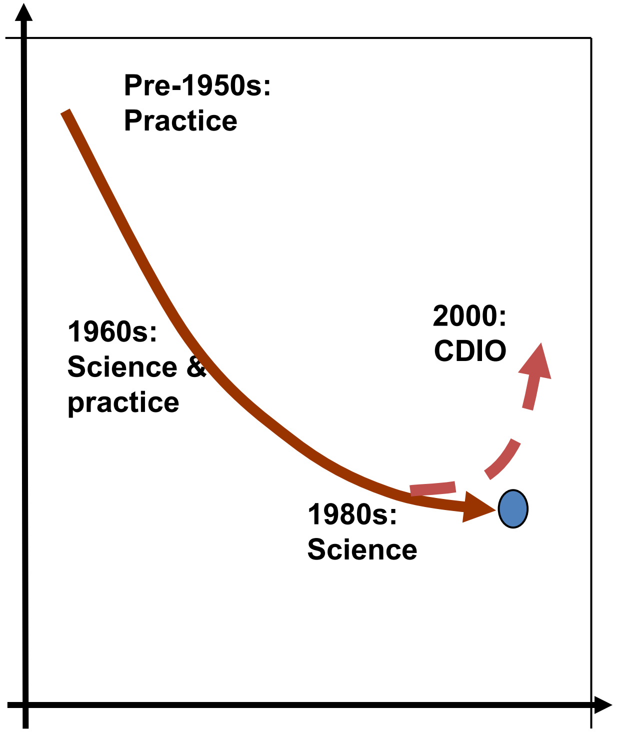
- To encourage schools to meet real world needs and rethink their educational strategies, ABET, listed its expectations for graduating engineer Industry-university-government roundtable for enhancing engineering education (IUGREEE)



The Underlying Needs For Reform

- Industry and ABET had identified the destination; it was up to educators to plan the route.
- Faced with the gap between scientific and practical engineering demands, the **professional and dedicated** educators took up the challenge to reform engineering education.
- The result of the endeavor is the worldwide **CDIO** Initiative to educate students who:
- Understand how to Conceive-Design-Implement-Operate.





The Learning Context for Professional Practice

- A focus on the needs of customers, clients, and patients
- Delivery of products, processes, and services
- Incorporation of inventions and new technologies
- Stewardship of the environment
- A focus on solutions, not disciplines
- Working with others and providing leadership in technical endeavors
- Communicating effectively
- Working efficiently, within resources, and/or profitably

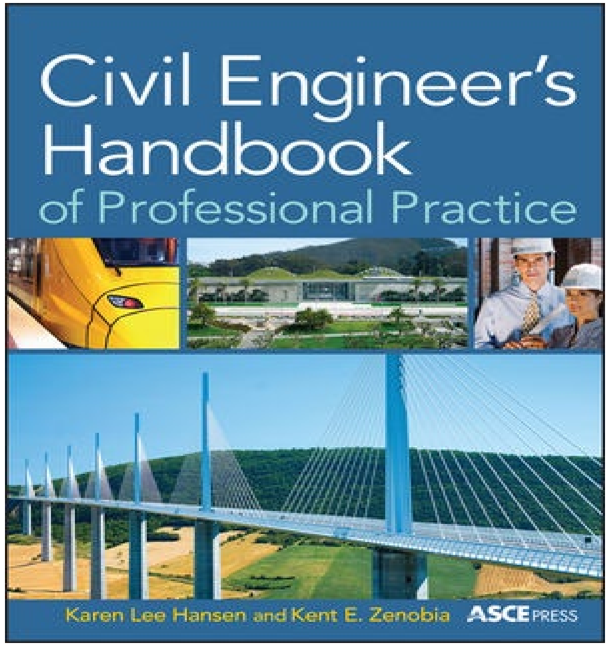
Input →

CDIO as the context of engineering education

Benefits of Learning in Context

Learning in the context of professional practice:

- Increases retention of new knowledge and skills
- Interconnects concepts and knowledge that build on each other
- Communicates the rationale and relevance of what students are learning
- Enables students to build their own frameworks for learning



What is CDIO?

- Innovative educational framework
- Applied in engineering education programs
- Based on engineering fundamentals of: CONCEIVING & DESIGNING & IMPLEMENTING & OPERATING (life Cycle of a product)
- Real world systems and products
- To produce next generation engineers

Real problems

1. Are complex, ill-defined, contain tensions
2. Need interpretations and estimations
3. Require systems view
4. Cross disciplinary boundaries (within and outside science and technology)
5. Sit in contexts with societal and business aspects

Context for engineering education: the C-D-I-O process

Lifecycle of a product, process, or system:

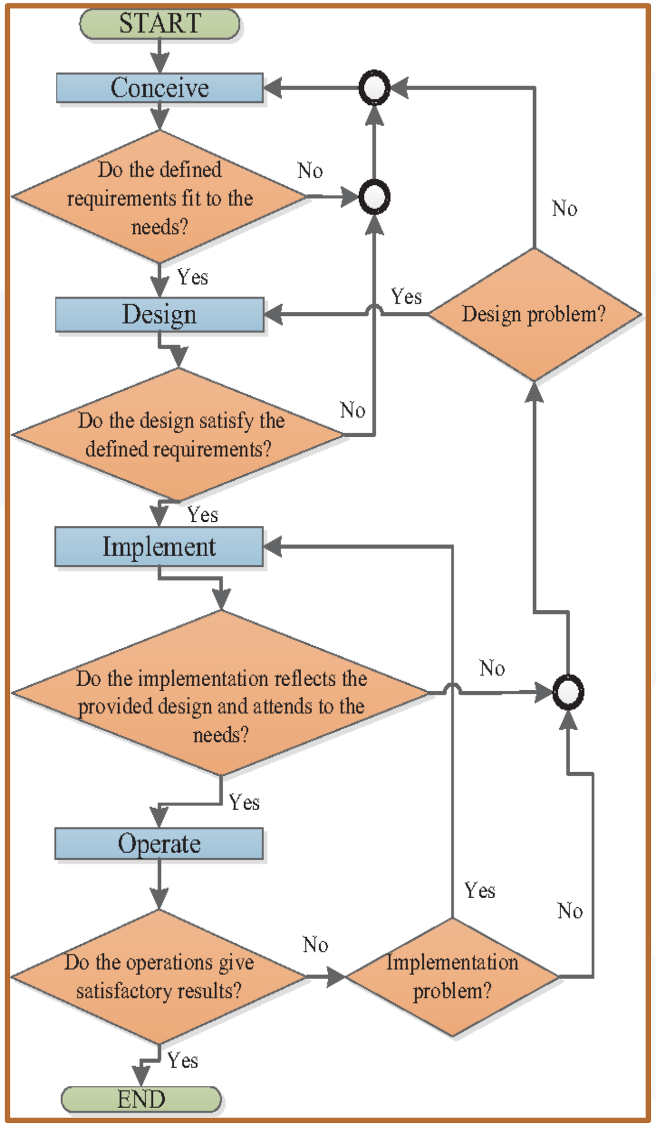
Conceive: customer needs, technology, enterprise strategy, regulations; and conceptual, technical, and business plans.

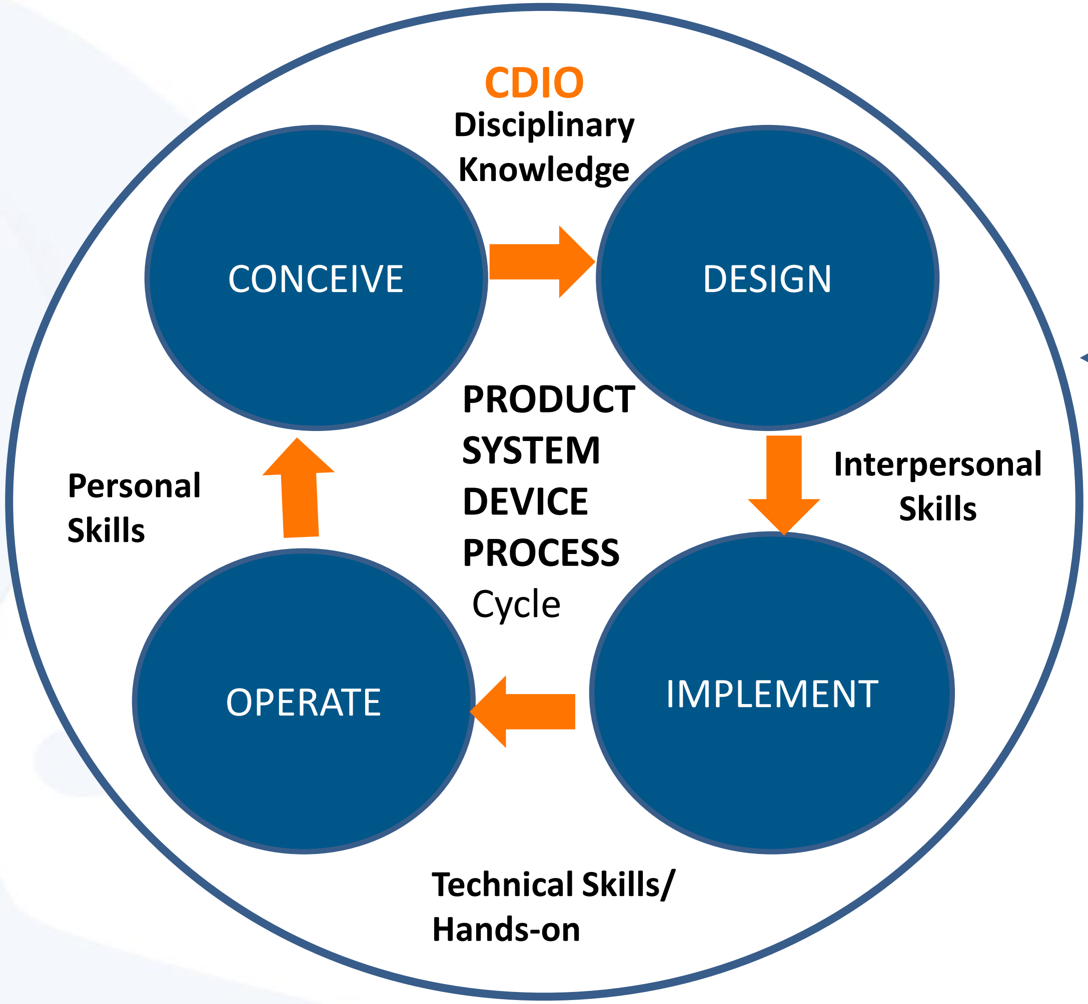
Design: plans, drawings , illustrations, and algorithms that describe what will be implemented.

Implement: transformation of the design into the product, process, or system, including manufacturing, coding, testing and validation

Operate: the implemented product or process delivering the intended value, including maintaining, evolving and retiring the system.

CDIO Framework





CDIO is one of the most interesting and innovative approaches that we found in the is how the learning outcomes (knowledge, skills and attitudes) are set in the context of the professional practice of each career, to equip students to perform effectively in the real workplace.

These four terms have been chosen because they are applicable to a wide range of disciplines.

Conceiving Phase

Through this phase the students will have the skill to:

accept	apprehend	envisage	get	suspect
assume	catch	expect	grasp	take
believe	compass	fancy	imagine	twig
perceive	comprehend	feel	judge	
realize	deem	follow	reckon	
appreciate	dig	gather	suppose	

And ready to demonstrate the use of these skills

Conceive Phase Leads to:

Through this phase the students will have the skill to:

Conceive	
Mission	**Conceptual Design**
• Business Strategy	• Requirements
• Technology Strategy	• Function
• Customer Needs	• Concepts
• Goals	• Technology
• Competitors	• Architecture
• Program Plan	• Platform Plan
• Business Plan	• Market Positioning
	• Regulation
	• Supplier Plan
	• Commitment

And ready to demonstrate the use of these skills

Design Phase Leads to:

Through this phase the students will have the skill to:

Design	
Preliminary Design	**Detailed Design**
• Requirements Allocation	• Element Design
• Model Development	• Requirements Verification
• System Analysis	• Failure & Contingency Analysis
• System Decomposition	• Validated Design
• Interface Specifications	• Integration

And ready to demonstrate the use of these skills

Implement Phase Leads to:

Through this phase the students will have the skill to:

Implement	
Element Creation	Systems Integration & Test
• Hardware Manufacturing	• System Integration
• Software Coding	• System Test
• Sourcing	• Refinement
• Element Testing	• Certification
• Element Refinement	• Implementation Ramp-up
	• Delivery

And ready to demonstrate the use of these skills

Operate Phase Leads to:

Through this phase the students will have the skill to:

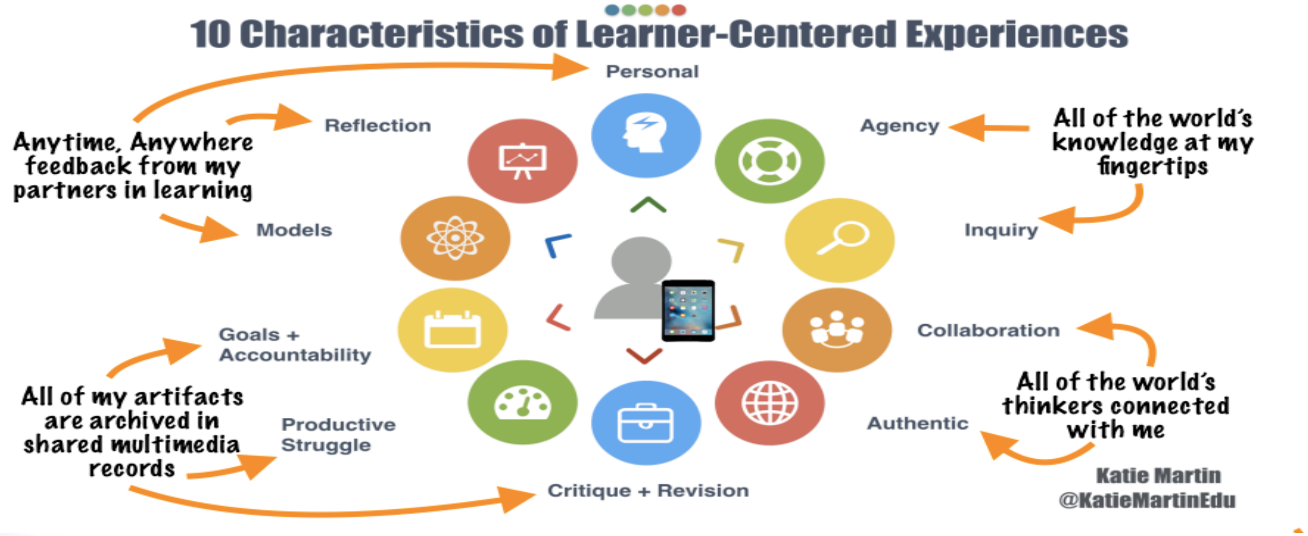
Operate	
Lifecycle Support	Evolution
• Sales & Distribution	• System Improvement
• Operations	• Product Family Expansion
• Logistics	• Retirement
• Customer Support	
• Maintenance and Repair	
• Recycling	
• Upgrading	

And ready to demonstrate the use of these skills

The CDIO Vision

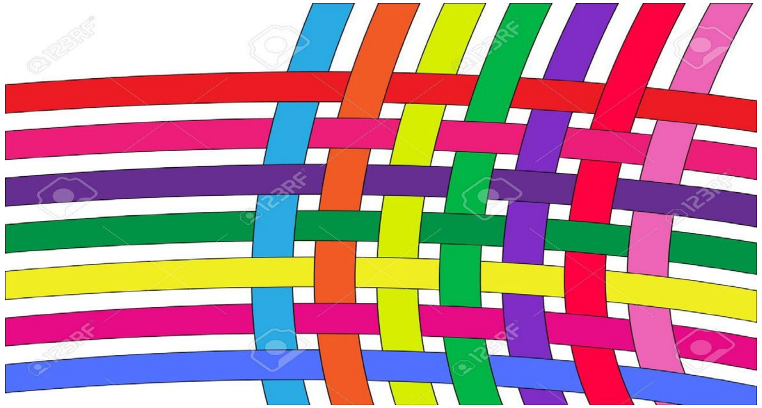
An education that stresses disciplinary knowledge set in the context of Conceiving-Designing-Implementing-Operating products, processes, and systems

- A curriculum that is cantered on students, multidisciplinary, and based on specified learning outcomes
- Featuring active and experiential learning, including a variety of project-based learning experiences
- Set in both classrooms and modern learning laboratories and workspaces
- Constantly improved through robust assessment and evaluation processes



The salient features of the vision are that:

- Stakeholder involvement.
- Disciplinary courses with activities interwoven that develop personal and interpersonal skills, and product, process and system building skills.
- Design-implement experiences set in both the classroom and in modern learning workspaces as the basis for engineering-based experiential learning.
- Active and experiential learning, can be incorporated into lecture-based courses.
- A comprehensive assessment and evaluation process



Goals of CDIO

- To educate students to master a deeper working knowledge of the technical fundamentals.
- To educate engineers to lead in the creation and operation of new products and systems.
- To educate all to understand the importance and strategic impact of research and technological development on society.
- To attract and retain student in engineering.

Transform The Culture

Current	Desired
Engineering Science R&D Context Reductionist Individual	Engineering Product Context Integrative Team

But still based on a rigorous treatment of Engineering Fundamentals

CDIO Initiators and Collaborating Institutions

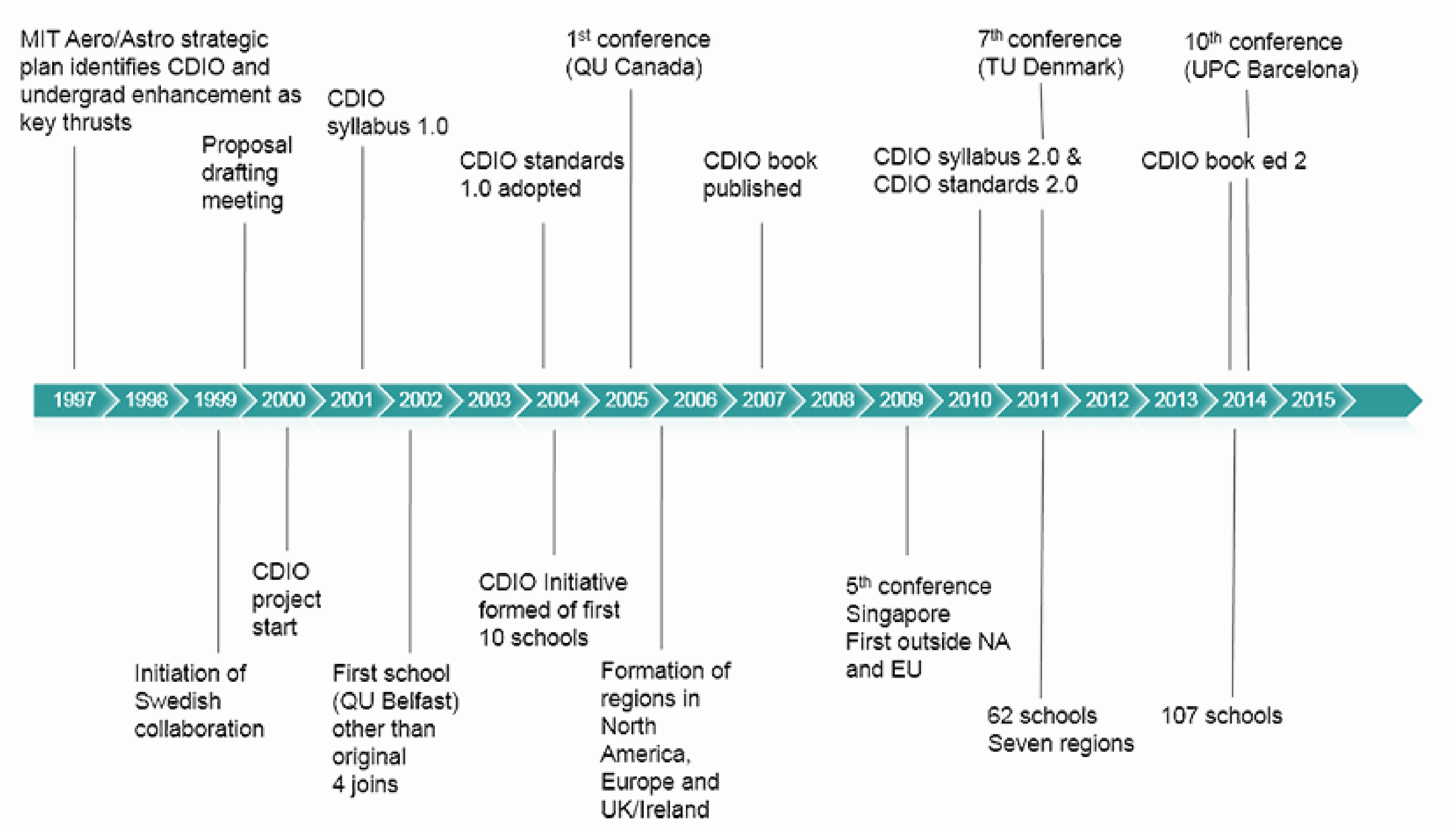
Development and implementation of the CDIO approach was initiated at one in the USA and three universities in Sweden and :

CDIO Concept late 1990

Massachusetts Institute of Technology (MIT) in Cambridge, Massachusetts, USA

CDIO Initiative 2000

- **Chalmers University of Technology (Chalmers) in Göteborg,**
- **the Royal Institute of Technology (KTH) in Stockholm,**
- **Linköping University (LiU) in Linköping**
- **Massachusetts Institute of Technology (MIT) in Cambridge, Massachusetts, USA.**


MIT Aero/Astro strategic plan identifies CDIO and undergrad enhancement as key thrusts
Proposal drafting meeting
CDIO syllabus 1.0
CDIO standards 1.0 adopted
1st conference (QU Canada)
CDIO book published
CDIO syllabus 2.0 & CDIO standards 2.0
7th conference (TU Denmark)
CDIO book ed 2
10th conference (UPC Barcelona)
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Initiation of Swedish collaboration
CDIO project start
First school (QU Belfast) other than original 4 joins
CDIO Initiative formed of first 10 schools
Formation of regions in North America, Europe and UK/Ireland
5th conference Singapore First outside NA and EU
62 schools Seven regions
107 schools

Over 150 universities worldwide and still growing!

CDIO | A Worldwide Innovative Educational Framework

CDIO Syllabus

- The CDIO Syllabus is a list of knowledge, skills, and attitudes desired of graduating engineers.
- What is the full set of knowledge, skills, and attitudes that engineering students should possess as they leave the university, and at what level of proficiency?
- It is rationalized against the norms of contemporary engineering practice,
- The principal value of the Syllabus is that it can be applied across a variety of programs and can serve as a model for all programs to derive specific learning outcomes

CDIO Syllabus Goals

1. The specific objective of the CDIO Syllabus is to create a clear, complete, consistent, and generalizable set of goals for undergraduate engineering education, in sufficient detail that they can be understood and implemented by engineering faculty.

2. These goals would form the basis for educational and learning outcomes, the design of curricula, as well as the basis for a comprehensive system of student learning assessment.

3. In addition, they would form the basis for effective communication, benchmarking, interuniversity sharing, and international correspondence.

CDIO Syllabus Goals

4. Is to summarize formally a set of knowledge, skills and attitudes that alumni, industry and academia desire in a future generation of young engineers.

5. To define expected outcomes in terms of learning objectives of the personal, interpersonal and system building skills necessary for modern engineering practice.

6. To design new educational initiatives, and it can be employed as the basis for a rigorous outcomes-based assessment process, such as that required by the Accreditation Board for Engineering Technology (ABET), and increasingly by other international accreditation processes as well

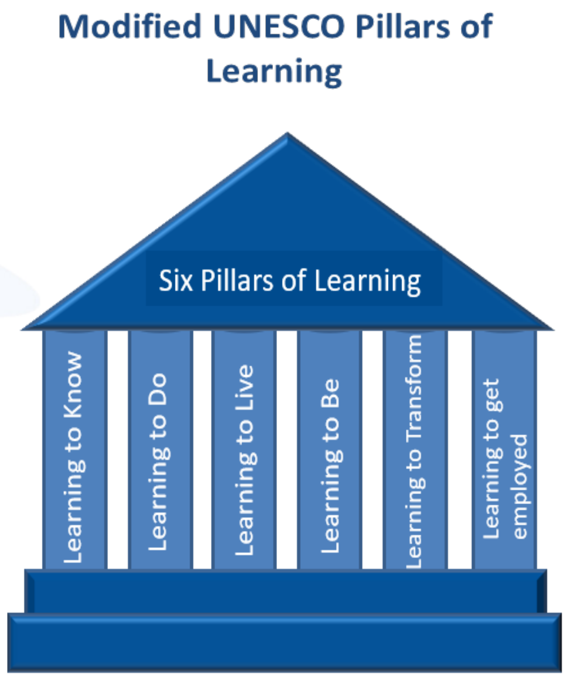
The CDIO Syllabus Characteristics

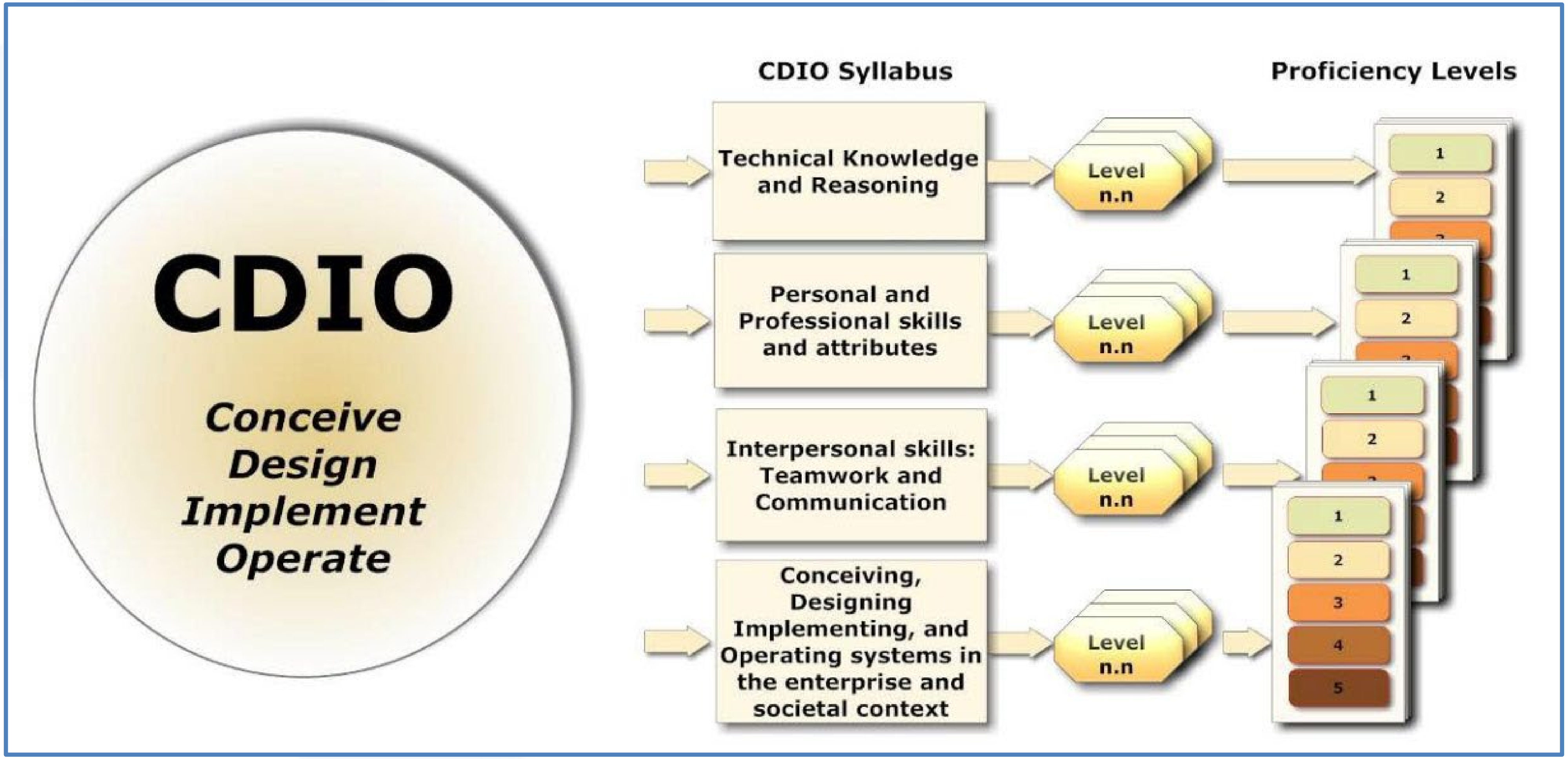
- Comprehensive — all relevant primary source material correlated and included.
- Prioritized by stakeholders — extensive survey of stakeholders to determine priority and level of accomplishment.
- Reviewed by peers — experts in each field reviewed materials and correlated with field-specific primary source material.
- Appropriate — filtered to those aspects appropriate to university teaching and learning.
- Expressed as learning objectives or competency statements in an appropriate taxonomy.
- Basis for rigorous curriculum design and assessment processes.

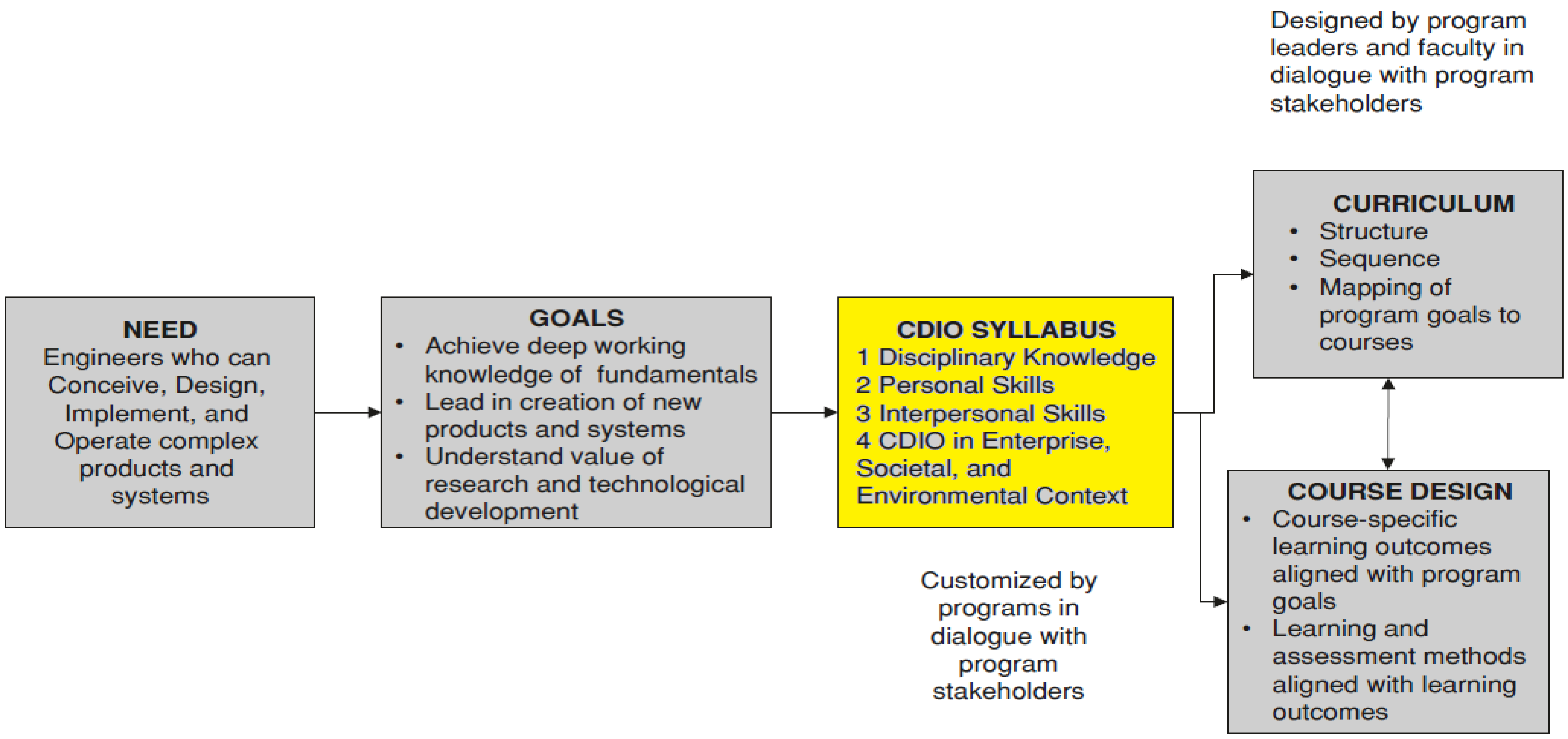
The content of each section was expanded to a second level to a third level and to a fourth level.

The organization of the CDIO Syllabus and the UNESCO

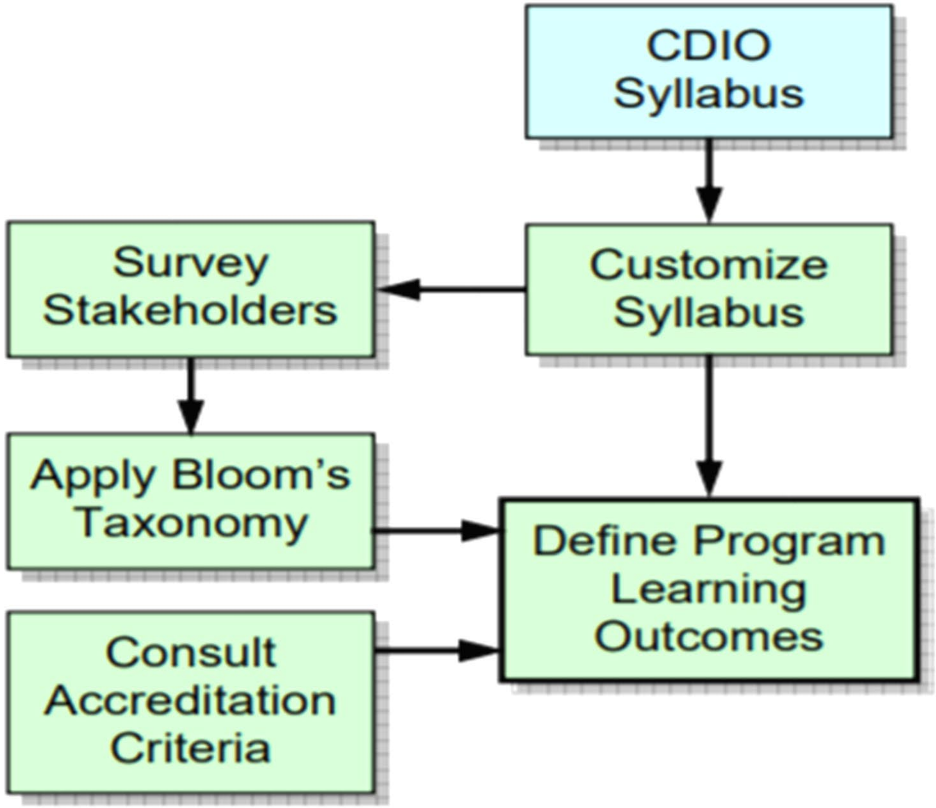
- *Learning to Know*, that is, acquiring the instruments of understanding
- *Learning to Do,* to be able to act creatively on one's environment
- *Learning to Live* Together, to co-operate with other people
- *Learning to Be,* an essential progression that proceeds from the previous three
- *Learning to transform* the world: key competencies in education for sustainable development
- *Learning to get employed* through attaining the skills and competencies needed by the workplace: knowledge, affinity, psychomotor, personal and interpersonal




CDIO
Conceive
Design
Implement
Operate
CDIO Syllabus
Proficiency Levels
Technical Knowledge and Reasoning
Personal and Professional skills and attributes
Interpersonal skills: Teamwork and Communication
Conceiving, Designing Implementing, and Operating systems in the enterprise and societal context
Level n.n
Level n.n
Level n.n
Level n.n
1
2
3
4
5



Development and integration of the CDIO Syllabus



The CDIO Methodology: Developing Program Learning Outcomes

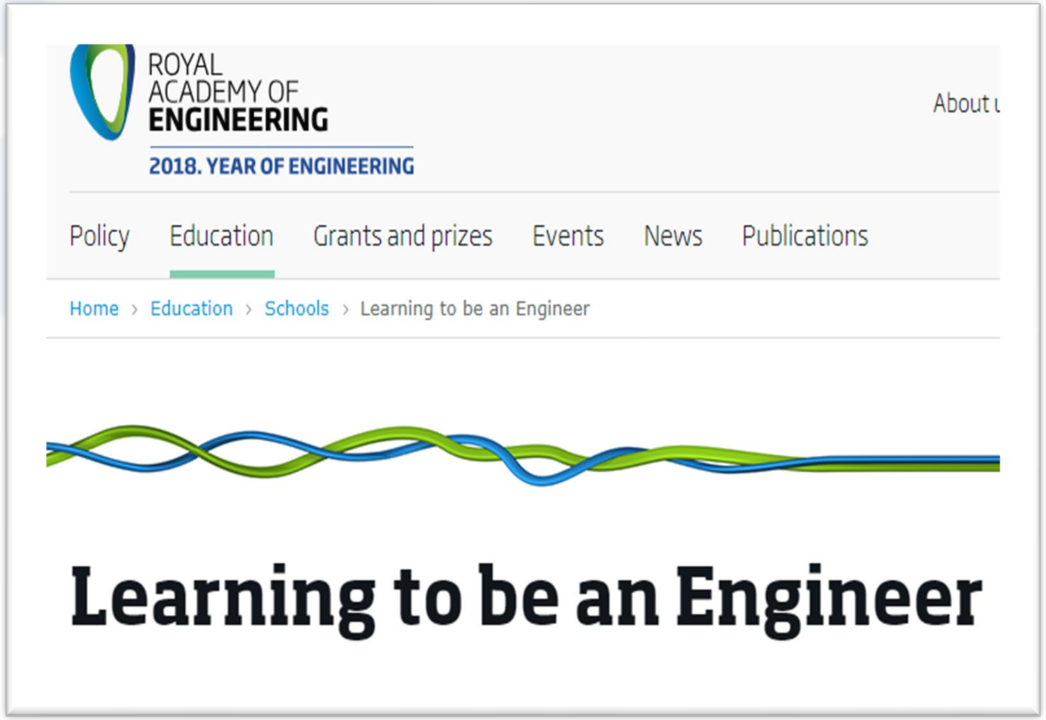
Proceedings of the 4th International CDIO Conference, Hogeschool Gent, Gent, Belgium, June 16-19, 2008

The organization of the CDIO Syllabus

The organization of the CDIO Syllabus can be described as an adaptation of the UNESCO framework to the context of engineering education.

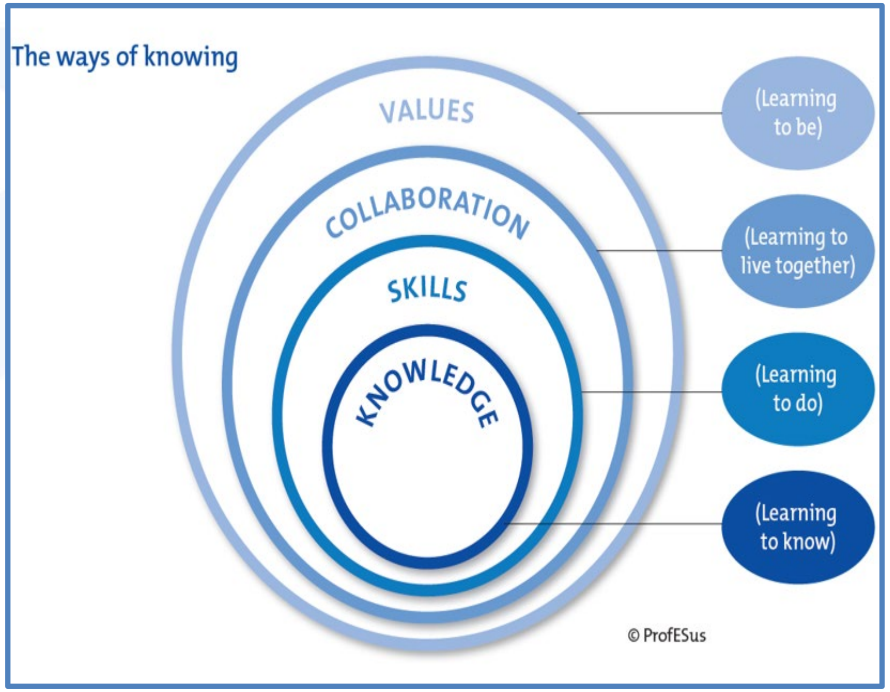
At the first level, the CDIO Syllabus is divided into four categories:

1. Technical Knowledge and Reasoning (or UNESCO Learning to Know) Section 1 of the CDIO Syllabus defines the mathematical, scientific and technical knowledge that an engineering graduate should have developed.
2. Personal and Professional Skills and Attributes (or UNESCO Learning to Be) Section 2 of the Syllabus deals with individual skills, including problem solving, ability to think creatively, critically, and systemically, and professional ethics.



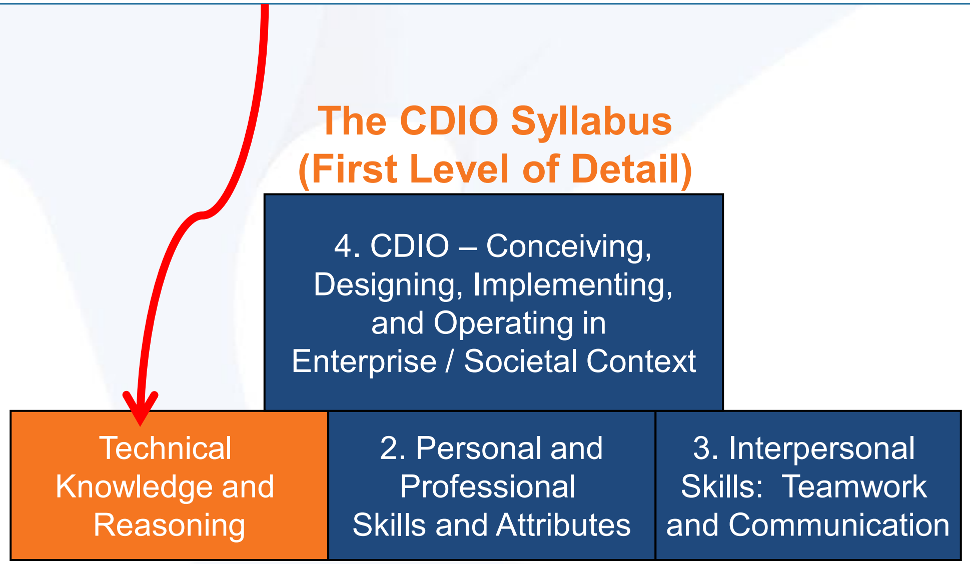
The organization of the CDIO Syllabus

3. Interpersonal Skills: Teamwork and Communication (or UNESCO Learning to Live Together) Section of the Syllabus lists skills that are needed in order to be able to work in groups and communicate effectively.
4. Conceiving, Designing, Implementing and Operating Systems in the Enterprise, Societal and Environmental Context (or UNESCO Learning to Do) Finally, Section 4 of CDIO Syllabus is about what engineers do, that is, conceive-design-implement-operate products, processes and systems within an enterprise, societal, and environmental context.



CDIO Syllabus and The Attributes of an Engineer Program Learning Outcome

What is the full set of knowledge, skills and attitudes that a student should possess as they graduate from a university? At what level of proficiency? <u>Beyond traditional engineering disciplinary knowledge</u>



UNESCO's Four Pillars of Education

- **Learning to <u>know</u> (1)**
- **Learning to <u>be</u> (2)**
- **Learning to <u>live together</u> (3)**
- **Learning to <u>do</u> (4)**

The Syllabus and The professional Tracks

There are at least five different professional tracks that engineers follow, according to their individual talents and interests. The tracks and supporting sections of the Syllabus are:

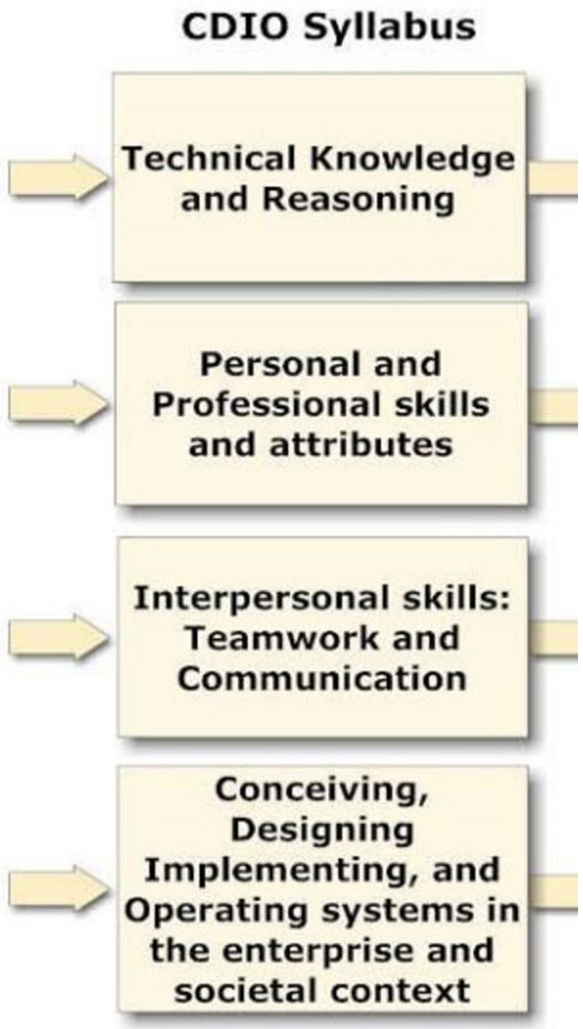
1. **The Researcher** : Experimentation, Investigation and Knowledge Discovery (2.2)
2. **The System Designer/Engineer** : Conceiving, System Engineering and Management (4.3)
3. **The Device Designer/Developer** : Designing (4.4), Implementing (4.5)
4. **The Product Support Engineer/Operator** : Operating (4.6)
5. **The Entrepreneurial Engineer/Manager** : Enterprise and Business Context (4.2)

(n.n) Syllabus Element

Instructional System Designer

The CDIO Syllabus
at the first level of detail

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



CDIO Syllabus: Second Level

1. Technical knowledge and reasoning
    - 1.1 knowledge of underlying science
    - 1.2 core fundamental knowledge
    - 1.3 advanced fundamental knowledge
2. Personal and professional skills and attributes
    - 2.1 analytic reasoning and problem solving
    - 2.2 experimentation, investigation and knowledge discovery
    - 2.3 system thinking
    - 2.4 attitudes, thoughts and learning
    - 2.5 ethics, quality and other responsibilities

CDIO Syllabus :The Second Level

3 Interpersonal skills: teamwork and communication

- 3.1 multi-disciplinary teamwork
- 3.2 communications
- 3.3 communications in foreign languages

4 Conceiving, designing, implementing, and operating systems in the enterprise and societal context, the innovation process

- 4.1 external, societal and environmental context
- 4.2 enterprise and business context
- 4.3 conceiving, system engineering and management
- 4.4 designing
- 4.5 implementing
- 4.6 operating
- 4.7 leading engineering endeavors
- 4.8 engineering entrepreneurship

CDIO Syllabus The Third and the Fourth Levels

2.5 ETHICS, EQUITY AND OTHER RESPONSIBILITIES [3f]

2.5.1 Ethics, Integrity and Social Responsibility
- One's ethical standards and principles
- The moral courage to act on principle despite adversity
- The possibility of conflict between professionally ethical imperatives
- A commitment to service
- Truthfulness
- A commitment to help others and society more broadly

2.5.2 Professional Behavior
- A professional bearing
- Professional courtesy
- International customs and norms of interpersonal contact

2.5.3 Proactive Vision and Intention in Life
- A personal vision for one's future
- Aspiration to exercise his/her potentials as a leader
- One's portfolio of professional skills
- Considering one's contributions to society
- Inspiring others

The Relevance of SYLLABUS to Engineering EDUCATION

In the past ten years, the CDIO Syllabus has played a key role in the design of curriculum, teaching, and assessment in engineering education. As a formal statement of the intended learning outcomes of an engineering program, the Syllabus was able to :

1. Capture the expressed needs of program stakeholders
2. Highlight the overall goals of an engineering program
3. used as a starting point for defining these learning outcomes at the course level
4. Provide a framework for benchmarking outcomes
5. Serve as a template for writing program objectives and outcomes
6. Provide a guide for the design of curriculum
7. Suggest appropriate teaching and learning methods
8. Provide the targets for student learning assessment
9. used in program accreditation.
10. Serve as a framework for overall program evaluation, and
11. Communicate with faculty, students, and other stakeholders about the direction and purpose of a renewed engineering education that is centered on students and focused on outcomes.

The CDIO Syllabus And The Accreditation correlated with ABET EC2010 Criterion 3

CDIO Syllabus	ABET EC2010 Criterion 3										
	a	b	c	d	e	f	g	h	i	j	k
1.1 Knowledge of Underlying Mathematics, Science	■										
1.2 Core Engineering Fundamental Knowledge	■										
1.3 Adv. Engr. Fund. Knowledge, Methods, Tools	▒										■
2.1 Analytical Reasoning and Problem Solving					■						▒
2.2 Exper., 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 Communication in Foreign Languages											
4.1 External, Societal and Environmental Context			▒					■		■	
4.2 Enterprise and Business Context			▒					■			
4.3 Conceiving, Systems Engr. and Management			■								
4.4 Designing			■								
4.5 Implementing			▒								
4.6 Operating			▒								

■ Strong Correlation ▒ Good Correlation

The CDIO Syllabus correlated with the Canadian Engineering Accreditation Board (CEAB) Graduate Attributes

	CEAB Graduate Attributes Criteria 3.1											
CDIO Syllabus	1	2	3	4	5	6	7	8	9	10	11	12
1.1 Knowledge of Underlying Mathematics, Science	■											
1.2 Core Engineering Fundamental Knowledge	■											
1.3 Advanced Eng. Fundamental Knowledge, Methods, 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 Communication 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				▒								

■ Strong Correlation ▒ Good Correlation

European Accreditation (EUR-ACE)programme outcomes
The (EUR-ACE) syllabus

1 Knowledge and Understanding

1.1 Knowledge and understanding of the scientific and mathematical principles underlying their branch of engineering

1.2 A systematic understanding of the key aspects and concepts of their branch of engineering

1.3 Coherent knowledge of their branch of engineering including some at the forefront of the branch

2 Engineering Analysis

2.1 The ability to apply their knowledge and understanding to identify, formulate and solve engineering problems using established methods

2.2 The ability to apply their knowledge and understanding to analyse engineering products, processes and methods

2.3 The ability to select and apply relevant analytic and modelling methods

3 Engineering Design

3.1 The ability to apply their knowledge and understanding to develop and realise designs to meet defined and specified requirements

3.2 An understanding of design methodologies, and an ability to use them

4 Investigations

- 4.1 The ability to conduct searches of literature, and to use data bases and other sources of information
- 4.2 The ability to design and conduct appropriate experiments, interpret the data and draw
- 4.3 Workshop and laboratory skills

5 Engineering Practice

- 5.1 The ability to select and use appropriate equipment, tools and methods
- 5.2 The ability to combine theory and practice to solve engineering problems
- 5.3 An understanding of applicable techniques and methods, and of their limitations
- 5.4 An awareness of the non-technical implications of engineering practice

6 Transferable skills

- 6.1 Function effectively as an individual and as a member of a team
- 6.2 Use diverse methods to communicate effectively with the engineering community and with society at large
- 6.3 Demonstrate awareness of the health, safety and legal issues and responsibilities of engineering practice, the impact of engineering solutions in a societal and environmental context, and commit to professional ethics, responsibilities and norms of engineering practice
- 6.4 Demonstrate an awareness of project management and business practices, such as risk and change management, and understand their limitations
- 6.5 Recognise the need for, and have the ability to engage in independent, life-long learning

CDIO & EUR-ACE

- **How CDIO & EUR-ACE Syllabuses compare?**

EUR-ACE syllabus, 2nd cycle	CDIO syllabus level x.x																
	1.1	1.2	1.3	2.1	2.2	2.3	2.4	2.5	3.1	3.2	3.3	4.1	4.2	4.3	4.4	4.5	4.6
1.1	x																
1.2		x															
1.3			x														
1.4						x									x		
2.1				x													
2.2				x										x	x		
2.3				x										x	x		
2.4			x	x										x	x		
3.1														x	x		
3.2							x							x	x		
3.3						x								x	x		
4.1					x												
4.2					x												
4.3					x												
4.4			x		x												
5.1		x	x	x													
5.2		x	x	x		x											
5.3		x	x	x													
5.4												x	x				
6.1									x								
6.2										x							
6.3								x				x					
6.4													x				
6.5							x										
6.6									x					x			

The CDIO Standards

1. Defining the distinguishing features of a CDIO program

2. Serving as guidelines for educational reform,

3. Providing a tool for continuous improvement).

4. CDIO Standards are to be used for:
   - ✓ Program design
   - ✓ Periodic program self-evaluation
   - ✓ Benchmarking, discussions and co-development with other programs

5. For each standard:
   - ✓ a description explains the meaning of the standard, highlighting reasons for setting the standard.
   - ✓ Rational explains why the standard has been selected and formulated
   - ✓ Rubrics for self-evaluation using the standards have also been developed.

The Grouping of the Standards

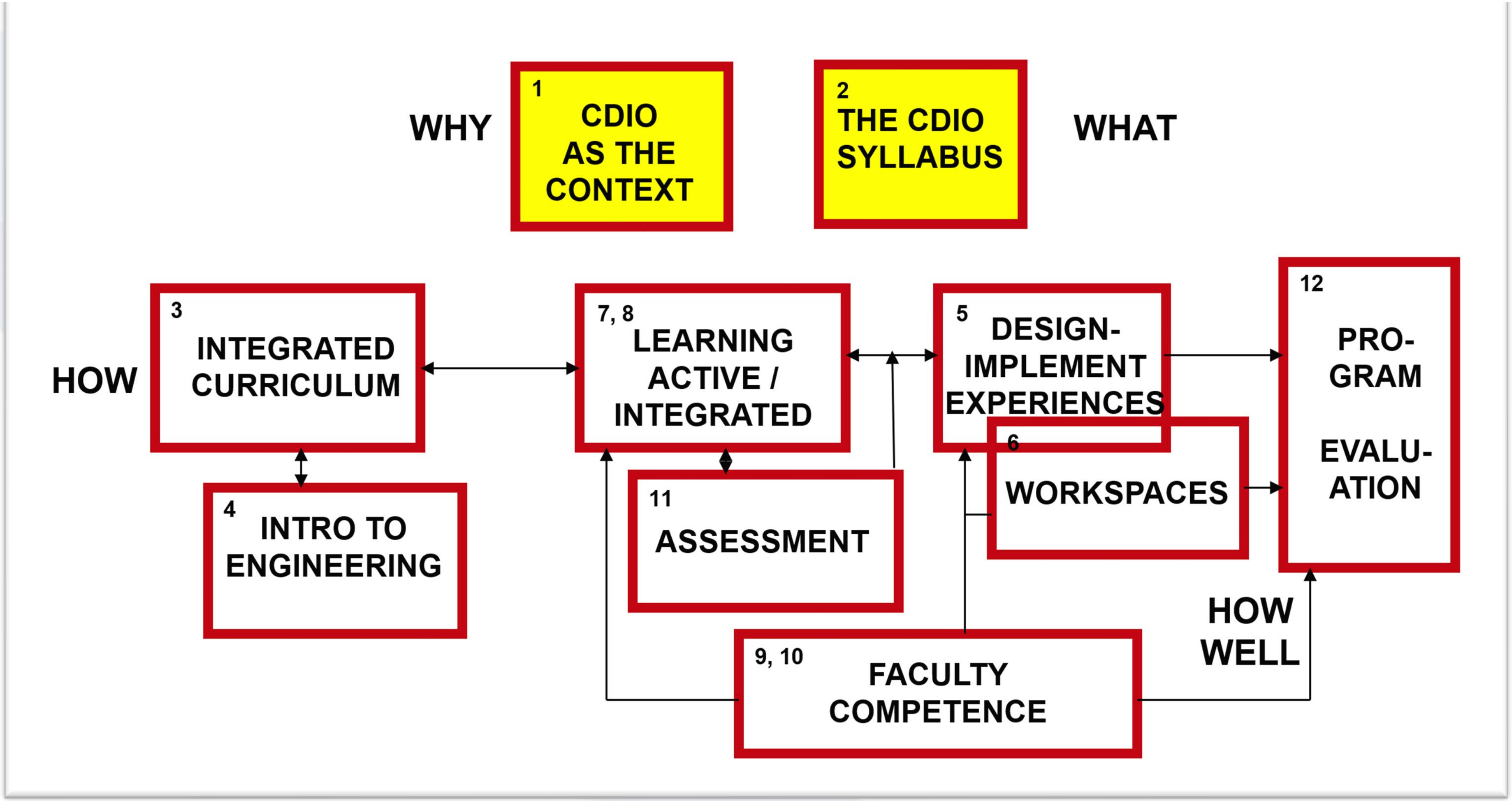
The 12 CDIO Standards address the following Issues in Engineering Education:

1. The foundational principle of a lifecycle context of education (Standard 1).
2. Curriculum development (Standards 2, 3 and 4).
3. Design-implement experiences and workspaces (Standards 5 and 6).
4. Methods of teaching and learning (Standards 7 and 8).
5. Faculty development (Standards 9 and 10).
6. Assessment and evaluation (Standards 11 and 12).

CDIO Standards

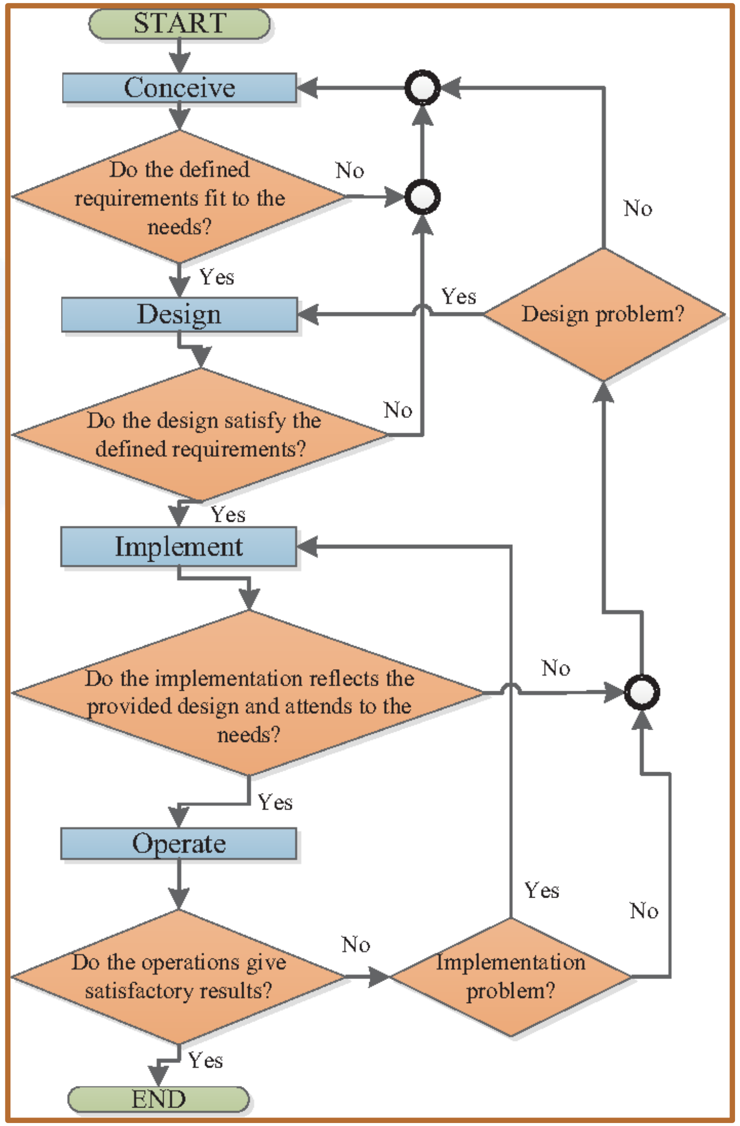
Context	Standard 1	CDIO as the context
Curriculum	Standard 2	CDIO Syllabus Outcomes
	Standard 3	Integrated Curriculum
	Standard 4	Introduction to Engineering
	Standard 5	Design-Build Experiences
Workspace/Labs	Standard 6	CDIO Workspaces
'eaching and Learning Methods	Standard 7	Integrated Learning Experiences
	Standard 8	Active Learning
Enhancement of Faculty Competence	Standard 9	Enhancement of Staff CDIO Skills
	Standard 10	Enhancement of Staff Teaching Skills
Assessment Methods	Standard 11	CDIO Skills Assessment
	Standard 12	CDIO Program Evaluation

The Standards Network



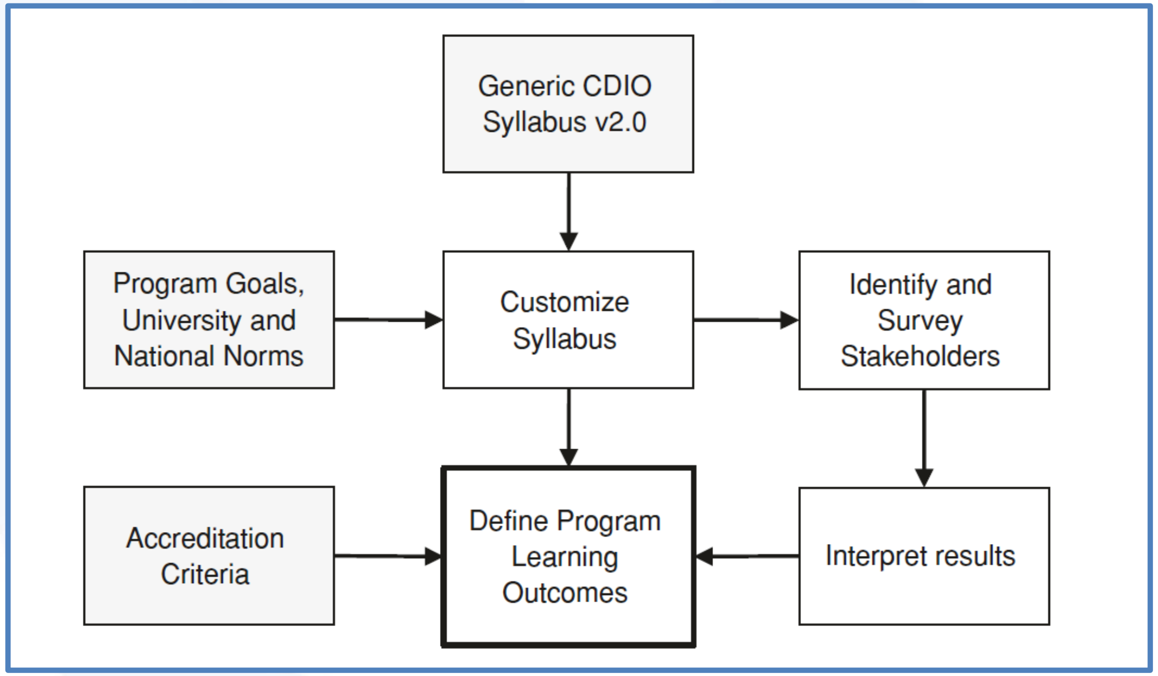
Standard 1 – The Context

Adoption of the principle that product, process, and system lifecycle development and deployment -- Conceiving, Designing, Implementing and Operating -- are the context for education



Standard 2 – Learning Outcomes

Specific, detailed learning outcomes for personal and interpersonal skills, and product, process, and system building skills, as well as disciplinary knowledge, consistent with program goals and validated by program stakeholders

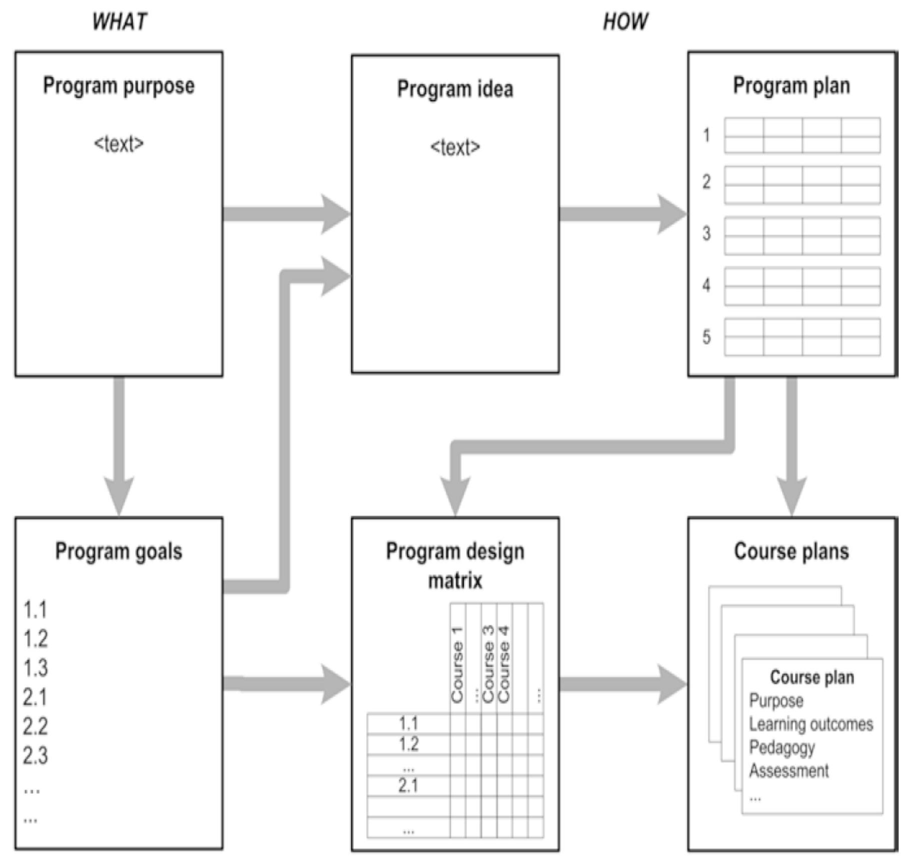


Process for defining program learning outcomes based on the CDIO Syllabus

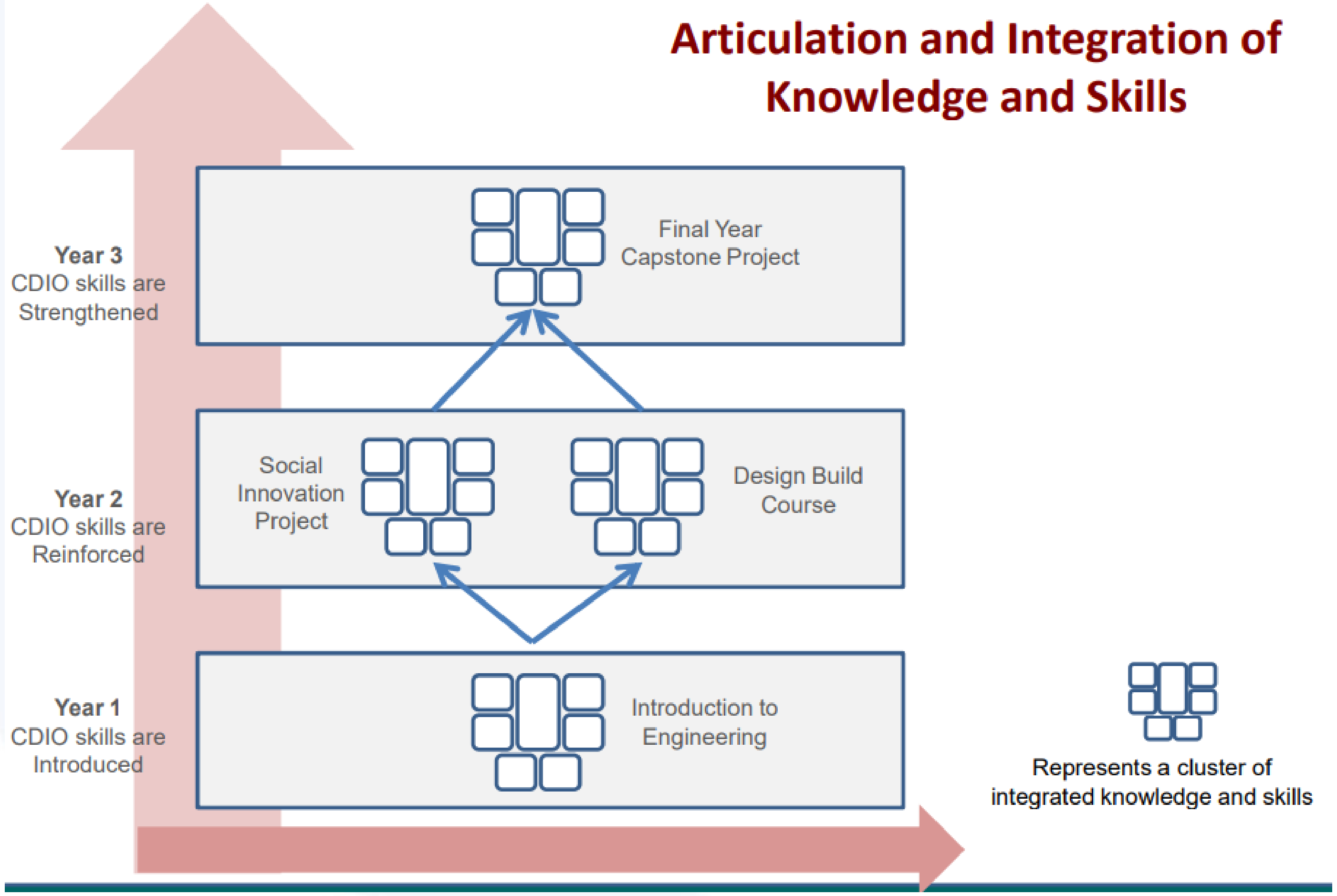
Standard 3 -- Integrated Curriculum
A curriculum designed with mutually supporting disciplinary courses, with an explicit plan to integrate personal and interpersonal skills, and product, process, and system building skills

An integrated curriculum includes learning experiences that lead to the acquisition of personal and interpersonal skills, and product, process, and system building skills (Standard 2), interwoven with the learning of disciplinary knowledge and its application in professional engineering.

Disciplinary courses are mutually supporting when they make explicit connections among related and supporting content and learning outcomes. An explicit plan identifies ways in which the integration of skills and multidisciplinary connections are to be made, for example, by mapping the specified learning outcomes to courses and co-curricular activities that make up the curriculum

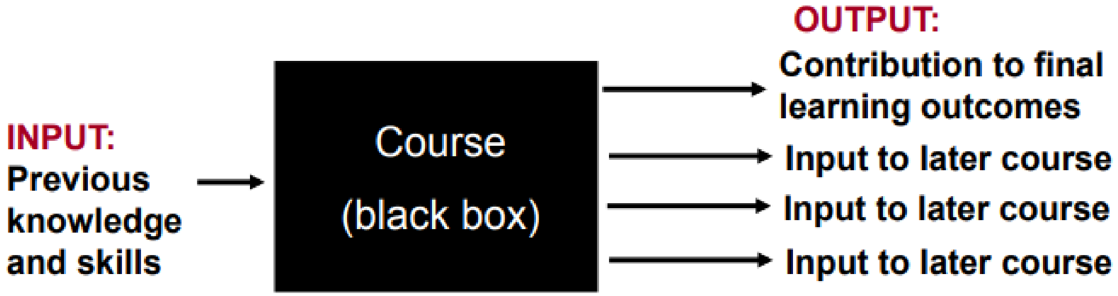


Horizontal and Vertical Articulation and Integration of Knowledge and Skills



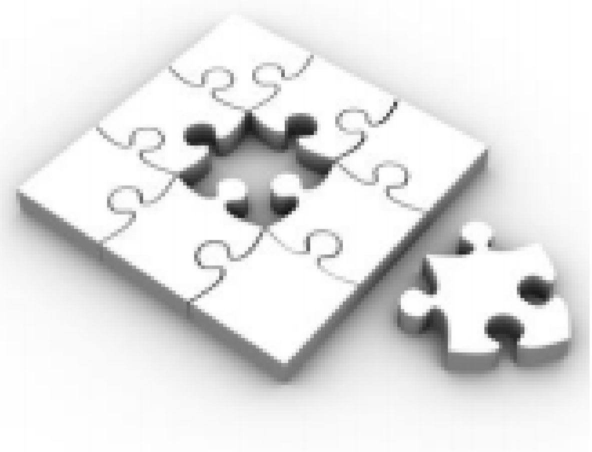
Sequencing the curriculum

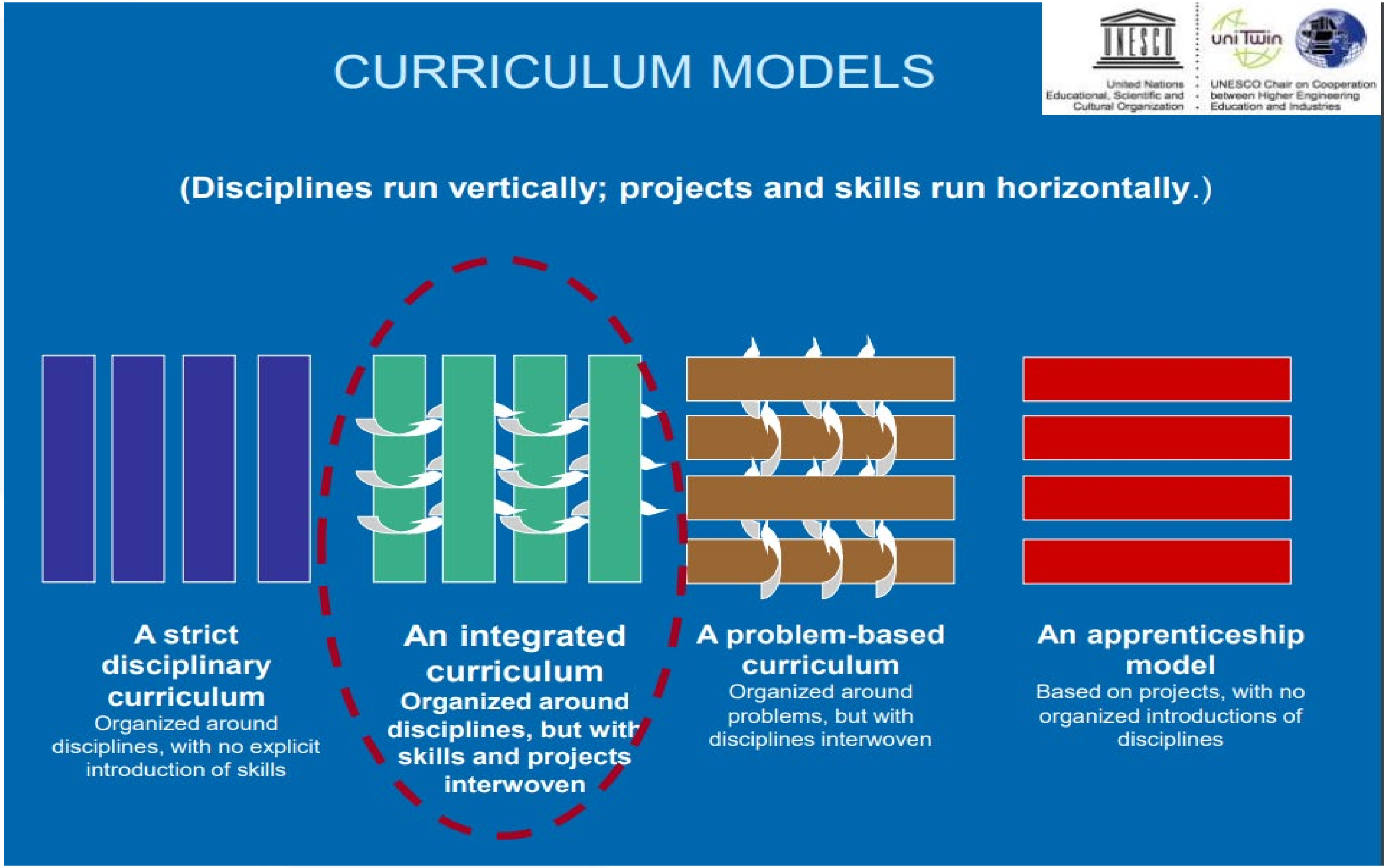
THE BLACK-BOX EXERCISE



All courses are presented through input and output only:

- Enables efficient discussions
- Makes connections visible (as well as lack thereof)
- Gives all faculty an overview of the program
- Serves as a basis for improving coordination
- Use for adjusting intentions in planning phase
- Use for checking existing programs

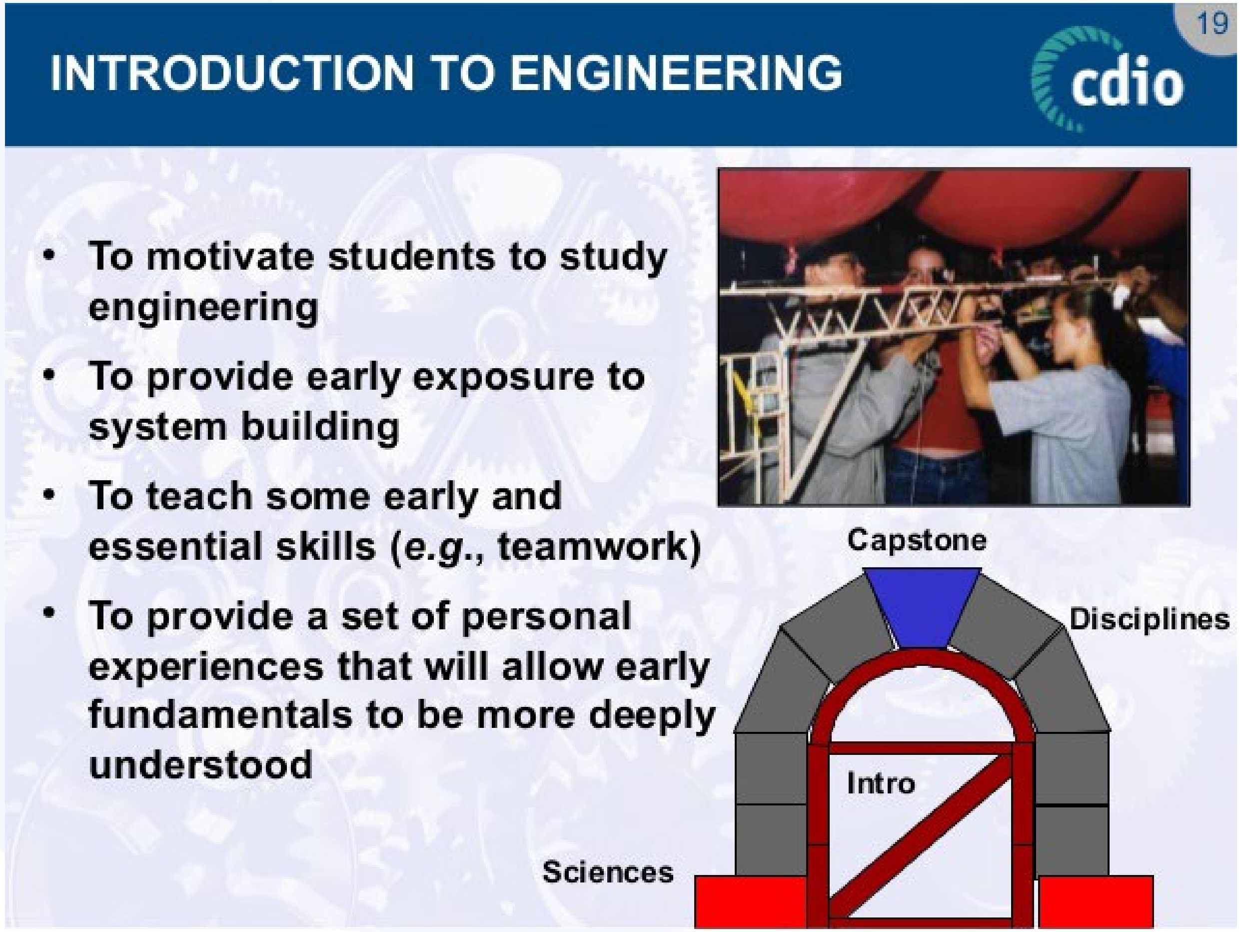




CURRICULUM MODELS
United Nations Educational, Scientific and Cultural Organization
UNESCO Chair on Cooperation between Higher Engineering Education and Industries
(Disciplines run vertically; projects and skills run horizontally.)
A strict disciplinary curriculum
Organized around disciplines, with no explicit introduction of skills
An integrated curriculum
Organized around disciplines, but with skills and projects interwoven
A problem-based curriculum
Organized around problems, but with disciplines interwoven
An apprenticeship model
Based on projects, with no organized introductions of disciplines

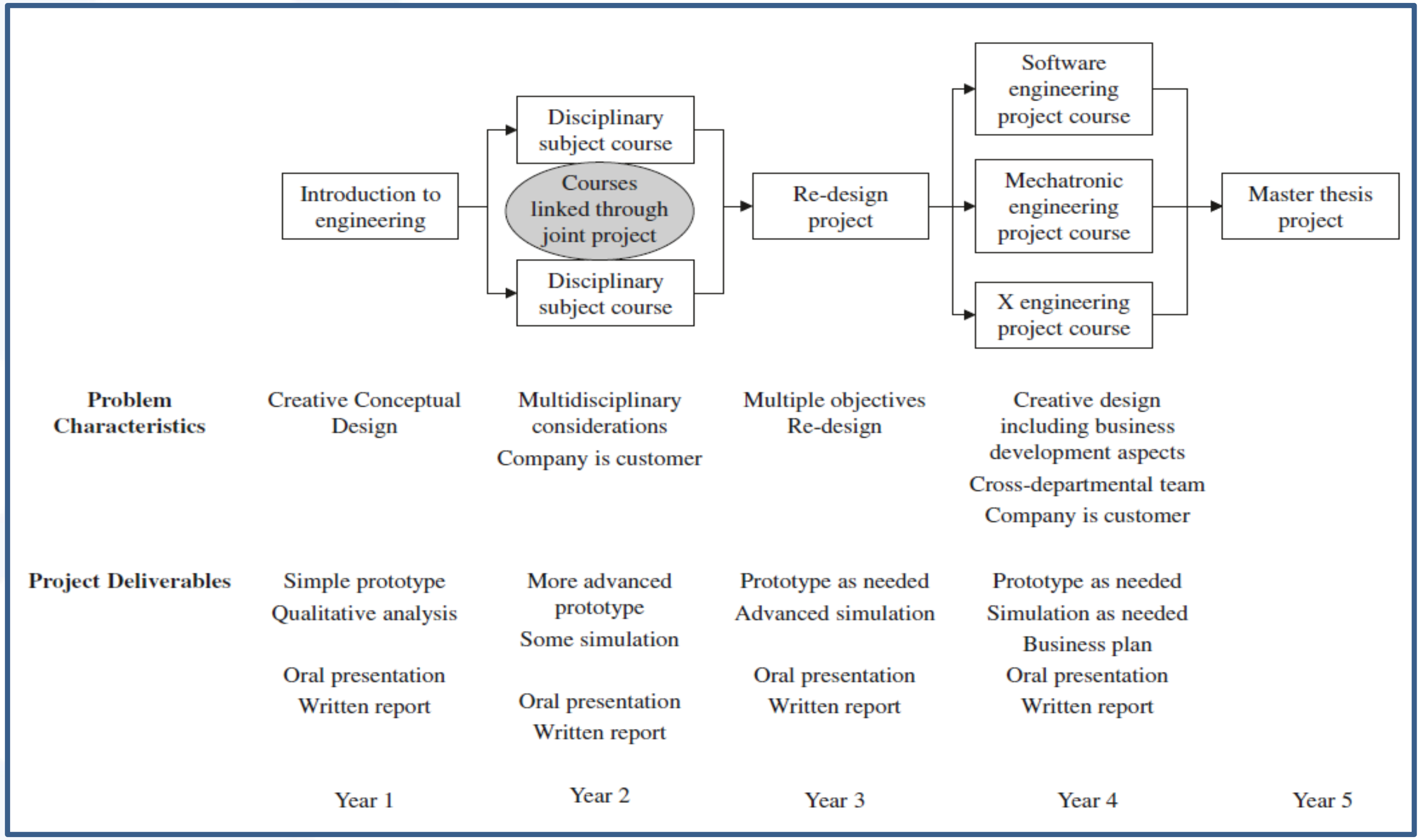
Standard 4 -- Introduction to Engineering
An introductory course that provides the framework for engineering practice in product, process, and system building, and introduces essential personal and interpersonal skills

Engineering for k-12



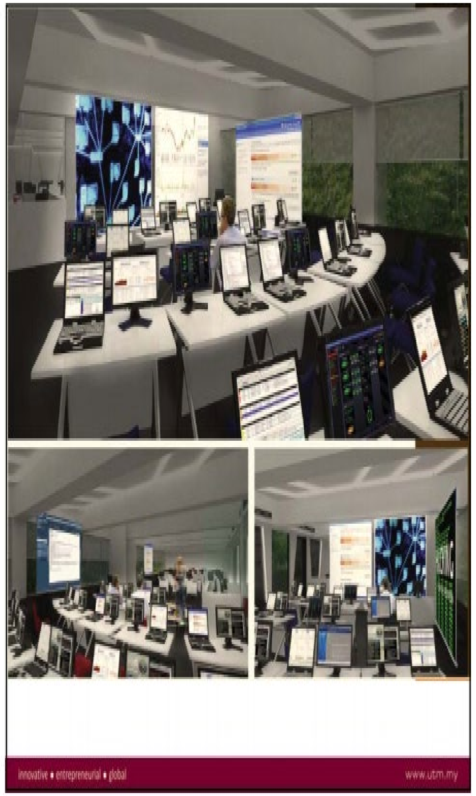
Standard 5 -- Design-Implement
Experiences A curriculum that includes two or more design-implement experiences, including one at a basic level and one at an advanced level

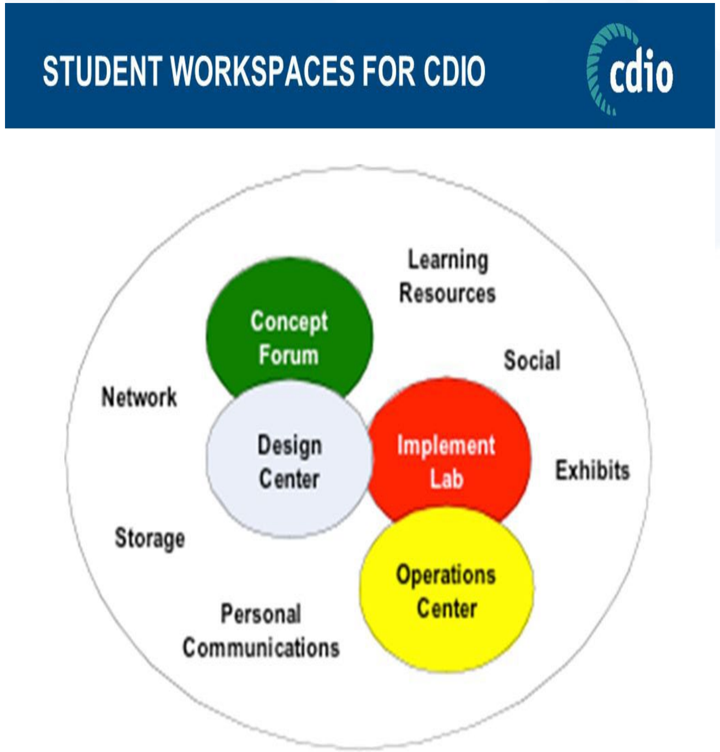
A plan to integrate design-implement experiences throughout a curriculum

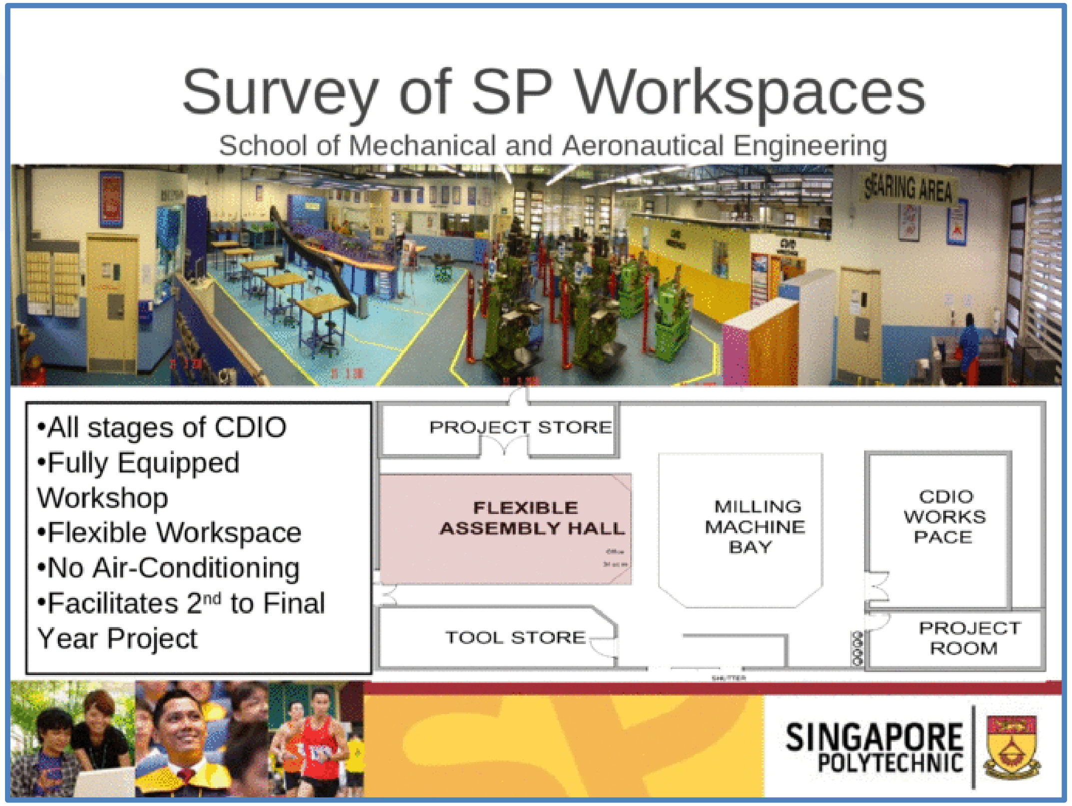


Standard 6 -- Workspaces

Engineering workspaces and laboratories that support and encourage hands-on learning of product, process, and system building, disciplinary knowledge, and social learning





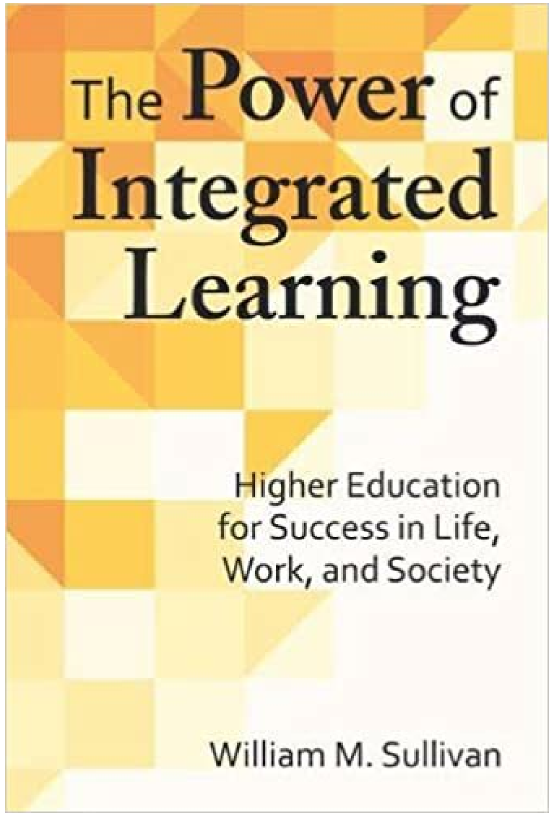


Standard 7 -- Integrated Learning Experiences
Integrated learning experiences that lead to the acquisition of disciplinary knowledge, as well as personal and interpersonal skills, and product, process, and system building skills

For example, students might consider the analysis of a product, the design of the product, and the social responsibility of the designer of the product, all in one exercise.

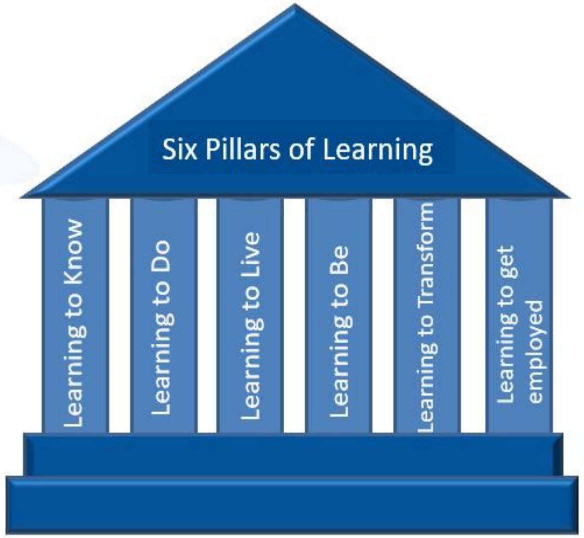
It is important that students recognize engineering faculty as role models of professional engineers, instructing them in disciplinary knowledge, personal and interpersonal skills, and product, process, and system building skills

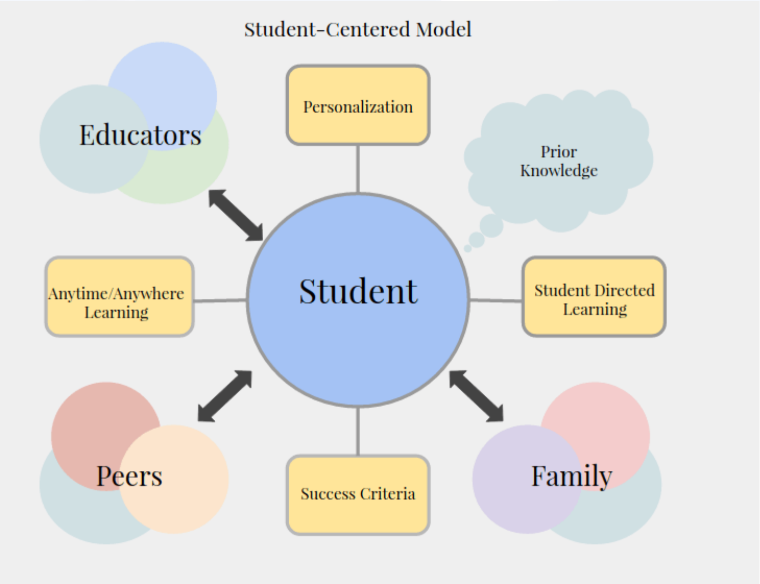
With integrated learning experiences, faculty can be more effective in helping students apply disciplinary knowledge to engineering practice and better prepare them to meet the demands of the engineering profession

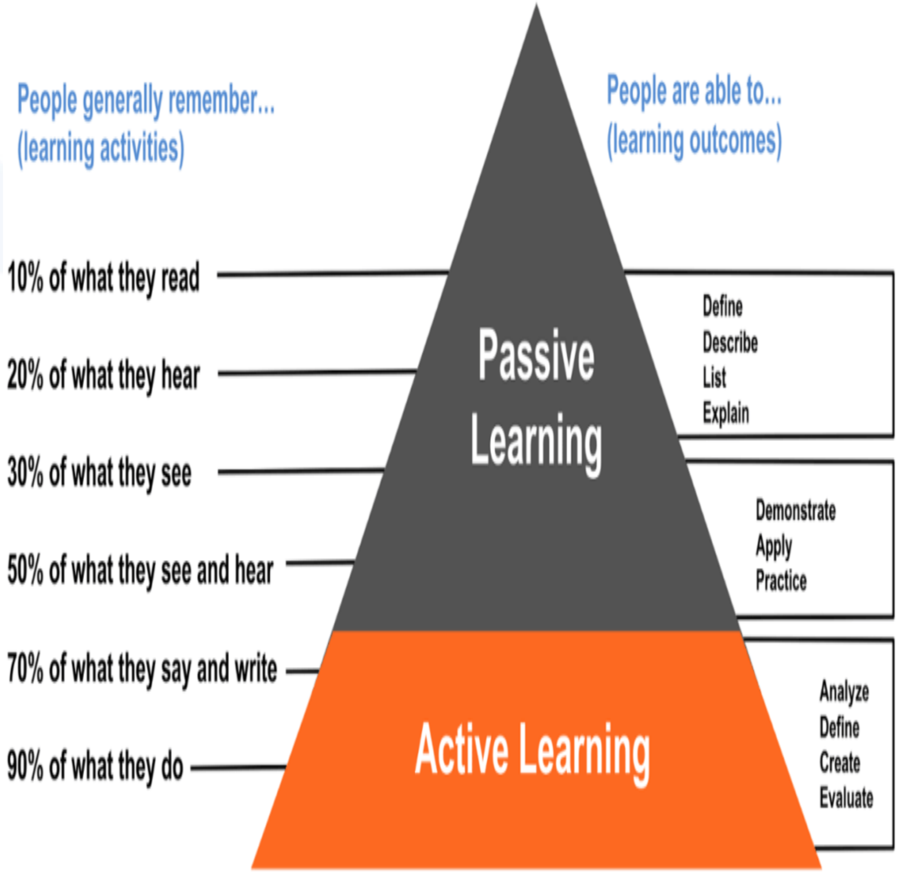


Standard 8 -- Active Learning
Teaching and learning based on active experiential learning methods

Modified UNESCO Pillars of Learning







Standard 9 -- Enhancement of Faculty Competence
Actions that enhance faculty competence in personal and interpersonal skills, and product, process, and system building skills

Standard 10 -- Enhancement of Faculty Teaching Competence
Actions that enhance faculty competence in providing integrated learning experiences, in using active experiential learning methods, and in assessing student learning

CDIO for program and faculty development

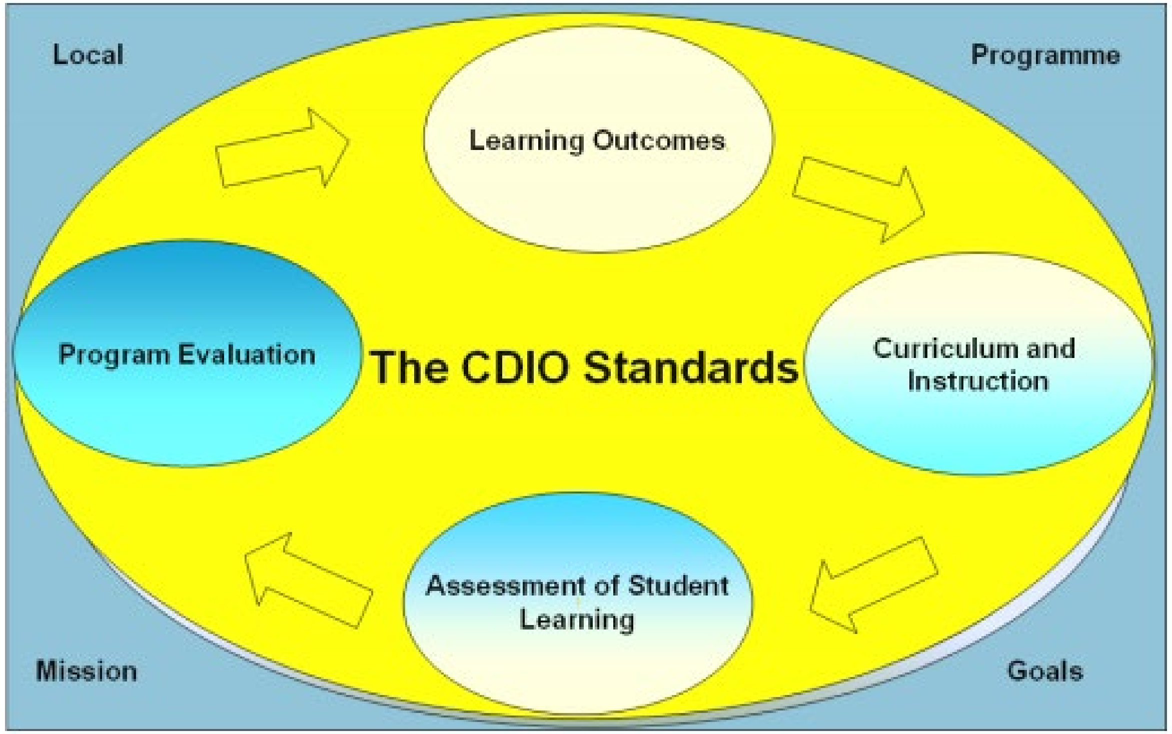
- **Juha Kontio,** Turku University of Applied Sciences and CDIO and continuous improvement **(Finland)**
- **Jens Bennedsen,** Aarhus University **(Denmark)**

Ron Hugo
University of Calgary-Canada

Isam Zabalawi
ACK- Kuwait

Standard 11 -- Learning Assessment
Assessment of student learning in personal and interpersonal skills, and product, process, and system building skills, as well as in disciplinary knowledge

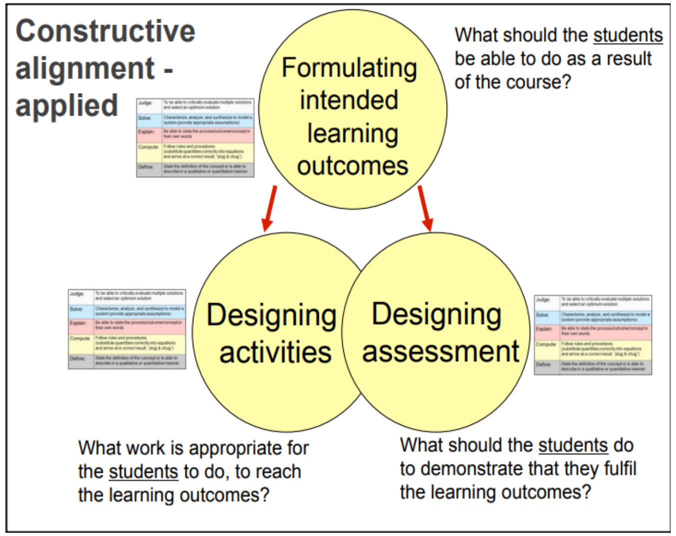
Standard 12 -- Program Evaluation
A system that evaluates programs against these twelve standards, and provides feedback to students, faculty, and other stakeholders for the purposes of continuous improvement



The Learning Assessment Process

"knowledge results from the combination of grasping experience and transforming it." Professor D.A. Kolb

- CDIO approach views assessment as learner-centered, promoting better learning in a culture where students and instructors learn together
- Assessment is learner-centered in that it is aligned with learning outcomes, uses multiple methods to gather evidence of achievement, and promotes learning in a supportive, collaborative environment.
- Assessment focuses on gathering evidence that students have developed proficiency in disciplinary knowledge, personal and interpersonal skills, and product, process, and system building skills.
- learning assessment is the focus of Standard 11.



Just as different categories of learning outcomes require different teaching methods that produce different learning experiences notably active and experiential learning approaches—they also require different assessment methods to ensure the reliability and validity of the assessment data

Self Assessment of Compliance
General Rubric:

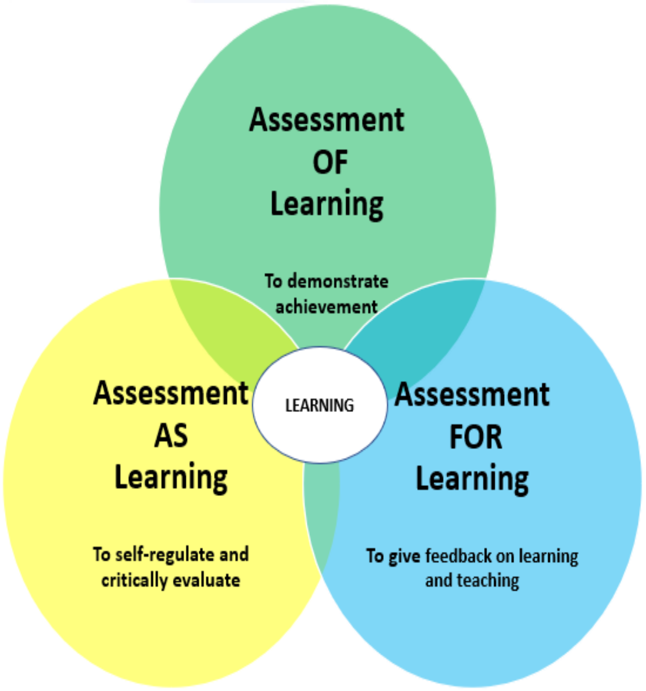
Scale Criteria

- 5 Evidence related to the standard is regularly reviewed and used to make improvements.
- 4 There is documented evidence of the full implementation and impact of the standard across program components and constituents.
- 3 Implementation of the plan to address the standard is underway across the program components and constituents.
- 2 There is a plan in place to address the standard.
- 1 There is an awareness of need to adopt the standard and a process is in place to address it.
- 0 There is no documented plan or activity related to the standard.

- The assessment of compliance with the CDIO standards in a self-report process.
- An engineering program gathers its own evidence and uses the rubrics to rate its status with respect to each of the 12 standards.
- The rubrics are customized to each standard, they follow the pattern of the general rubric.

Student Learning Assessment

- Student learning assessment in a CDIO approach uses a variety of methods to collect evidence of learning before, during, and after learning experiences to give both formative and summative views of the changes that have occurred in students' achievements and attitudes.
- Concept questions are effective both for learning new concepts and for giving instructors feedback on student learning.
- Evidence of student learning is gathered with written and oral questions.
- Performance ratings, product reviews, journals, portfolios, and other self-report instruments.



FORMATIVE ASSESSMENT
VERSUS
SUMMATIVE ASSESSMENT

Formative assessment	Summative assessment
Formative assessments occur during a learning activity	Summative assessments occur at the end of a learning activity
Aim to monitor student learning	Aim to evaluate student learning
Provide students with feedback	Yield a specific score or result
May occur several times during a course unit	May occur few times over the course of the academic year
Can use a wide range of question formats	Can only use a limited number of question formats

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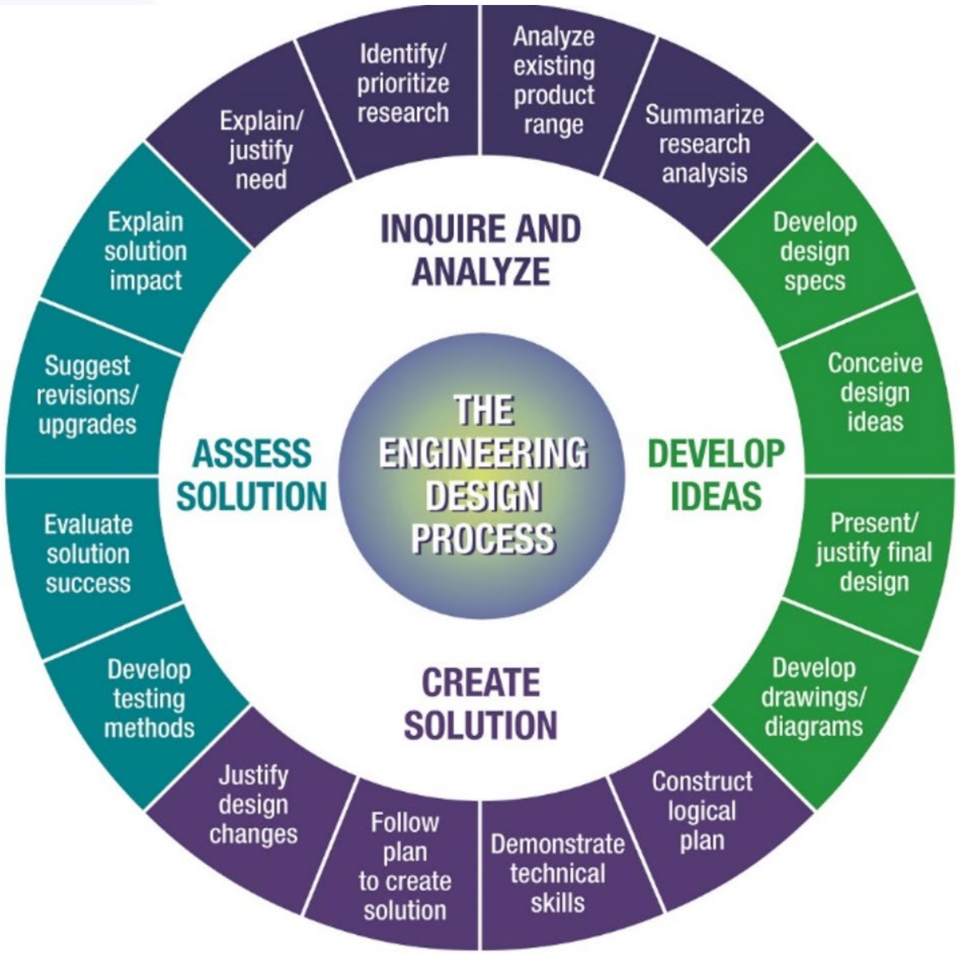

INQUIRE AND ANALYZE
Identify/ prioritize research
Analyze existing product range
Summarize research analysis
Explain/ justify need
DEVELOP IDEAS
Develop design specs
Conceive design ideas
Present/ justify final design
Develop drawings/ diagrams
CREATE SOLUTION
Construct logical plan
Demonstrate technical skills
Follow plan to create solution
Justify design changes
ASSESS SOLUTION
Develop testing methods
Evaluate solution success
Suggest revisions/ upgrades
Explain solution impact
THE ENGINEERING DESIGN PROCESS

Project Design Review

- The rating form embodies criteria designed to assess students' learning related to the project module outcomes. Project supervisors observe students and complete these forms.
- The performance of the student during the course of the project will be assessed on the skills outlined in the table below. The supervisor is expected to rate the student's performance using the following scale:

Project Design Review				
Project Learning Outcome	**Unsatisfactory**	**Satisfactory**	**Good**	**Excellent**
Communicated effectively in writing, verbally, and through graphic media.				
Managed time, resources, and priorities, and worked to given Deadlines.				
Used computers and information technology effectively.				
Located and assembled information using various external resources.				
Demonstrated generic problem-solving skills acquired during project.				
Worked and learned independently.				
Worked safely.				
Communicated effectively with technicians and other support staff.				

at Queen's University Belfast

Sample rubric to assess technical briefings & oral presentations overall comments

Overall Comments				
Presentation Quality	Poor	Fair	Good	Very Good
Main objective of presentation is clearly stated Presenter maintains good eye contact with the audience.				
Presenter uses voice effectively (volume, clarity, inflection)				
Presenter is poised and professional (appearance, posture, gestures)				
Transitions to the next presenter are smooth and effective				
Technical Content	**Poor**	**Fair**	**Good**	**Very Good**
Technical content is accurate and significant Technical content shows sufficient development Main points are emphasized and the relationship between ideas is clear.				
Ideas are supported with sufficient details and clear drawings.				
Graphics and demonstrations are effectively designed and used.				
Alternatives are presented with a rationale for those selected.				
Key issues are addressed.				
Questions are answered accurately and concisely.				

Selection guide to align assessment methods with intended learning outcomes

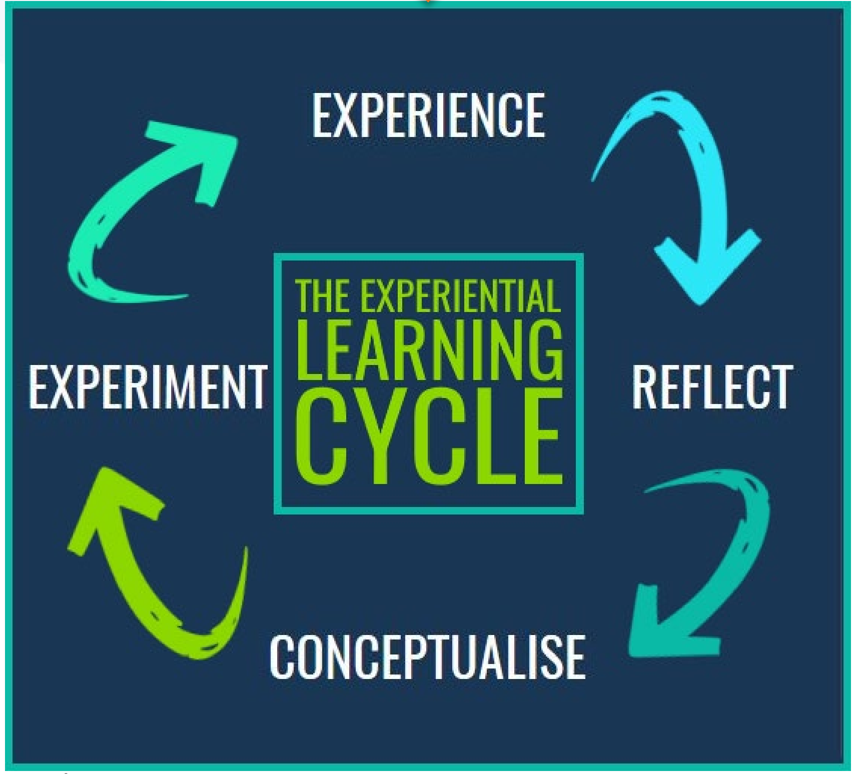
	Written & Oral Questions	Performance Ratings	Project Reviews	Journals & Portfolios	Self-Report Instruments
Conceptual understanding	X				
Problem Solving	X			X	
Knowledge Creation & Synthesis		X	X	X	
Skills and Processes		X	X	X	X
Attitudes			X	X	X

- In most engineering programs, learning assessment focuses on disciplinary content.

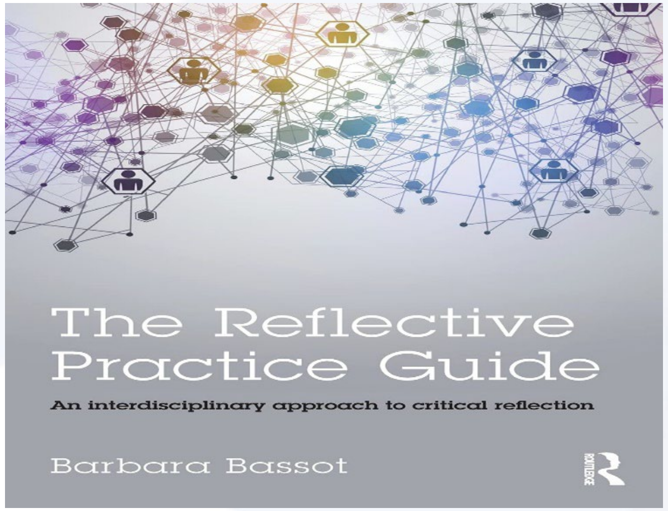
- While this focus continues to be important in a CDIO approach an equal emphasis needs to be placed on assessing the personal and interpersonal skills, and the product, process, and system building skills that are integrated into the curriculum.

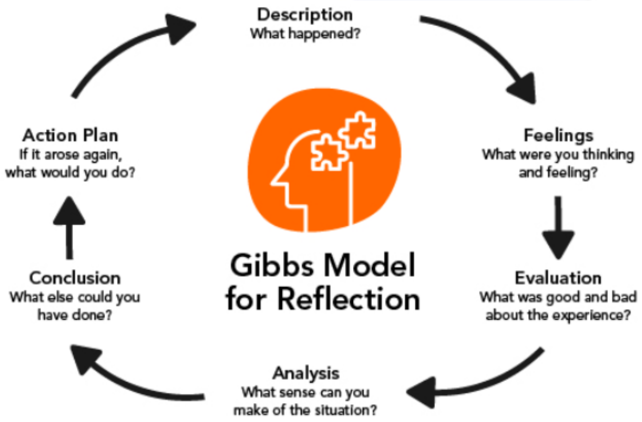
- A single assessment method will not suffice to gather evidence of the broad range of learning outcomes.

Kolb's research shows mastering expertise is a continuous process of experience, reflection, conceptualization and experimentation. These elements make up the experiential learning cycle which shows the relationship between each phase.



Sample rubric to assess a reflective journal





Very good	Required entries are included. Entries are dated and identified. Observations are descriptive and detailed. Interpretations are reasonable and based on evidence. Shows an understanding of the engineering process. Attention to formal, grammar, and spelling.
Good	Most required entries are included. Entries are dated or identified. Observations are descriptive. Some reflection is evident. Interpretations arc reasonable. Shows a basic awareness of the engineering process. Attention to format, grammar. and spelling.
Minimally satisfactory	More than one required entry is missing. Entries are dated or identified Observations are included. Reflection is insufficient or superficial. inadequate attention to format, grammar, and spelling.
Must be rewritten	Little basis for judgment.

Assessment Methods

Direct	Indirect
• Term Exams	• Active Leaning Participation Rate
• Oral Exams	• Number of hours students spend in learning and class participation
• Class Discussions	• Current enrolled students' surveys
• Students' Presentations	• Graduating students' surveys
• Research Evaluation by an assigned supervisor	• Alumni surveys
• International Exams	• Faculty surveys
• Internship	• Employers' surveys (for both Internees and Employees)
• Graduation Projects	• Faculty self-assessment
• Student Portfolio	• Graduating students' interviews
• Research Projects	• Current enrolled students' interviews
• Integrated Experiences portfolio	• Students' appreciation upon graduation
• Conference participation	
• Teamwork	
• Technical Interviews	
• Case study reports	
• Performance Evaluation reports	
• External Reviewers Feedback	

Indirect Assessment Methods

- Institutional and Program Surveys
  - Alumni Surveys
  - Employer Surveys
  - Graduating Seniors and Graduates Surveys
  - Student Satisfaction Surveys
- Other
  - Focus groups
  - Interviews(faculty members, graduating students, alumni)

Using Assessment Results to:

- Improve Teaching & Learning.
- Provide feedback to students.
- Develop and demonstrate a culture of quality.
- Enhance the coherence of curriculum.
- Facilitate the collaborations.
- Make decisions on facts.
- Make continuous academic and professional improvements.

Level of Proficiency

1	To have experienced of been exposed
2	To be able to participate in and contribute to
3	To be able to understand and explain
4	To be skilled in the practice or implementation
5	To be able to lead or innovate

2.4. PERSONAL SKILLS AND ATTITUDES	1	2	3	4	5
2.4.1. Initiative and Willingness to Take Risks					
2.4.2. Perseverance and Flexibility					
2.4.3. Creative Thinking					
2.4.4. Critical Thinking					
2.4.5. Awareness of One's Personal Knowledge, Skills, and Attitudes					
2.4.6. Curiosity and Lifelong Learning					
2.4.7. Time and Resource Management					
2.5. PROFESSIONAL SKILLS AND ATTITUDES					
2.5.1. Professional Ethics, Integrity, Responsibility and Accountability					
2.5.2. Professional Behavior					
2.5.3. Proactively Planning for One's Career					
2.5.4. Staying Current on World of profession					

CDIO Faculty Development Program

- The implementation of CDIO in curriculum and course design requires supporting the faculty members to understand the concepts and methodologies of CDIO.
- Taking a cue from different faculty training activities carried out across the CDIO community, the CDIO faculty development course was organized in a modular framework.
- Using the learning objectives as a basis for course design, the CDIO faculty development course was organized in 3 modules.
- Each module is mapped to the learning objectives and the content is further mapped to the modules.
- The course is typically delivered using seminar presentations, case study presentations, workshops, active discussions, and laboratory & workspace tours.

List of Learning Objectives for CDIO Faculty Development Course

L1 Explain the rationale of the CDIO approach to engineering education.

L2 Apply the CDIO methodology to curriculum development, including

- a) Formulating learning outcomes on the program level
- b) Devising a curriculum to integrate disciplinary fundamentals with personal and professional skills and attitudes, in particular business and entrepreneurship skills.
- c) Giving examples of strategies to enable and drive program-driven course development

L3 Apply the CDIO methodology to course development, including

- a) Formulating learning outcomes on the course level
- b) Developing appropriate learning activities for discipline-led learning and for problem based/project organized learning
- c) Developing appropriate assessment methods aligned with the intended learning outcomes
- d) Suggesting ways to address business and entrepreneurship skills on the course level

Faculty Development Program

1. ability to apply CDIO philosophy adopting the principle that product, process, and system lifecycle development and deployment -- Conceiving, Designing, Implementing and Operating -- are the context for engineering education (Standard 1 CDIO);
2. ability to plan specific, detailed learning outcomes for personal and interpersonal skills, and product, process, and system building skills, as well as disciplinary knowledge (Standard 2 CDIO);
3. ability to develop an integrated curriculum, designed with mutually supporting disciplinary courses, with an explicit plan to integrate personal and interpersonal skills, and product, process, and system building skills (Standard 3 CDIO);
4. ability to develop and implement an introductory course within the integrated curriculum, that provides the framework for practice in product, process, and system building, and introduces essential personal and interpersonal skills of graduates (Standard 4 CDIO)

Faculty Development Program

5. ability to organize design-built activities of students through the implementation in an integrated curriculum of at least two or more design-implement experiences at a basic and advanced levels (Standard 5 CDIO);
6. ability to create engineering workspaces and laboratories that support and encourage hands on learning of product, process, and system building, disciplinary knowledge, and social learning (Standard 6 CDIO);
7. ability to ensure integrated learning experiences that lead to the acquisition of disciplinary knowledge, as well as personal and interpersonal skills, and product, process, and system building skills (Standard 7 CDIO);
8. ability to apply active learning methods (teamwork, case-study, games, problem-based learning, context learning) improving the quality of training and enhancing the level of acquired learning outcomes (Standard 8 CDIO);

Faculty Development Program

9. Ability for actions that enhance faculty competence in personal and interpersonal skills, and product, process, and system building skills (Standard 9 CDIO);
10. Ability for actions that enhance faculty competence in providing integrated learning experiences, in using active experiential learning methods, and in assessing student learning (Standard 10 CDIO);
11. Ability to assess student learning in personal and interpersonal skills, and product, process, and system building skills, as well as in disciplinary knowledge (Standard 11 CDIO);
12. Ability to evaluate educational program against all CDIO standards, and provide feedback to students, faculty, and other stakeholders for the purposes of continuous improvement (Standard 12 CDIO).

Modernization of Engineering Education Based on International CDIO Standards
Association for Engineering Education of Russia,
National Research Tomsk Polytechnic University, A.I. Chuchalin

Module 1 (M1)

Train and create awareness of CDIO initiative and how to implement CDIO in raw material related program and course development.

a) CDIO Introduction, History L1
b) CDIO Syllabus and Standards L1
c) Methods for curriculum design L2 - a, b
Methods for course design L3 - a, b, c

Module 2 (M2)

Show examples and case studies to give ideas and inspiration to the practitioner to implement CDIO both at program level and course level.

Case study on curriculum design L2 - c
Case study on course design L3 - a, b, c
Case study on involvement of Business and Entrepreneurship in Engineering L3 – d

Module 3 (M3)

Developing CDIO based curriculum, courses and projects for the specific programs and courses related to the field of raw materials including mining and metallurgy aspects with industrial involvement.

a. Workshop on curriculum design L2 - a, b, c

b. Workshop on course design L3 – a, b, c, d

Kanishk Bhadani, Erik Hulthén, Johan Malmqvist, Chalmers University of Technology, Sweden
Catrin Edelbro,Luleå University of Technology, Sweden
Alan Ryan, David Tanner, Lisa O'Donoghue, University of Limerick, Ireland
Kristina Edström, KTH Royal Institute of Technology, Sweden Proceedings of the 13th International CDIO Conference, University of Calgary, Calgary, Canada, June 18-22, 2017

cdio
CONCEIVE DESIGN IMPLEMENT OPERATE™

About — About CDIO | Implement — Implementing CDIO | Participation — Participating Members | Knowledge Library — Publications & Presentations | Meetings — Open Meetings & Conferences

CDIO Academy and CDIO Award

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    - › Previous winners of the CDIO Academy

What is the CDIO Academy?

The CDIO Academy is an opportunity for engineering students that are active at CDIO institutions, to showcase their design-implement projects, meet their peers from engineering programs around the world, and participate in workshops and plenary sessions presented by prominent leaders in engineering education.

The CDIO Academy takes places alongside with the CDIO conference and there is a specific program for the participants of the CDIO Academy.

What is the CDIO Academy about?

The CDIO conference runs from the June 25^{th} to 27^{th} and has the overall title CHANGE.

For the CDIO Academy the headline is *Change the Business – Change the world*. The idea is that the participants in the Academy work with the basic resource WATER in accordance to the overall CHANGE agenda.

The CDIO Academy is a challenge

Aarhus University invites 40 students from all over the world to participate in the CDIO Academy. The students will be put in teams with other students from different corners of the world and with different engineering backgrounds.

How to participate

The CDIO Academy is held each year at the international CDIO conference, and it is a student challenge within the larger conference, with presentations, design-implement experiences, and a juried design project exhibit.

The CDIO Academy invites teams of engineering students to participate in the challenge and to submit innovative design projects to the competition.

Competition Criteria

Project areas are provided by cutting-edge companies, and maybe an innovative design of a product, process, or system.

The projects must meet the following selection criteria:

- Relevant to the design project theme
- Demonstrates a design-implement product, process, or system
- Demonstrates two or more phases of the Conceive, Design, Implement and Operate approach
- Has the potential for practical application
- Demonstrates knowledge of the context to which the project applies
- Provides evidence of effective teamwork

CDIO Academy 2017

University of Calgary

June 18-21, 2017

CDIO ACADEMY 2017

Welcome to the CDIO Academy, taking place at the University of Calgary in Calgary, Canada from June 18 – 21, 2017.
50 undergraduate engineering students from all over the world will work together to research, design, and pitch their answer to a question that is strongly related to the conference theme, Engineering Education in the Digital Age.

The question being asked at the 2017 CDIO Academy is:

- What is the biggest challenge facing autonomous vehicles, and what may a solution be?

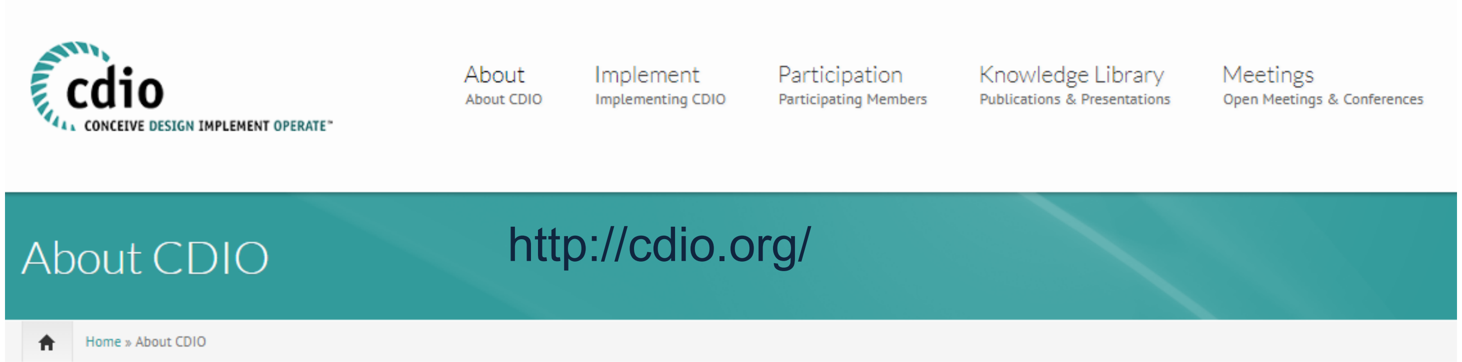
- Project introduction and competition information can be found here.

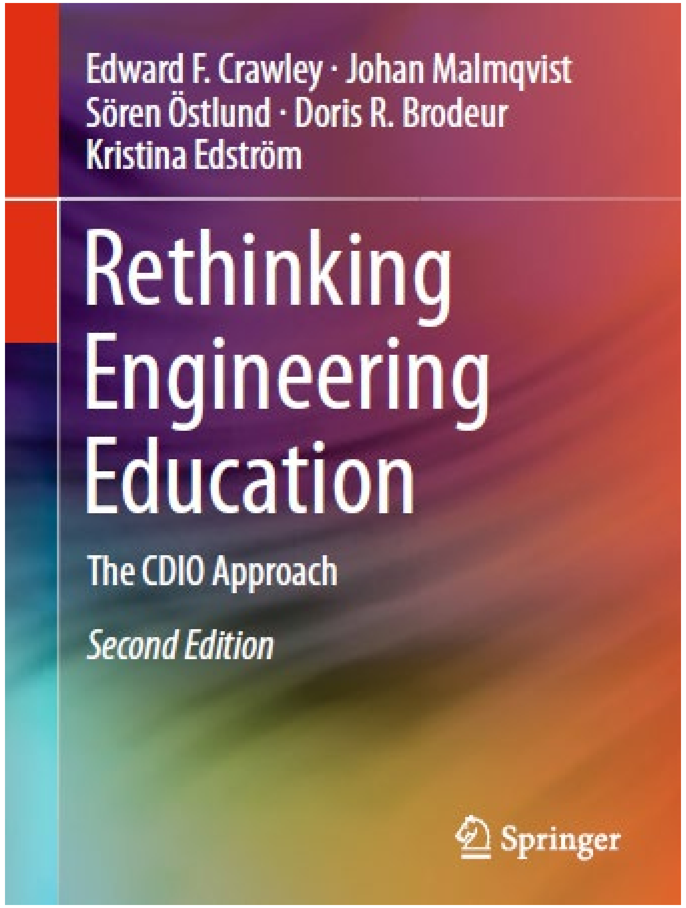
Get Started

Here are some suggestions to get started:

- ✓ Read the first two or three chapters of the book:

  Rethinking Engineering Education – The CDIO Approach
- ✓ Read the section of this website on "Startup Advice"
- ✓ Read the section of this website on "Early Successes"
- ✓ Attend an Introductory CDIO Workshop (See the schedule of upcoming CDIO meetings)
- ✓ Visit another university that has implemented CDIO
- ✓ Invite a leader of a CDIO program at another university to meet with you and your colleagues
- ✓ Read through the materials in the iKit





List of Generic Competences For Engineering Students

- Ability to communicate in a second (foreign) language
- Capacity to learn and stay up-to-date with learning
- Ability to communicate both orally and through the written word in first language
- Ability to be critical and self-critical
- Ability to plan and manage time
- Ability to act on the basis of ethical reasoning
- Capacity to generate new ideas (creativity)
- Ability to search for, process and analyse information from a variety of sources
- Ability to work autonomously
- Ability to identify, pose and resolve problems

- Ability to apply knowledge in practical situations
- Ability to make reasoned decisions
- Ability to undertake research at an appropriate level
- Ability to work in a team
- Knowledge and understanding of the subject area and understanding of the profession
- Ability to motivate people and move toward common goals
- Commitment to conservation of the environment
- Ability to communicate key information from one’s discipline or field to non-experts
- Ability for abstract and analytical thinking, and synthesis of ideas
- Ability to interact constructively with others regardless of background and culture and respecting diversity

- Ability to design and manage projects
- Ability to interact with others in a constructive manner, even when dealing with difficult issues
- Ability to show awareness of equal opportunities and gender issues
- Commitment to health, well-being and safety
- Ability to take the initiative and to foster the spirit of entrepreneurship and intellectual curiosity
- Ability to evaluate and maintain the quality of work produced
- Ability to use information and communications technologies
- Commitment to tasks and responsibilities
- Ability to adapt to and act in new situations and cope under pressure
- Ability to act with social responsibility and civic awareness
- Ability to work in an international context

CDIO syllabus 3.0

4 CONCEIVING, DESIGNING, IMPLEMENTING AND OPERATING SYSTEMS IN THE ENTERPRISE, SOCIETAL AND ENVIRONMENTAL CONTEXT – THE INNOVATION PROCESS (UNESCO: LEARNING TO DO)

4.1 SOCIETAL AND ENVIRONMENTAL CONTEXT [3h]

4.1.1 *Roles and Responsibility of Engineers*

The goals and roles of the engineering profession
The responsibilities of engineers to society and a sustainable future
One's own role and impact as a responsible engineer in promoting a sustainable society [SD, self-awareness, 2019]

4.1.2 *The Impact of Engineering on Society and the Environment*

The impact of engineering on the environmental, social, knowledge and economic systems
Using interdisciplinary knowledge and skills to understand and address complex problems [Interdisciplinarity]
Assessment of sustainability effects/impacts [SD, normative competency, inspired av Wiek et al, 2016]
Measures and strategies for minimizing/eliminating negative impacts and promoting/enhancing positive impacts [SD, systems thinking/IPS]

4.1.3 *Society's Regulation of Engineering*

The role of society and its agents to regulate engineering
The way in which legal and political systems regulate and influence engineering
How professional societies license and set standards
How intellectual property is created, utilized and defended
Protection of personal data and information (GDPR etc)

4.1.4 *The Historical and Cultural Context*

The diverse nature and history of human societies as well as their literary, philosophical and artistic traditions
The history of technological innovation and how society and technology have co-evolved [Smulders et al]
Learning from historical and cultural contexts about sustainability issues and potential solutions [SD,anticipatory,2019]

4.1.5 *Contemporary Issues and Values* **[3j]**

The important contemporary political, social, legal and environmental issues and values
The processes by which contemporary values are set, and one's role in these processes
The mechanisms for expansion and diffusion of knowledge
Definitions and principles of sustainability and sustainable development [moved here from the eliminated section 4.1.7]

4.1.6 *Visions of the future*

CDIO syllabus 3.0

Concepts about the future, including long-term, short-term; possible, probable, plausible and desirable [SD, anticipatory competence, Wiek et al. 2016]
Scenario construction, forecasting, backcasting and visioning [SD, parts of anticipatory competence, Wiek et al. 2016]
Visions for a sustainable future for the society and for one's profession [SD, anticipatory, 2019; normative competence, Wiek et al, 2016]

4.1.7 *Developing a Global and International Perspective* [Internationalisation]
The internationalization of human activity
The similarities and differences in the political, social, economic, business and technical norms of various cultures
International and intergovernmental agreements and alliances
Unofficial global communities and network
Postcolonialism [SD, …]
Consequences of technical systems in a global perspective [SD, systems-thinking,2019]One's own role and possibilities to have a global impact [SD, self-awareness, 2019]

4.2 ENTERPRISE AND BUSINESS CONTEXT

4.2.1 *Appreciating Different Enterprise Cultures*
The differences in process, culture, and metrics of success in various enterprise cultures:
Corporate vs. academic vs. governmental vs. non-profit/NGO
Market vs. policy-vs. value driven [SD, …]Large vs. small
Centralized vs. distributed
Research and development vs. operations
Mature vs. growth phase vs. entrepreneurial
Longer vs. shorter development cycles
With vs. without the participation of organized labor
Proactive vs. reactive in a transformation towards a sustainable future [SD, ...]

4.2.2 *Enterprise Stakeholders, Strategy and Goals*
The stakeholders and beneficiaries of an enterprise (owners, employees, customers, etc.)
People in other contexts, future generations, and other species, as stakeholders [SD, …]
Obligations to stakeholders
The mission, scope and goals of the enterprise
Enterprise strategy and resource allocation an enterprise's core competence and marketsKey alliances and supplier relations

4.2.3 *Technical Entrepreneurship*
Entrepreneurial opportunities that can be addressed by technology
Technologies that can create new values and contribute to sustainable development [SD, ...]
Commercial value of data and information
Entrepreneurial finance and organization

CDIO syllabus 3.0

4.2.4 *Working in Organizations*

- The function of management
- Various roles and responsibilities in an organization
- The roles of functional and program organizations
- Working effectively within hierarchy and organizations
- Change, dynamics and evolution in organizations

4.2.5 *Working in International Organizations*

- Culture and tradition of enterprise as a reflection of national culture
- Equivalence of qualifications and degrees
- Governmental regulation of international work

4.2.6 *New Technology Development and Assessment*

- The research and technology development process
- Identifying and assessing emerging technologies that
  - might disrupt the business rules, processes, and models,
  - can contribute to sustainable development and/or
  - can give rise to unintended and unwanted consequences [SD, …]
- Technology development roadmaps
- Intellectual property regimes and patents
- Open innovation

4.2.7 *Engineering Project Finance and Economics*

- Financial and managerial goals and metrics
- Project finance – investments, return, timing
- Financial planning and control
- Impact of projects on enterprise finance, income and cash

CDIO syllabus 3.0

4.3 CONCEIVING, SYSTEM ENGINEERING AND MANAGEMENT [3c]

4.3.1 *Understanding Societal and Planetary Goals and Constraints*

Needs vs. wants with respect to justice and sufficiency [SD,...]
Conditions for operating within planetary boundaries and social foundations for human societies [SD, Raworth, 2017]
Power, politics, authority in strategy building and change [SD/Strategic competency, Wiek et al. 2016]
Theories of change (e.g., behavior change, social transformations) [SD/Strategic competency, Wiek et al. 2016]
Barriers including obstacles, inertia, path dependencies [SD/Strategic competency, Wiek et al. 2016]
Transitions and transformations (and other change dynamics) [SD/IPS, Wiek et al 2016]

4.3.2 *Understanding Needs and Setting Goals*

Needs and opportunities
Customer needs
Opportunities that derive from new technology or latent needs
Factors that set the context of the system goals
Enterprise goals, strategies, capabilities and alliances
Competitors and benchmarking information
Ethical, social, environmental, legal and regulatory influences and constraints [SD, …]
The probability of change in the factors that influence the system, its goals and resources available
System goals and requirements
The language/format of goals and requirements
Initial target goals (based on needs, opportunities and other influences)
System performance metrics
Requirement completeness and consistency
Allocation of margins, responding to change and handling unknown or unanticipated requirements during the lifecycle of a design.
Capture user experiences and use case scenarios

4.3.3 *Defining Function, Concept and Architecture*

Necessary system functions (and behavioral specifications)
System concepts
Incorporation of the appropriate level of technology
Trade-offs among and recombination of concepts
High-level architectural form and structure
The decomposition of form into elements, assignment of function to elements, and definition of interfaces

CDIO syllabus 3.0

4.3.4 *System Engineering, Modeling and Interfaces*

Appropriate models of technical performance and other attributes

Consideration of implementation and operations

Life cycle value and costs (economic, social, environmental, design, implementation, operations, opportunity, etc.) [SD, CDIO Standard 1]

Trade-offs among various goals, function, concept and structure and iteration until convergence

'Trusted' system design (addressing aspects of cyber security, data privacy, consumer understanding, transparency)

System designs that are non-deterministic, that continue to learn and modify themselves during operation (e.g. critical decisions that are allocated to autonomous vehicles).

Plans for interface management

4.3.5 *Development Project Management*

Waterfall, agile and scrum project management models

Project control for short-term andlong-term impact assessment and schedule [SD/Normative competency, Wiek et al. 2016]

Appropriate transition points and reviews

Configuration management and documentation

Performance compared to baseline

Earned value recognition

The estimation and allocation of resources

Risks and alternatives

Possible development process improvements

multi-project and program management

Continuous deployment and DevOps

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4.3.6 Product information and knowledge management

Capturing data and crafting a design in a digital environment.

Model-based systems engineering, using digital representations of the system, simulations, and immersive technologies

Digital SE as part of digital end-to-end business

Modeling, visualization and digital representation of system designs and end-to-end solutions

Digital twins

Knowledge sharing; data stewardship, open data sets

4.4 DESIGNING [3c]

4.4.1 *The Design Process*

Requirements for each element or component derived from system level goals and requirements

Alternatives in design

The initial design

Life cycle consideration and responsibility in design (economic, social, environmental) [SD, ...]

Experimental prototypes and test articles in design development

Appropriate optimization in the presence of constraints

Iteration until convergence

The final design

Accommodation of changing requirements

Fast generation of multiple design options and evaluating them instantly in a virtual environment ('Optioneering')

What-if scenario analysis

4.4.2 *The Design Process Phasing and Approaches*

The activities in the phases of system design (e.g., conceptual, preliminary and detaileddesign) [Development methodology]

Process models appropriate for particular development projects (agile, waterfall, spiral, concurrent, set-based design, etc.) [Development methodology]

The process for single, platform and derivative products

4.4.3 *Utilization of Knowledge in Design*

Technical and scientific knowledge

Modes of thought (problem solving, inquiry, system thinking, creative and critical thinking)

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Prior work in the field, standardization and reuse of designs (including reverse engineering and refactoring, redesign)
Design knowledge capture

4.4.4 *Disciplinary Design*
Appropriate techniques, digital tools and processes
Design tool calibration and validation
Quantitative analysis of alternatives
Modeling, simulation, visualization and test
Analytical refinement of the design

4.4.5 *Multidisciplinary Design*
Interactions between disciplines
Dissimilar conventions and assumptions
Differences in the maturity of disciplinary models
Multidisciplinary design environments (physical and digital)

4.4.6 *Design for Sustainability, Safety, Aesthetics, Operability and Other Objectives*
Design for:
Performance, quality, robustness, life cycle cost and value
Sustainability: [SD, …]
Life cycle perspective for a product or service
Circular economy
Systems perspective including environmental, social and economic aspects
Reduced environmental impact
Efficient use of energy, materials and land
Use of data to drive energy and resource allocation
Intergenerational equity
Gender equality
Retirement, reusability, recycling, and remanufacturing
Safety and security
Aesthetics
Human factors, interaction and supervision
Implementation, verification, test channels and service models (e.g. cloud, software-as-a-service, product-servicesystem …)
Operations
Reliability, availability, maintainability, dependability, failure mode and effects analysis
Evolution, product improvement

4.5 IMPLEMENTING [3c]

4.5.1 *Designing a Sustainable Implementation Process*
The goals and metrics for implementation performance, cost and quality
The implementation system design:
Task allocation and cell/unit layout
Workflow
Considerations for human user/operators
Cyberphysical factory design
Consideration of sustainability

4.5.2 *Hardware Manufacturing Process*
The manufacturing of parts
The assembly of parts into larger constructs
Tolerances, variability, key characteristics and statistical process control

4.5.3 *Software Implementing Process*
The breakdown of high-level components into module designs (including algorithms and data structures)
Algorithms (data structures, control flow, data flow)

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The programming language and paradigms
The low-level design (coding)
The system build

4.5.4 *Hardware Software Integration*
The integration of software in electronic hardware (size of processor, communications, etc.)
The integration of software with sensor, actuators and mechanical hardware
Hardware/software function and safety
Cyber-Physical systems

4.5.5 *Test, Verification, Validation and Certification*
Test and analysis procedures (hardware vs. software, acceptance vs. qualification)
The verification of performance to system requirements
The validation of performance to customer needs
The validation of system design behavior, performance and safety of system designs with "learned" behaviors.
The certification to standards

4.5.6 *Implementation Management*
The organization and structure for implementation
Sourcing and partnering
Supply chains and logistics
Control of implementation cost, performance and schedule
Quality assurance
Human health and safety
Environmental security
Possible implementation process improvements

4.6 OPERATING [3c]

4.6.1 *Designing and Optimizing Sustainable and Safe Operations*
The goals and metrics for operational performance, cost and value
Sustainable operations
Safe and secure operations
Operations process architecture and development
Operations (and mission) analysis and modeling

4.6.2 *Training and Operations*
Training for professional operations:
Simulation
Instruction and programs
Procedures
Education for consumer operation
Operations processes
Operations process interactions

4.6.3 *Supporting the System Life Cycle*
Maintenance and logistics
Life cycle performance and reliability
Life cycle value and costs (economic, social, environmental) [SD, …]
Feedback to facilitate system improvement
Continuous development [Development methodology]

4.6.4 *System Improvement and Evolution*
Pre-planned product improvement
Improvements based on needs observed in operation
Evolutionary system upgrades
Contingency improvements/solutions resulting from operational necessity

4.6.5 *Disposal, End-of-Life, and Circularity [SD, …]*
The end of useful life
Disposal options
Residual value at life-end
Waste hierarchy (reduce, reuse, repair, recycle, recover, disposal) [SD, EU 2018]
Environmental and social considerations and constraints for disposal [SD, …]

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4.6.6 *Operations Management*

The organization and structure for operations
Partnerships and alliances
Control of operations cost, performance and scheduling
Quality and safety assurance
Possible operations process improvements
Life cycle management
Human health and safety
Environmental security

The Extended CDIO Syllabus: Leadership and Entrepreneurship

This extension to the CDIO Syllabus is provided as a resource for programs that seek to respond to stakeholder expressed needs in the areas of Engineering Leadership and Entrepreneurship

4.7 LEADING ENGINEERING ENDEAVORS

Engineering Leadership builds on factors already included above, including:

- **Attitudes of Leadership – Core Personal Values and Character,** including topics in Attitudes, Thought and Learning (2.4), and in Ethics, Equity and Other Responsibilities (2.5) **Relating to Others**, including topics in Teamwork (3.2), Communications (3.2), Collaboration (3.1) and potentially Communications in Foreign Languages (3.4)
- **Making Sense of Context**, including topics in Societal and Environmental Context (4.1), Enterprise and Business Context (4.2) Conceiving, Systems Engineering and Management (4.3) and System Thinking (2.3)

In addition there are several topics that constitute creating a **Purposeful Vision**:

4.7.1 *Identifying the Issue, Problem or Paradox (which builds on Understanding Needs and Setting Goals 4.3.2)*

Synthesizing the understanding of needs or opportunities (that relate to technical systems)
Clarifying the central issues
Framing the problem to be solved
Identifying the underlying paradox to be examined

4.7.2 *Thinking Creatively and Communicating Possibilities (which builds on and expands Creative Thinking 2.4.3)*

How to create new ideas and approaches
New visions of technical systems that meet the needs of customers and society
Communicating visions for products and enterprises
Compelling and holistic visions for the future

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4.7.3 Defining the Solution (which builds on and expands Understanding Needs and Setting Goals 4.3.2)

The vision for the engineering solution
Achievable goals for quality performance, budget and schedule
Consideration of direct and indirect stakeholders
Consideration of technology options
Consideration of regulatory, political and competitive forces
Collaboration with direct and indirect stakeholders in outlining interventions

4.7.4 Creating New Solution Concepts (which builds on and expands 4.3.2 and 4.3.3)

Setting requirements and specifications
The high-level concept for the solution
Architecture and interfaces
Alignment with other projects of the enterprise
Alignment with enterprise strategy, resources and infrastructure

And several topics that lead to **Delivering on the Vision:**

4.7.5 Building and Leading an Organization and Extended Organization (which builds on 4.2.4 and 4.2.5)

Recruiting key team members with complementary skills

Start-up of team processes, and technical interchange
Defining roles, responsibilities and incentives
Leading group decision-making
Assessing group progress and performance
Building the competence of others and succession
Partnering with external competence
Continuous self-evaluation in relation to collaboration, teamwork and leadership [SD, self-awareness, 2019]
Ability to show leadership that recognizes feelings and varying desires [SD, self-awareness, 2019]

4.7.6 Planning and Managing a Project to Completion (which builds on 4.3.4)

Plans of action and alternatives to deliver completed projects on time
Deviation from plan, and re-planning
Managing human, time, financial and technical resources to meet plan
Program risk, configuration and documentation
Program economics and the impact of decisions on them
Interfaces to program and project portfolio management in large-scale environments
Continually evaluate and further motivate one´s actions in managing a project and its human resources [SD, self-awareness, 2019]

4.7.7 Exercising Project/Solution Judgment and Critical Reasoning (which builds on 2.3.4, 2.4.4, 2.4.5, 2.5.3)

Making complex technical decisions with uncertain and incomplete information
Questioning and critically evaluating the decisions of others
Corroborating inputs from several sources
Evaluating evidence and identifying the validity of key assumptions
Understanding alternatives that are proposed by others
Judging the expected evolution of all solutions in the future

4.7.8 Innovation – the Conception, Design and Introduction of New Goods and Services (which is the leadership of 4.3 and 4.4)

From research to readiness for industrial application and commercialization
Designing and introducing new goods and services to the marketplace
Designing solutions to meet customer and societal needs
Designing solutions with the appropriate balance of new and existing technology
Robust, flexible and adaptable products
Consideration of current and future competition
Validating the effectiveness of the solution

4.7.9 Invention – the Development of New Devices, Materials or Processes that Enable New Goods and Services (which builds on 4.2.6)

Science and technology basis and options
Imagining possibilities
Inventing a practical device or process that enables a new product or solution Adherence to intellectual property regimes

4.7.10 Implementation and Operation – the Creation and Operation of the Goods and Services that will Deliver Value (which are the leadership of 4.5 and 4.6)

Leading implementing and operating
Importance of quality
Safe operations
Operations to deliver value to the customer and society

These last three items are in fact the leadership of the core processes of engineering: conceiving, designing, implementing and operating

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4.8 ENGINEERING ENTREPRENEURSHIP

Engineering Entrepreneurship includes by reference all of the aspects of Societal and Enterprise Context (4.1 and 4.2), all of the skills of Conceiving, Designing, Implementing and Operating (4.3 – 4.6) and all of the elements of Engineering Leadership (4.7).

In addition, there are the entrepreneurship specific skills:

4.8.1 *Company Founding, Formulation, Leadership and Organization*
- Creating the corporate entity and financial infrastructure
- Team of supporting partners (bank, lawyer, accounting, etc.)
- Consideration of local labor law and practices
- The founding leadership team
- The initial organization
- The board of the company
- Advisors to the company

4.8.2 *Business Plan Development*
- A need in the world that you will fill
- A technology that can become a product
- A team that can develop the product
- Plan for development
- Uses of capital
- Liquidity strategy

4.8.3 *Company Capitalization and Finances*
- Capital needed, and timing of need (to reach next major milestone)
- Investors as sources of capital
- Alternative sources of capital (government, etc.)
- Structure of investment (terms, price, etc.)
- Financial analysis for investors
- Management of finances
- Expenditures against intermediate milestones of progress

4.8.4 *Innovative Product Marketing*
- Size of potential market
- Competitive analyses
- Penetration of market
- Product positioning
- Relationships with customers
- Product pricing
- Sales initiation
- Distribution to customers

4.8.5 *Conceiving Products and Services around New Technologies*
- New technologies available
- Assessing the readiness of technology
- Assessing the ability of your enterprise to innovate based on the technology
- Assessing the product impact of the technology
  - Incremental, architectural, radical/disruptive
- Accessing the technologies through partnerships, licenses, etc.
- A team to productize the technology

4.8.6 *The Innovation System, Networks, Infrastructure and Services*
- Relationships for enterprise success
- Mentoring of the enterprise leadership
- Supporting financial services
- Investor networks
- Suppliers

4.8.7 *Building the Team and Initiating Engineering Processes (conceiving, designing, implementing and operating)*
- Hiring the right skill mix
- Technical process startup
- Building an engineering culture

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4.8.8 *Managing Intellectual Property*

IP landscape for your product or technology

IP strategy – offensive and defensive

Filing patents and provisional patents

IP legal support

Entrepreneurial opportunities that can be addressed by technology

Technologies that can create new products and systems

Entrepreneurial finance and organization

4.9 RESEARCH [Linköping]

Research builds on factors already included above, including:

- x, including topics in Attitudes, Thought and Learning (2.4), and in Ethics, Equity and Other Responsibilities (2.5)
  x, including topics in Collaboration (3.1) Teamwork (3.2), Communications (3.2) and potentially Communications in Foreign Languages (3.4)
- x, including topics in External, Societal and Environmental Context (4.1), Enterprise and Business Context (4.2) Conceiving, Systems Engineering and Management (4.3) and System Thinking (2.3)

4.9.1 *Identification of needs, structuring and planning of research projects*

Identifying relevant research problems

Reviewing and synthesizing relevant previous work

Specifying the aims with respect to sustainability and various stakeholders' needs

Selecting research approach and methodology

Designing and structuring the project

4.9.2 *Execution of research*

Performing empirical and theoretical work

Documenting research process and findings

Analyzing results

Drawing appropriate conclusions, acknowledging limitations

4.9.3 *Presentation and evaluation of research*

Reporting the work in a coherent manuscript

Explaining what makes the work trustworthy and accurate

Relating the work with previous work

Acknowledging the work of others

Discussing implications of the work

4.9.4 *Research ethics*

Safeguarding the quality of the research

Honesty in reporting the research

Accountability for research from idea to publication

Respect for colleagues, research participants, society and environment

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