NTNU

Norwegian University of Science and Technology

C D I O

Conceiving - Designing - Implementing - Operating (CDIO)
An innovative educational framework for producing the next generation of engineers
How can CDIO impact programs and courses?

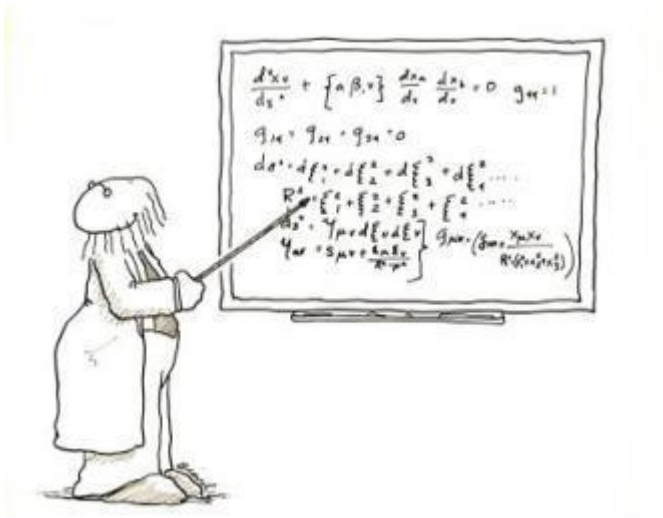
25 Januar 2017
Reidar Lyng
SEED / Uniped

What is CDIO?

- An idea of what engineering students should learn: To become "Engineers who can engineer"
- A methodology for engineering education reform: The CDIO Syllabus and the 12 CDIO Standards
- A community: The CDIO Initiative with 120 universities as members

Background: Stakeholder needs (i)

Disciplinary theory and "problem-solving"



NECESSARY BUT NOT SUFFICIENT

Real problems need science, technology, understanding of context, and creativity

Real problems

- are complex, ill-defined, contain tensions
- need interpretations and estimations
- require systems view
- cross disciplinary boundaries (within and outside science and technology)
- sit in contexts with societal and business aspects

See for instance Roberts (1982), Schwab (1974), Thomas P. Hughes, Gibbons et al (1994)

Bakground: Stakeholder needs (ii)

Individual approach

NECESSARY BUT NOT SUFFICIENT

Modes of practice - communication and collaboration

- Work processes involve communication and dialogue with customers, suppliers, colleagues, citizens, authorities, competitors…
  (writing reports and giving presentations is only a part of this)
- Collaboration is the ability to work productively within and across organizational boundaries, in a globalized world
  (working in homogeneous project teams on well-defined tasks is only a part of this)

Background: Stakeholder needs (iii)

Education set in the context of:

Science and technology

Education for the context of:

Professional practice, real problem-solving, and innovation

NECESSARY BUT NOT SUFFICIENT

Background

CURRENT

- **Engineering Science**
- **R&D Context**
- **Reductionist**
- **Individual**

DESIRED

- **Engineering**
- **Product Context**
- **Integrative**
- **Team**

... but still based on a rigorous treatment of engineering fundamentals

Background

- 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 future researchers to understand the importance and *strategic value of their work*

A CDIO-BASED QUALITY ASSURANCE SYSTEM

- **CDIO syllabus – *WHAT***
- **CDIO standards – *HOW***
- **CDIO curriculum design process – *from WHAT to HOW***
- **CDIO standards self-evaluation – *HOW WELL***

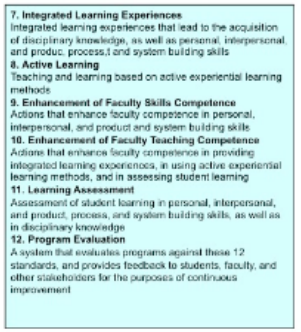
1 **Disciplinary Knowledge & Reasoning**
- 1.1 Knowledge of underlying mathematics and sciences
- 1.2 Core engineering fundamental knowledge
- 1.3 Advanced engineering fundamental knowledge, methods and tools

2 **Personal and Professional Skills**
- 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

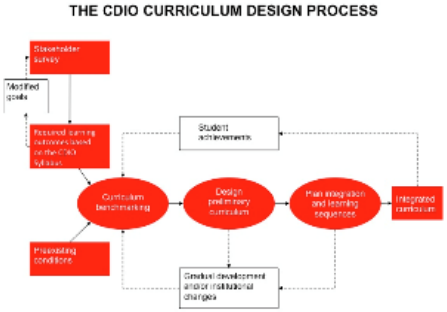
3 **Interpersonal Skills**
- 3.1 Teamwork
- 3.2 Communications
- 3.3 Communication in a foreign language

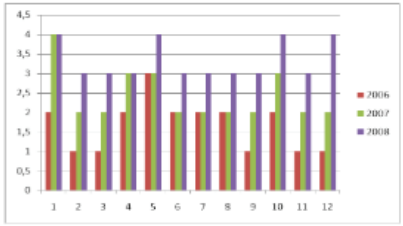
4 **CDIO of Complex Systems**
- 4.1 External, societal and environmental context
- 4.2 Enterprise and business context
- 4.3 Conceiving, systems engineering and management
- 4.4 Designing
- 4.5 Implementing
- 4.6 Operating
- 4.7 Leadership
- 4.8 Entrepreneurship

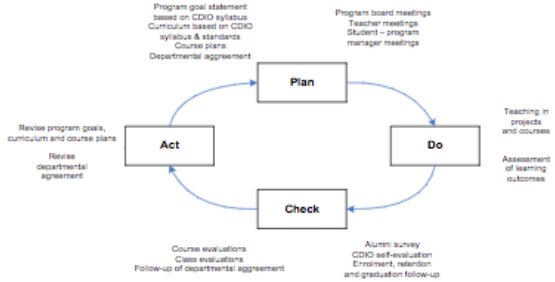
1. The Context
Adoption of the principle that product, Process, and system lifecycle development and deployment are the context for engineering education
2. Learning Outcomes
Specific, detailed learning outcomes for personal, interpersonal, and product, process and system building skills, consistent with program goals and validated by program stakeholders
3. Integrated Curriculum
A curriculum designed with mutually supporting disciplinary subjects, with an explicit plan to integrate personal, interpersonal, and product, process, and system building skills
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
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
6. Engineering Workspaces
Workspaces and laboratories that support and encourage hands-on learning of product, process, and system building, disciplinary knowledge, and social learning



7. Integrated Learning Experiences
Integrated learning experiences that lead to the acquisition of disciplinary knowledge, as well as personal, interpersonal, and produc. process,t and system building skills
8. Active Learning
Teaching and learning based on active experiential learning methods
9. Enhancement of Faculty Skills Competence
Actions that enhance faculty competence in personal, interpersonal, and product and system building skills
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
11. Learning Assessment
Assessment of student learning in personal, interpersonal, and product, process, and system building skills, as well as in disciplinary knowledge
12. Program Evaluation
A system that evaluates programs against these 12 standards, and provides feedback to students, faculty, and other stakeholders for the purposes of continuous improvement







C D I O

Conceiving--Designing--Implementing--Operating

a model of the entire product, process, and system lifecycle – *"from idea to ashes"*

- **Conceiving** - defining the need and technology, considering the enterprise strategy and regulations, developing the concept, architecture, and business case - deciding what you will design

- **Designing** - creating the design, i.e. the information artifact (plans, drawings, algorithms, etc) which describes what you will implement

- **Implementing** - transforming the information artifact - the design - into the product you deliver (manufacturing/coding, test and validation)

- **Operating** - using the implemented product to deliver the intended value, including maintaining, evolving and retiring the system

Again…

- The product, process, and system lifecycle
- is considered the context for engineering education in that it is part of the cultural framework, or environment, in which technical knowledge and other skills are taught, practiced and learned.

CDIO Syllabus – WHAT?

syllabus ≈ pensum (...i bred bemärkelse)

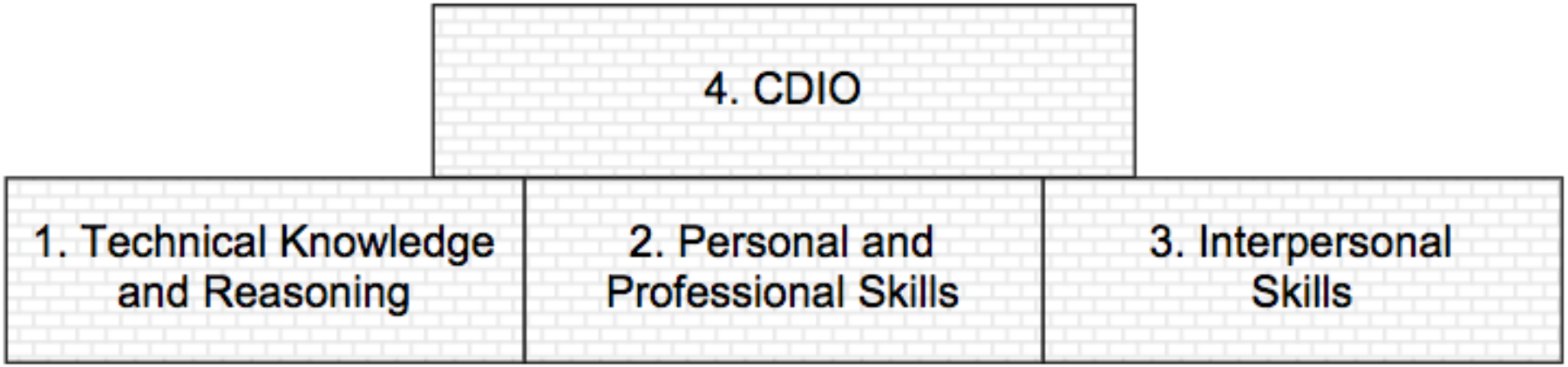


Figure 1: Building blocks of knowledge, skills, and attitudes necessary to Conceive, Design, Implement, and Operate Systems in the Enterprise and Societal Context (CDIO).

CDIO Syllabus (2)

1 TECHNICAL KNOWLEDGE AND REASONING
- 1.1. KNOWLEDGE OF UNDERLYING SCIENCES
- 1.2. CORE ENGINEERING FUNDAMENTAL KNOWLEDGE
- 1.3. ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE

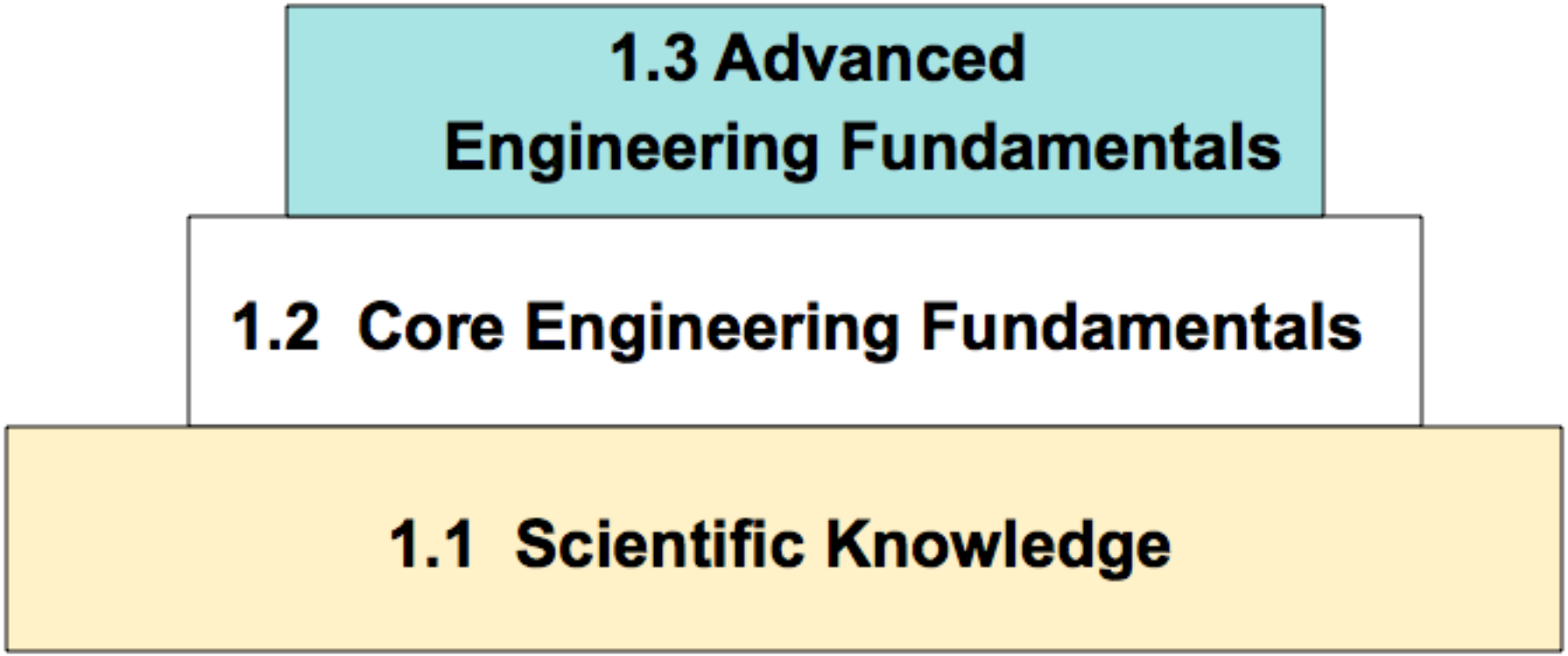
2 PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES
- 2.1. ENGINEERING REASONING AND PROBLEM SOLVING
- 2.2. EXPERIMENTATION AND KNOWLEDGE DISCOVERY
- 2.3. SYSTEM THINKING
- 2.4. PERSONAL SKILLS AND ATTITUDES
- 2.5. PROFESSIONAL SKILLS AND ATTITUDES

3 INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION
- 3.1. TEAMWORK
- 3.2. COMMUNICATION
- 3.3. COMMUNICATION IN FOREIGN LANGUAGES

4 CONCEIVING, DESIGNING, IMPLEMENTING AND OPERATING SYSTEMS IN THE ENTERPRISE AND SOCIETAL CONTEXT
- 4.1. EXTERNAL AND SOCIETAL CONTEXT
- 4.2. ENTERPRISE AND BUSINESS CONTEXT
- 4.3. CONCEIVING AND ENGINEERING SYSTEMS
- 4.4. DESIGNING
- 4.5. IMPLEMENTING
- 4.6. OPERATING

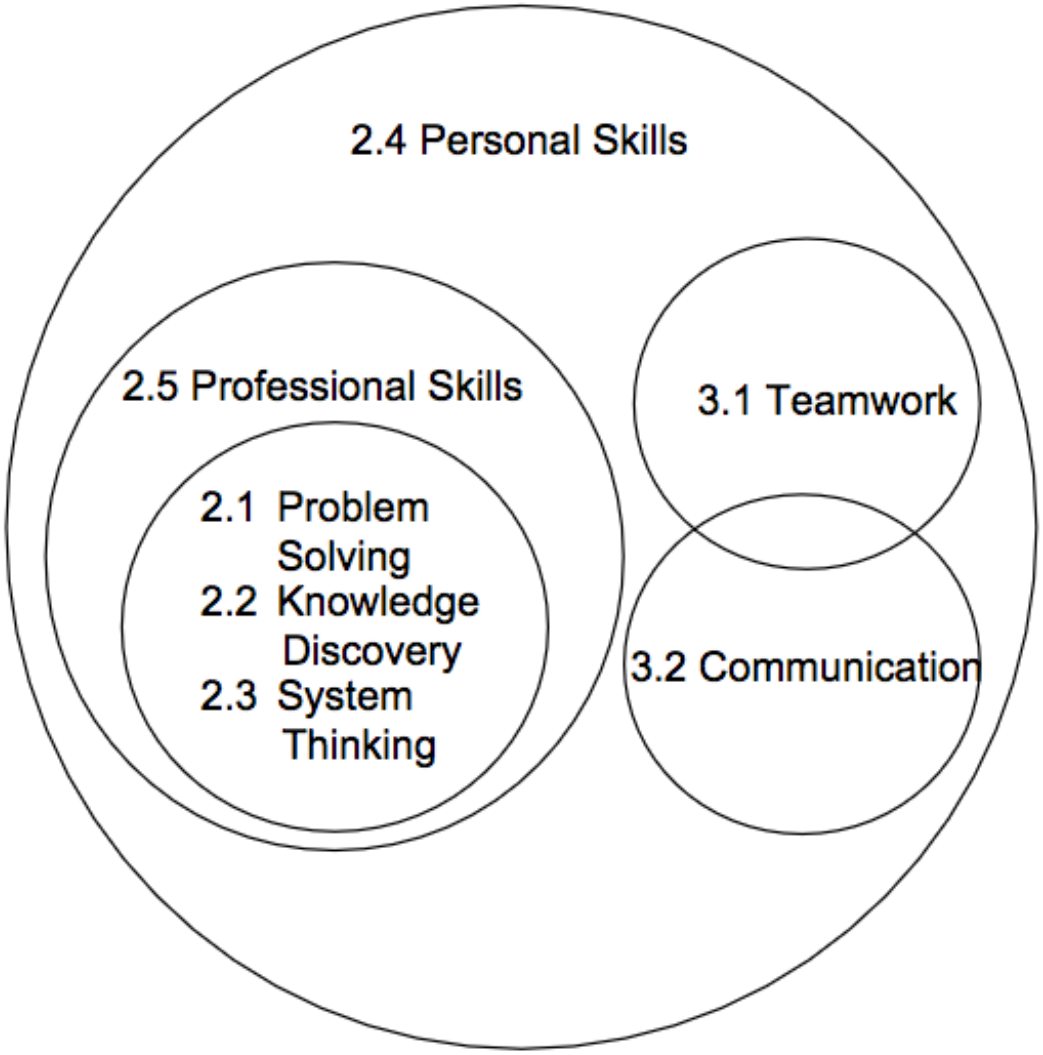
CDIO Syllabus (3)

Technical knowledge and reasoning – 2nd level



CDIO Syllabus (4)

Personal and interpersonal skills – 2nd level



CDIO Syllabus

The full syllabus contains 2-3 more levels of detail

- **A generalized list of competences that an engineer should possess**
- **Program specific (1) and general (2-4)**
- **Created and validated by alumni, faculty and students**
- **A ”complete” reference model**

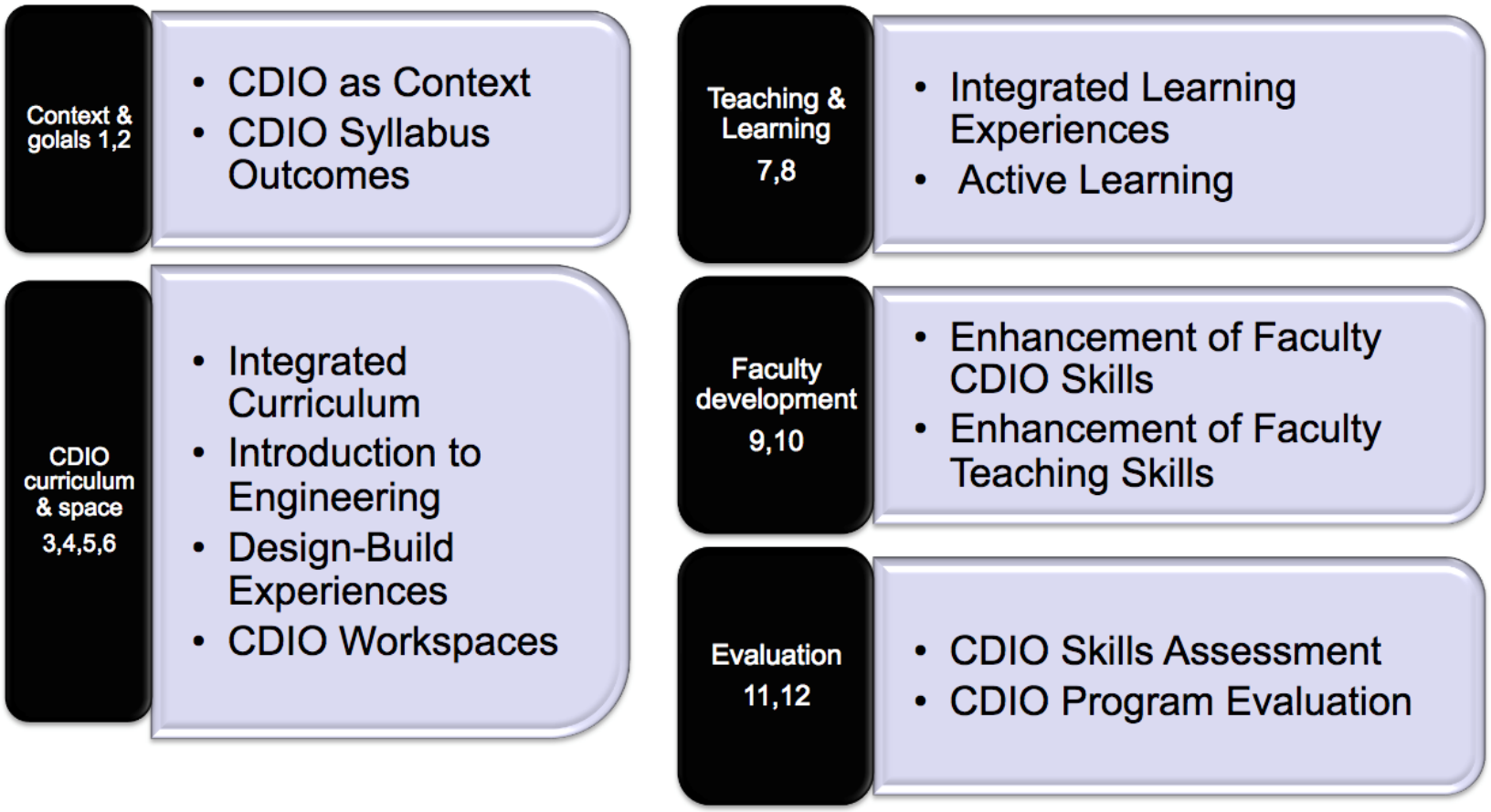
1 Disciplinary Knowledge & Reasoning:
- 1.1 Knowledge of underlying mathematics and sciences
- 1.2 Core engineering fundamental knowledge
- 1.3 Advanced engineering fundamental knowledge, methods and tools

2 Personal and Professional Skills
- 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 Interpersonal Skills
- 3.1 Teamwork
- 3.2 Communications
- 3.3 Communication in a foreign language

4 CDIO of Complex Systems
- 4.1 External, societal and environmental context
- 4.2 Enterprise and business context
- 4.3 Conceiving, systems engineering and management
- 4.4 Designing
- 4.5 Implementing
- 4.6 Operating
- 4.7 Leadership
- 4.8 Entrepreneurship

CDIO Standards – HOW?



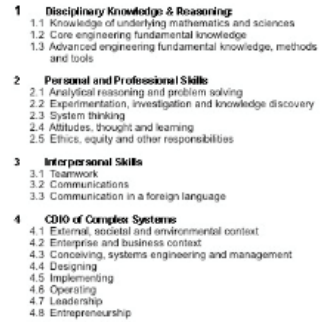
CDIO Standard 2

CDIO 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.

A CDIO-BASED QUALITY ASSURANCE SYSTEM

- **CDIO syllabus – *WHAT***
- **CDIO standards – *HOW***
- **CDIO curriculum design process – *from WHAT to HOW***
- **CDIO standards self-evaluation – *HOW WELL***



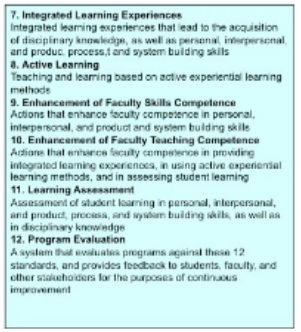
1 **Disciplinary Knowledge & Reasoning**
- 1.1 Knowledge of underlying mathematics and sciences
- 1.2 Core engineering fundamental knowledge
- 1.3 Advanced engineering fundamental knowledge, methods and tools

2 **Personal and Professional Skills**
- 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

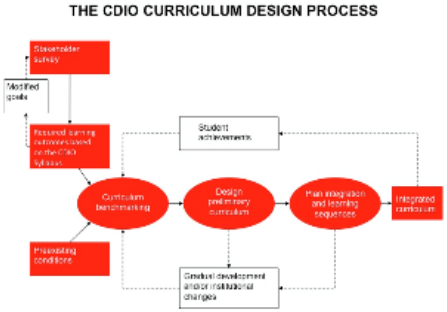
3 **Interpersonal Skills**
- 3.1 Teamwork
- 3.2 Communications
- 3.3 Communication in a foreign language

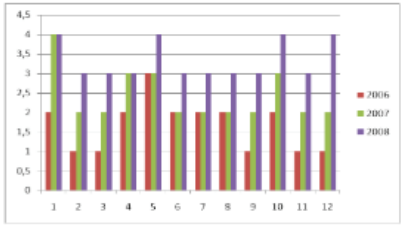
4 **CDIO of Complex Systems**
- 4.1 External, societal and environmental context
- 4.2 Enterprise and business context
- 4.3 Conceiving, systems engineering and management
- 4.4 Designing
- 4.5 Implementing
- 4.6 Operating
- 4.7 Leadership
- 4.8 Entrepreneurship

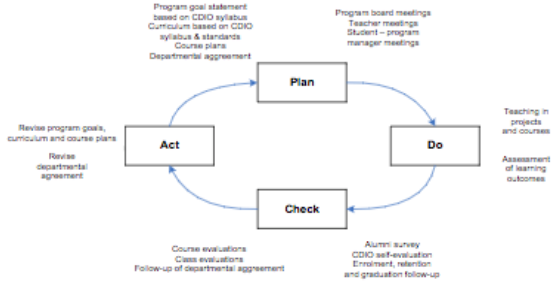
1. The Context
Adoption of the principle that product, Process, and system lifecycle development and deployment are the context for engineering education
2. Learning Outcomes
Specific, detailed learning outcomes for personal, interpersonal, and product, process and system building skills, consistent with program goals and validated by program stakeholders
3. Integrated Curriculum
A curriculum designed with mutually supporting disciplinary subjects, with an explicit plan to integrate personal, interpersonal, and product, process, and system building skills
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
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
6. Engineering Workspaces
Workspaces and laboratories that support and encourage hands-on learning of product, process, and system building, disciplinary knowledge, and social learning



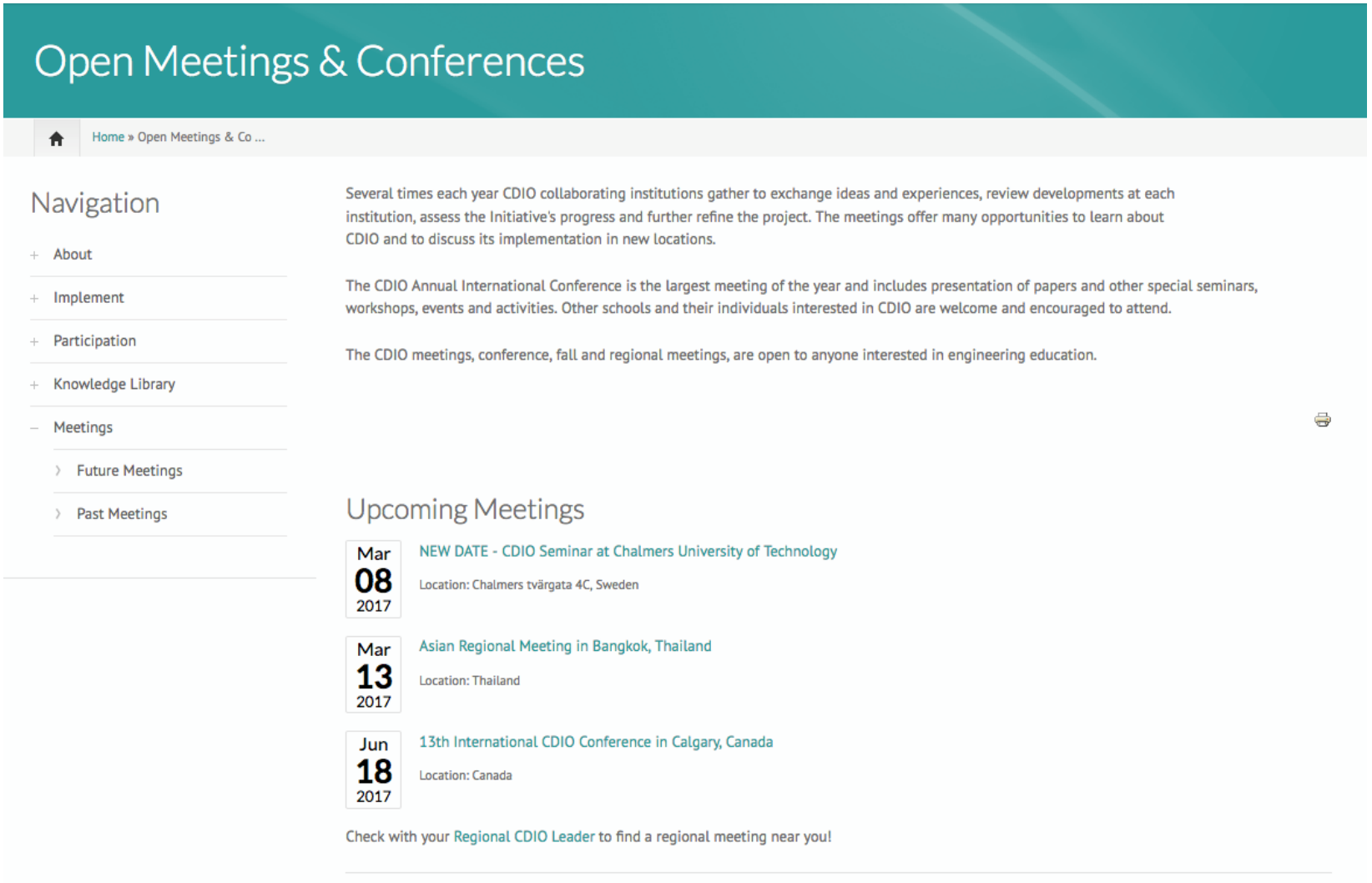
7. Integrated Learning Experiences
Integrated learning experiences that lead to the acquisition of disciplinary knowledge, as well as personal, interpersonal, and produc. process,t and system building skills
8. Active Learning
Teaching and learning based on active experiential learning methods
9. Enhancement of Faculty Skills Competence
Actions that enhance faculty competence in personal, interpersonal, and product and system building skills
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
11. Learning Assessment
Assessment of student learning in personal, interpersonal, and product, process, and system building skills, as well as in disciplinary knowledge
12. Program Evaluation
A system that evaluates programs against these 12 standards, and provides feedback to students, faculty, and other stakeholders for the purposes of continuous improvement







www.cdio.org


Open Meetings & Conferences
Home » Open Meetings & Co ...
Navigation
About
Implement
Participation
Knowledge Library
Meetings
Future Meetings
Past Meetings
Several times each year CDIO collaborating institutions gather to exchange ideas and experiences, review developments at each institution, assess the Initiative's progress and further refine the project. The meetings offer many opportunities to learn about CDIO and to discuss its implementation in new locations.
The CDIO Annual International Conference is the largest meeting of the year and includes presentation of papers and other special seminars, workshops, events and activities. Other schools and their individuals interested in CDIO are welcome and encouraged to attend.
The CDIO meetings, conference, fall and regional meetings, are open to anyone interested in engineering education.
Upcoming Meetings
Mar 08 2017
NEW DATE - CDIO Seminar at Chalmers University of Technology
Location: Chalmers tvärgata 4C, Sweden
Mar 13 2017
Asian Regional Meeting in Bangkok, Thailand
Location: Thailand
Jun 18 2017
13th International CDIO Conference in Calgary, Canada
Location: Canada
Check with your Regional CDIO Leader to find a regional meeting near you!

CDIO – A Network

CDIO Syllabus – 3rd level

1 TECHNICAL KNOWLEDGE AND REASONING
- 1.1 KNOWLEDGE OF UNDERLYING SCIENCES [a]
- 1.2 CORE ENGINEERING FUNDAMENTAL KNOWLEDGE [a]
- 1.3 ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE [k]

2 PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES
- 2.1 ENGINEERING REASONING AND PROBLEM SOLVING [e]
  - 2.1.1 Problem Identification and Formulation
  - 2.1.2 Modeling
  - 2.1.3 Estimation and Qualitative Analysis
  - 2.1.4 Analysis With Uncertainty
  - 2.1.5 Solution and Recommendation
- 2.2 EXPERIMENTATION AND KNOWLEDGE DISCOVERY [b]
  - 2.2.1 Hypothesis Formulation
  - 2.2.2 Survey of Print and Electronic Literature
  - 2.2.3 Experimental Inquiry
  - 2.2.4 Hypothesis Test, and Defense
- 2.3 SYSTEM THINKING
  - 2.3.1 Thinking Holistically
  - 2.3.2 Emergence and Interactions in Systems
  - 2.3.3 Prioritization and Focus
  - 2.3.4 Trade-offs, Judgment and Balance in Resolution
- 2.4 PERSONAL SKILLS AND ATTRIBUTES
  - 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 [i]
  - 2.4.7 Time and Resource Management
- 2.5 PROFESSIONAL SKILLS AND ATTITUDES
  - 2.5.1 Professional Ethics, Integrity, Responsibility, and Accountability [f]
  - 2.5.2 Professional Behavior
  - 2.5.3 Proactively Planning for One's Career
  - 2.5.4 Staying Current on World of Engineering

3 INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION
- 3.1 TEAMWORK [d]
  - 3.1.1 Forming Effective Teams
  - 3.1.2 Team Operation
  - 3.1.3 Team Growth and Evolution
  - 3.1.4 Leadership
  - 3.1.5 Technical Teaming
- 3.2 COMMUNICATIONS [g]
  - 3.2.1 Communications Strategy
  - 3.2.2 Communications Structure
  - 3.2.3 Written Communication
  - 3.2.4 Electronic/Multimedia Communication
  - 3.2.5 Graphical Communication
  - 3.2.6 Oral Presentation and Inter-Personal Communications
- 3.3 COMMUNICATION IN FOREIGN LANGUAGES
  - 3.3.1 English
  - 3.3.2 Languages of Regional Industrial Nations
  - 3.3.3 Other languages

4 CONCEIVING, DESIGNING, IMPLEMENTING, AND OPERATING SYSTEMS IN THE ENTERPRISE AND SOCIETAL CONTEXT
- 4.1 EXTERNAL AND SOCIETAL CONTEXT [h]
  - 4.1.1 Roles and Responsibility of Engineers
  - 4.1.2 The Impact of Engineering on Society
  - 4.1.3 Society's Regulation of Engineering
  - 4.1.4 The Historical and Cultural Context
  - 4.1.5 Contemporary Issues and Values [j]
  - 4.1.6 Developing a Global Perspective
- 4.2 ENTERPRISE AND BUSINESS CONTEXT
  - 4.2.1 Appreciating Different Enterprise Cultures
  - 4.2.2 Enterprise Strategy, Goals, and Planning
  - 4.2.3 Technical Entrepreneurship
  - 4.2.4 Working Successfully in Organizations
- 4.3 CONCEIVING AND ENGINEERING SYSTEMS [c]
  - 4.3.1 Setting System Goals and Requirements
  - 4.3.2 Defining Function, Concept and Architecture
  - 4.3.3 Modeling of System and Insuring Goals Can Be Met
  - 4.3.4 Development Project Management
- 4.4 DESIGNING [c]
  - 4.4.1 The Design Process
  - 4.4.2 The Design Process Phasing and Approaches
  - 4.4.3 Utilization of Knowledge in Design
  - 4.4.4 Disciplinary Design
  - 4.4.5 Multidisciplinary Design
  - 4.4.6 Multi-Objective Design (DFX)
- 4.5 IMPLEMENTING [c]
  - 4.5.1 Designing the Implementation Process
  - 4.5.2 Hardware Manufacturing Process
  - 4.5.3 Software Implementing Process
  - 4.5.4 Hardware Software Integration
  - 4.5.5 Test, Verification, Validation, and Certification
  - 4.5.6 Implementation Management
- 4.6 OPERATING [c]
  - 4.6.1 Designing and Optimizing Operations
  - 4.6.2 Training and Operations
  - 4.6.3 Supporting the System Lifecycle
  - 4.6.4 System Improvement and Evolution
  - 4.6.5 Disposal and Life-End Issues
  - 4.6.6 Operations Management

CDIO Syllabus – 4th level

2 PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES

2.1 ENGINEERING REASONING AND PROBLEM SOLVING [e]

2.1.1 *Problem Identification and Formulation*
- Data and symptoms
- Assumptions and sources of bias
- Issue prioritization in context of overall goals
- A plan of attack (incorporating model, analytical and numerical solutions, qualitative analysis, experimentation and consideration of uncertainty)

2.1.2 *Modeling*
- Assumptions to simplify complex systems and environment
- Conceptual and qualitative models
- Quantitative models and simulations

2.1.3 *Estimation and Qualitative Analysis*
- Orders of magnitude, bounds and trends
- Tests for consistency and errors (limits, units, etc.)
- The generalization of analytical solutions

2.1.4 *Analysis With Uncertainty*
- Incomplete and ambiguous information
- Probabilistic and statistical models of events and sequences
- Engineering cost-benefit and risk analysis
- Decision analysis
- Margins and reserves

2.1.5 *Solution and Recommendation*
- Problem solutions
- Essential results of solutions and test data
- Discrepancies in results
- Summary recommendations
- Possible improvements in the problem solving process

CDIO Syllabus

- Rational — knowledge, skills, attitudes rationalized against the norms of engineering practice
- Comprehensive — *all* relevant primary source material correlated and included
- Prioritized by stakeholder — 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 teach at university
- Expressed as learning objectives in an appropriate taxonomy
- Basis for rigorous educational design and assessment process