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École Mines-Télécom

CDIO standards for continuous improvement of engineering educational programmes

Les Modèles de Référence du CDIO … comme approche systémique pour l'amélioration continue des formations d'ingénieurs

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CDIO EU/UK Regional Conference, January 2019
La Rochelle

cesi ÉCOLE D'INGÉNIEURS

WHAT ABOUT YOUR CONTEXT?

Accreditation, labels and evaluation processes …

At your programme level:

1. Are your accredited (nat. or intl.)?
2. Do you have labels related to educational quality?
3. Do you have specific qualitv assurance models in pla

Kristina Edström: « Progression »

EXAMPLES

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9001 - 21001

PROGRAMME OUTCOMES & GRADUATE OUTCOMES MAPPING

Table 2. CDIO Syllabus v2.0 at the Second Level of Detail
(Underlined Text is Updated from v1.0)

1 DISCIPLINARY KNOWLEDGE AND REASONING	**3 INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION**
1.1 KNOWLEDGE OF UNDERLYING MATHEMATICS AND SCIENCE	3.1 TEAMWORK
1.2 CORE FUNDAMENTAL KNOWLEDGE OF ENGINEERING	3.2 COMMUNICATIONS
1.3 ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE, METHODS AND TOOLS	3.3 COMMUNICATIONS IN FOREIGN LANGUAGES
2 PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES	**4 CONCEIVING, DESIGNING, IMPLEMENTING, AND OPERATING SYSTEMS IN THE ENTERPRISE, SOCIETAL AND ENVIRONMENTAL CONTEXT**
2.1 ANALYTICAL REASONING AND PROBLEM SOLVING	4.1 EXTERNAL, SOCIETAL AND ENVIRONMENTAL CONTEXT
2.2 EXPERIMENTATION, INVESTIGATION AND KNOWLEDGE DISCOVERY	4.2 ENTERPRISE AND BUSINESS CONTEXT
2.3 SYSTEM THINKING	4.3 CONCEIVING, SYSTEMS ENGINEERING AND MANAGEMENT
2.4 ATTITUDES, THOUGH AND LEARNING	4.4 DESIGNING
2.5 ETHICS, EQUITY AND OTHER RESPONSIBILITIES	4.5 IMPLEMENTING
	4.6 OPERATING

Not Prescriptive

La CTI définit ci-dessous sans à priori de hiérarchisation, de phase d'acquisition ou de mode pédagogique un ensemble de 14 acquis d'apprentissage constituant un référentiel générique de toute formation d'ingénieur

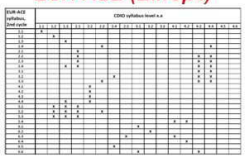
VALIDATION AGAINST NATIONAL ACCREDITATION FRAMEWORKS

- **The CDIO syllabus has been compared national accreditations in many countries**
- **Same pattern:**
  - **The CDIO Syllabus states outcomes for engineering education that reflect a broader view of the engineering profession**
  - **Its greater levels of detail facilitate program and course development.**
  - **A program whose design is based on the CDIO Syllabus will also satisfy its national requirements for specified program outcomes.**

ABET EC 2010 (USA)

CEAB (CANADA)

EUR-ACE (Europe)



Le Syllabus ICRE

Énoncé des objectifs de la formation du premier cycle en ingénierie
(Conceive-Design-Implement-Operate)

EDWARD F. CRAWLEY

Afin d'en présenter clairement la logique, notre approche a été de baser le Syllabus ICRE sur les fonctions essentielles du génie :

> *Les ingénieurs diplômés devraient être en mesure d'Imaginer-Concçevoir-Réaliser-Exploiter des systèmes complexes d'ingénierie à valeur ajoutée dans un environnement moderne de travail en équipe.*

TAB. 1 – Premier et second niveau de l'organisation du Syllabus ICRE

1. Connaissances techniques et raisonnement
   - 1.1. Connaissance des sciences de base
   - 1.2. Connaissance des principes fondamentaux de l'ingénierie
   - 1.3. Niveau de connaissances avancé en ingénierie
2. Compétences et habiletés professionnelles et personnelles
   - 2.1. Raisonnement technique et résolution de problèmes
   - 2.2. Expérimentation et découverte scientifique
   - 2.3. Raisonnement de systèmes
   - 2.4. Habiletés et attributs personnelles
   - 2.5. Habiletés et compétences professionnelles
3. Habiletés interpersonnelles : travail d'équipe et communication
   - 3.1. Travail d'équipe
   - 3.2. Communication
4. Imaginer, concevoir, réaliser, exploiter des systèmes dans un contexte sociétal et d'entreprise
   - 4.1. Contexte externe et sociétal
   - 4.2. Contexte commercial et d'entreprise
   - 4.3. Imaginer des systèmes
   - 4.4. Concevoir
   - 4.5. Réaliser
   - 4.6. Exploiter

Boundaries and Bridges: a French Translation of the CDIO Syllabus

Alison Gourvès-Hayward [1], Christophe Morace [2] Détails
1 LCI - Département Langues et Culture Internationale
2 CRF - Centre de recherche sur la formation

QUALITY:
… NOT ONLY A QUESTION OF LEARNING OUTCOMES

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Accreditation Criteria, Guidelines and Procedures

L'école doit satisfaire aux exigences majeures de ce référentiel (R&O Livre 1)

Les critères sont ordonnés en six champs :

Champ A : Mission et organisation (formation / école / établissement)
Champ B : Ouvertures et partenariat
Champ C : Formation des élèves ingénieurs
Champ D : Recrutement des élèves ingénieurs
Champ E : Emploi des ingénieurs diplômés
Champ F : Démarche qualité et amélioration continue

… AND QUALITY ASSURANCE

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Accreditation Criteria, Guidelines and Procedures

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WITHIN CDIO: 12 REFERENCE MODELS, FLEXIBLE

THE CDIO STANDARDS: EFFECTIVE PRACTICE FRAMWORK

1st key entries

1. CDIO as Context*
Adoption of the principle that product and system lifecycle development and deployment are the context for engineering education

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

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

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

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

6. CDIO Workspaces
Workspaces and laboratories that support and encourage hands-on learning of product 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 product and system building skills

8. Active Learning
Teaching and learning based on active experiential learning methods

9. Enhancement of Faculty CDIO Skills*
Actions that enhance faculty competence in personal, interpersonal, and product and system building skills

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

11. CDIO Skills Assessment*
Assessment of student learning in personal, interpersonal, and product and system building skills, as well as in disciplinary knowledge

12. CDIO 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

*essential

EXAMPLE: EUR-ACE VS CDIO REFERENCE MODELS

EUR-ACE Guidelines	CDIO Standards	CDIO Coverage
1. Needs, Objectives and Outcomes	**1**, **2**, 4	Total
2. Educational Process	**3**, **5**, **7**, 8, **11**	Total
3. Resources and Partnerships	6, **9**, 10	Partial
4. Assessment of Educational Process	12	Total
5. Management System	12	Partial

CDIO as a Foundation for Program Accreditation/Certification in Portugal
June 2010, Rocha, Costa & Martins

*norme ISO 21001, 2018: « directive ESG selon laquelle la politique d'assurance qualité doit se mettre en pratique par une grande **variété de processus d'assurance qualité internes**: standard spécifiquement dédié aux **systèmes de management des établissements d'enseignement supérieu**r (CTI champ F) »*

ABET General Criteria	CDIO Standards	CDIO Coverage
1. Students	**11**	Partial
2. Program Educational Objectives	**1**	Total
3. Student Outcomes	**2**, **5**	Total
4. Continuous Improvement	12	Total
5. Curriculum	**3**, 4, **7**	Total
6. Faculty	8, **9**, 10	Total
7. Facilities	6	Partial
8. Institutional Support	---	None

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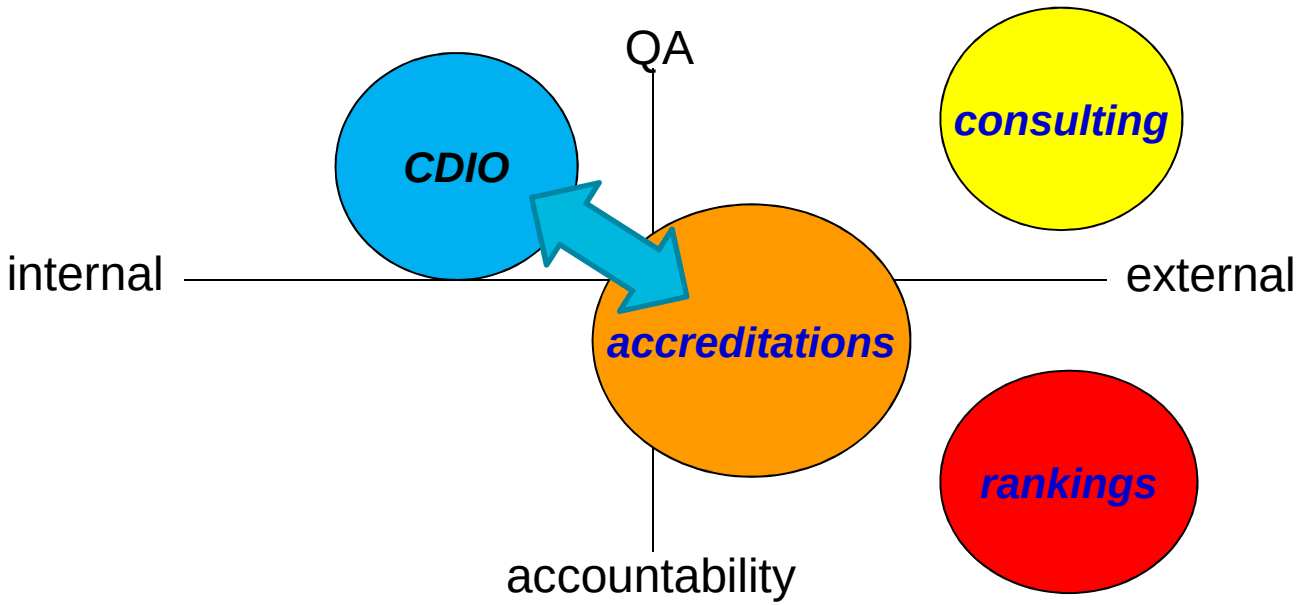
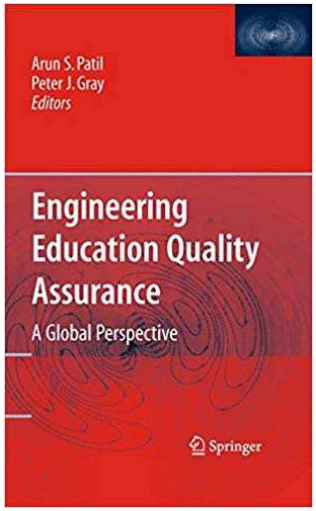
QUALITY ASSURANCE IN ACCREDITATION: A SHIFT TO QUALITY ENHANCEMENT





[Peter Gray, 2009]

Collaborative Quality Enhancement in Engineering Education: an Overview of Operational Models at a Programme Level.
Bennedsen, J., Rouvrais, S., Roslof, J., Kontio, J., and McCartan C.D.
EJEE European Journal of Engineering Education, 2018.

MATURITY FOR QUALITY ENHANCEMENT… OVER THE YEARS

Rating	Meaning	Level of Achievement
N	Not achieved	0 % to ≤ 15 %
P	Partially achieved	> 15 % to ≤ 50 %
L	Largely achieved	> 50 % to ≤ 85 %
F	Fully achieved	> 85 % to ≤ 100 %

Rating	Meaning	Level of Achievement
P -	Partially achieved -	> 15 % to ≤ 32.5 %
P +	Partially achieved +	> 32.5 % to ≤ 50 %
L -	Largely achieved -	> 50 % to ≤ 67.5 %
L +	Largely achieved +	> 67.5 % to ≤ 85 %

What about your own context?

At a programme level, what about your **maturity**?

- Learning outcomes (#2)
- Integrated curriculum (#3)
- Active learning (#8)
- Student assessments (#11)
- Faculty competence (#10)
- …

ISO/IEC 33020:2015 - A process measurement framework

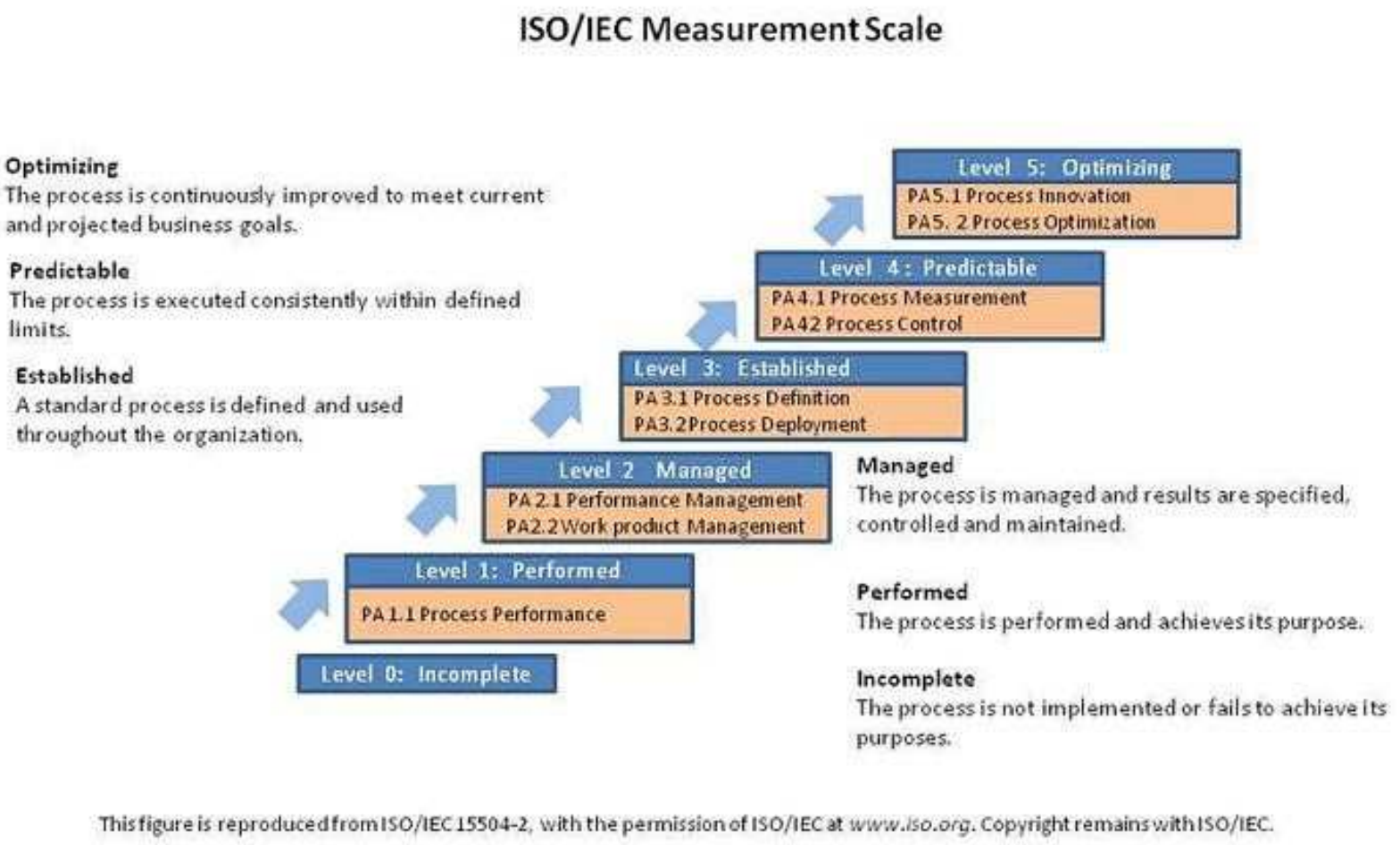
Supports the assessment of process capability, in accordance with requirements

- Can be used to construct a **Process Assessment Model**

- **Process capability** is a process quality characteristic related to the ability of a process to consistently meet current or projected goals
  - facilitates **self-assessment**
  - provides a basis for use in **process improvement** and process quality determination,
  - applicable across various application domains and sizes of organization
  - produces a set of process (capability) attribute ratings (process profile)
  - derives a process capability level

An Assessment Framework for Engineering Education Systems.
Rouvrais, S. and Lassudrie, C.
In Proceedings of the 14th intl. SPICE Conference. 4-6 November 2014, Vilnius University, Springer CCIS series, 447. A. Mitasiunas et al. (Eds.), pp. 250--255.

6 LEVELS OF MATURITY



GENERIC CDIO MATURITY LEVELS (SO CALLED 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 in place to address it
0	There is **no documented plan or activity** related to the standard

Implement
Operate
Design
Concieve

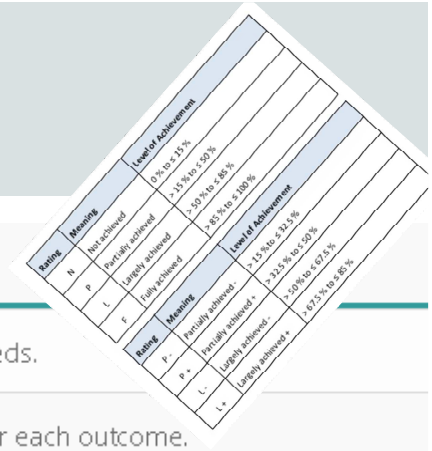
STAKEHOLDERS IN PROGRAMME EVALUATIONS

At a programme level:

- Deans
- Programme leaders
- Staff, faculty
- QA managers
- Students
- Alumni
- Industrial partners
- Professional bodies
- Accreditation bodies
- A.s.o

Managing the Continuous Improvement Loop of Educational Systems: **Students** as key actors in program evaluation.
Lassudrie, C., Kontio, J., and Rouvrais, S.
In Proceedings of the 9th intl. CDIO Conference: "Engineering Leadership in Innovation and Design". 9-13 June, 2013, MIT & Harvard School of Engineering and Applied Sciences, Cambridge, MA, USA.

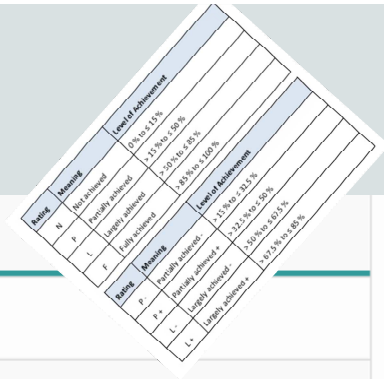
EXAMPLE ON STANDARD 2: SYLLABUS



Scale	Criteria
5	Evaluation groups regularly review and revise program learning outcomes, based on changes in stakeholder needs.
4	Program learning outcomes are aligned with institutional vision and mission, and levels of proficiency are set for each outcome.
3	Program learning outcomes are validated with key program stakeholders, including faculty, students, alumni, and industry representatives.
2	A plan to incorporate explicit statements of program learning outcomes is established.
1	The need to create or modify program learning outcomes is recognized and such a process has been initiated.
0	There are no explicit program learning outcomes that cover knowledge, personal and interpersonal skills, and product, process and system building skills.

Learning outcomes are reviewed and validated by key stakeholders, that is, groups who share an interest in the graduates of engineering programs, for **consistency** with program goals and relevance to engineering practice. Programs are encouraged to customize the CDIO Syllabus to their respective programs.
In addition, stakeholders help to determine the expected level of proficiency, or standard of achievement, for each learning outcome.

EXAMPLE ON STANDARD 3: INTEGRATED CURRICULUM



Scale	Criteria
5	Stakeholders regularly review the integrated curriculum and make recommendations and adjustments as needed.
4	There is evidence that personal, interpersonal, product, process, and system building skills are addressed in all courses responsible for their implementation.
3	Personal, interpersonal, product, process, and system building skills are integrated into one or more years in the curriculum.
2	A curriculum plan that integrates disciplinary learning, personal, interpersonal, product, process, and system building skills is approved by appropriate groups.
1	The need to analyze the curriculum is recognized and initial mapping of disciplinary and skills learning outcomes is underway.
0	There is no integration of skills or mutually supporting disciplines in the program.

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.

EXAMPLE ON STANDARD 11: STUDENT ASSESSMENT

Scale	Criteria
5	Evaluation groups regularly review the use of learning assessment methods and make recommendations for continuous improvement.
4	Learning assessment methods are used effectively in courses across the curriculum.
3	Learning assessment methods are implemented across the curriculum.
2	There is a plan to incorporate learning assessment methods across the curriculum.
1	The need for the improvement of learning assessment methods is recognized and benchmarking of their current use is in process.
0	Learning assessment methods are inadequate or inappropriate.

Assessment of student learning is the measure of the extent to which each student achieves specified learning outcomes.
Instructors usually conduct this assessment within their respective courses.
Effective learning assessment uses a variety of methods matched appropriately to learning outcomes that address disciplinary knowledge, as well as personal and interpersonal skills, and product, process, and system building skills, as described in Standard 2.
These methods may include written and oral tests, observations of student performance, rating scales, student reflections, journals, portfolios, and peer and self-assessment.

ACTION PLANS PER REFERENCE MODELS

CDIO STANDARD	EVIDENCE OF COMPLIANCE	RATING	ACTIONS
CDIO as Context Adoption of the principle that product and system lifecycle development and deployment – Conceiving, Designing, Implementing and Operating - are the context for engineering education			
CDIO Syllabus Outcomes Specific, detailed learning outcomes for personal, interpersonal and product and system building skills, consistent with program goals and validated by program stakeholders			
Integrated Curriculum A curriculum designed with mutually supporting disciplinary subjects, with an explicit plan to integrate personal, interpersonal and product and system building skills			
Introduction to Engineering An introductory course that provides the framework for engineering practice in product and system building, and introduces essential personal and interpersonal skills			

OTHER POTENTIAL REFERENCE MODELS FOR YOUR OWN CONTEXT (À LA QAEMP)

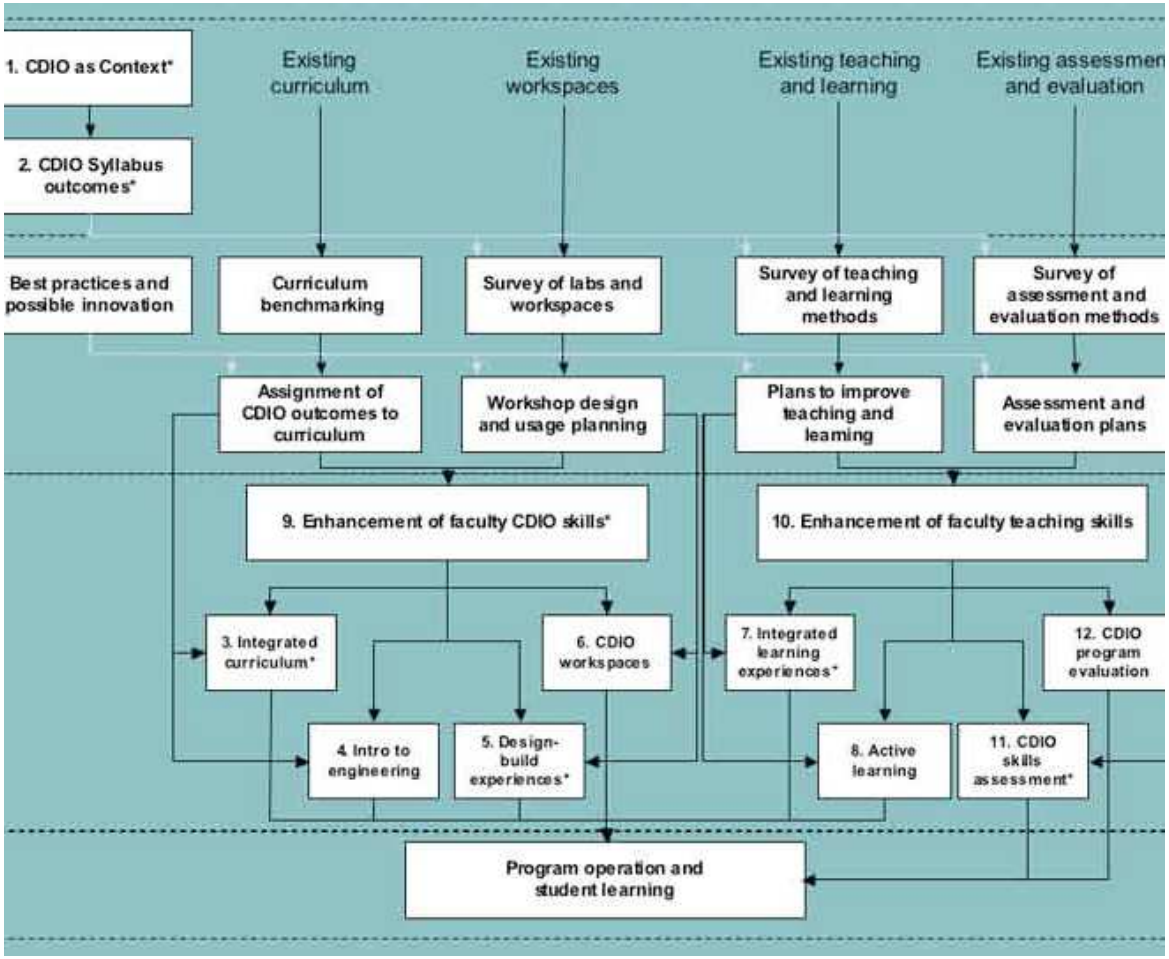
QUALITY ASSURANCE AND ENHANCEMENT MARKETPLACE FOR HIGHER EDUCATION INSTITUTIONS

A holistic view of learning is taken
Appropriate learning outcomes are identified (developed from required competences)
An integrated curriculum has been developed
A sound subject foundation is created
Active learning approaches are used
Appropriate workspaces (and equipment) are available
Personal and interpersonal skills development are embedded
Faculty development takes place (knowledge and teaching)
Appropriate assessment is employed (type, level and amount)
Programme evaluation to promote continuous improvement is undertaken.
The profession is introduced to students
Links to employability are made throughout
Projects are executed in teams (collaboration)
Support for learning is provided

Finding Good Friends to Learn from and to Inspire.
Bennedsen, J., and Rouvrais, S.
In Proceedings of the 46th Annual Frontiers in Education (FIE) IEEE Conference. "The Crossroads of Engineering and Business", October 12-15, Erie, PA, USA, 2016

Technology is used to promote a blended approach to learning
Feedback is timely, appropriate and formative
Research is used in teaching
Student participation in programme review and development
Wider stakeholder input to programme developmer e.g. Industry Advisory Board and Benchmark Statements
Student retention and progression is monitored
Work placements are promoted
Problem solving opportunities (links to the research process)
Design projects are integrated throughout the programme
Equality, diversity and equal opportunity considerations
Consideration for international students
Professional attributes and topical considerations e.g. sustainability, ethical behaviour, global awareness etc
Evidence of educational scholarship by faculty
Effectiveness of communication with students.

INSTITUTIONALIZING THE CDIO REFERENCE MODELS



What about IMTA experience?

Resistance to Change in Institutionalizing the CDIO Standards: From a Waterfall to and Agile Improvement Model.
Rouvrais, S. and Landrac, G.
In Proceedings of the 8th International CDIO Conference, Queensland University of Technology, Brisbane, July 1-4, 2012.

THE FRENCH FLEXIBILITY IN PUBLIC INSTITUTIONS?

Educational system transformation and improvement:

- Difficulties of French public-style as faculty/staff often prefer to navigate in a flexible manner… keep the pace
- There is a comfort zone of "business as usual in education"
  - Keep energy for scientific research, contracts, and quest of excellence for research evaluation of laboratories and individuals (CNRS Labs)
  - Recognition of educational involvement starts slowly to be also taken into account for the promotion of Assistant, A/Prof to Professor status

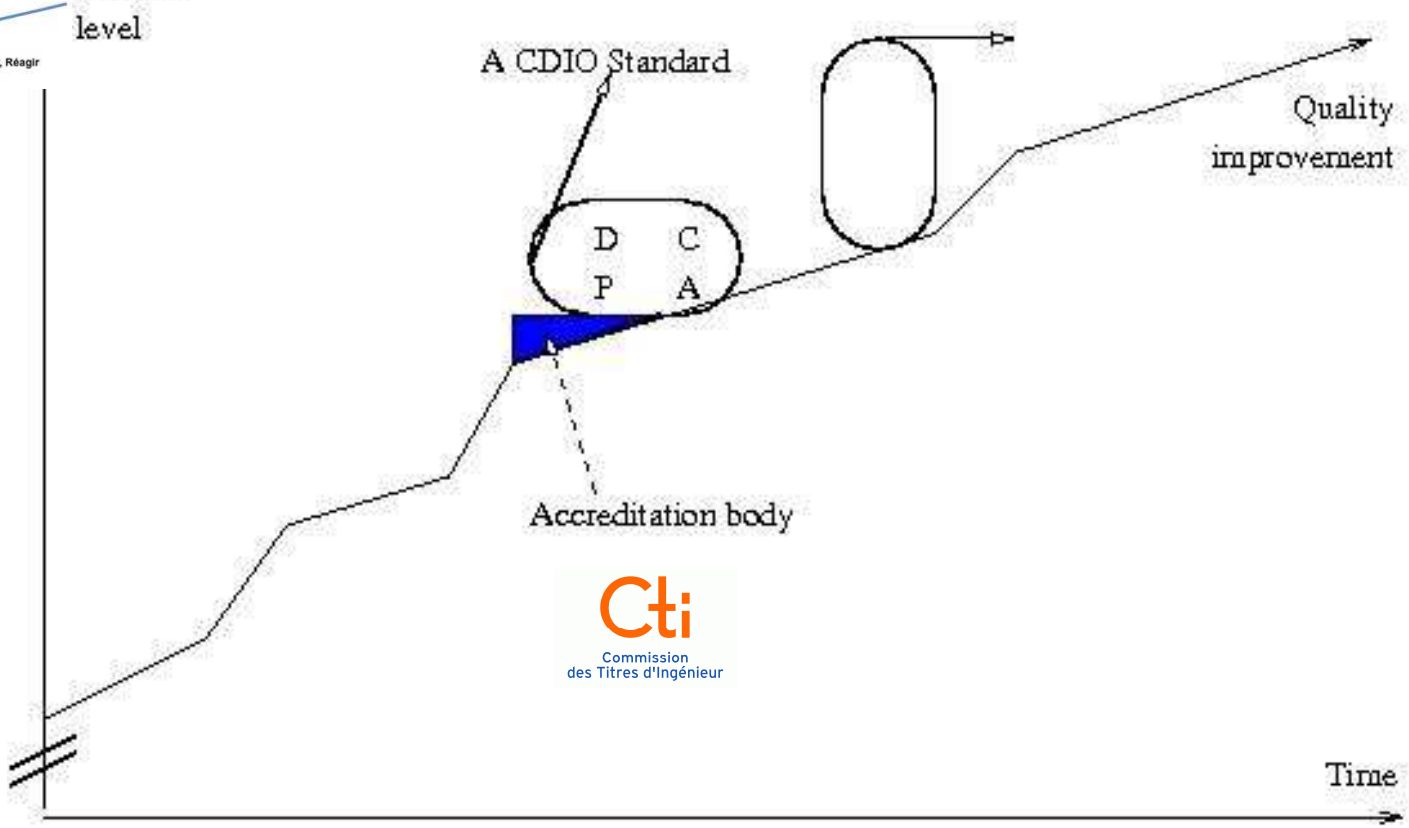
- But CTI largely recognized by faculty (e.g. programme outcomes)
- Somehow hard to institutionalize the CDIO standards: "yet one more QA system"
  - Aim: to be prepared for a more agile model for continuous improvement
  - Towards a progressive introduction of some of the CDIO standards
    - managing several models at a time ?

CDIO IN 2008 AT TELECOM BRETAGNE

To be continuously prepared for national or international formal accreditations,
Telecom Bretagne has chosen in 2008 to use the CDIO standards as a dynamic tool

- We decided to take CDIO standards one step at a time, at a slow pace:
  - to support peace among educational managers, program developers and teaching staff
- Industrial partners and students used as strong change agents

FIRST A CASCADE CYCLE…
WITH A DEMING ELLIPSE



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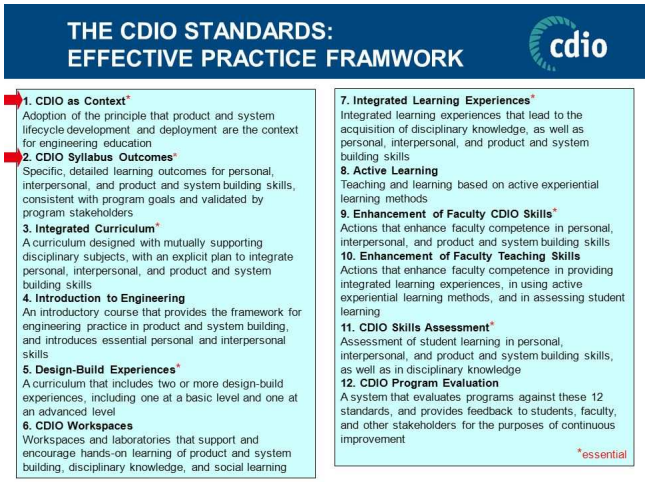
For both programs (FISE & FISA)

- The CDIO standard #1 (CDIO as a context) has first been elected by the board of directors as a driver of our educational strategy
- The CDIO syllabus standard #2 has been gently and progressively disclosed to key program designers and ultimately teaching members (levels 2 then level 3)

  cf HTML syllabus CDIO

- Nevertheless, at the beginning, detailed CDIO standards were not communicated to most of the teaching staff considering the large scope and alarming complexity of the former

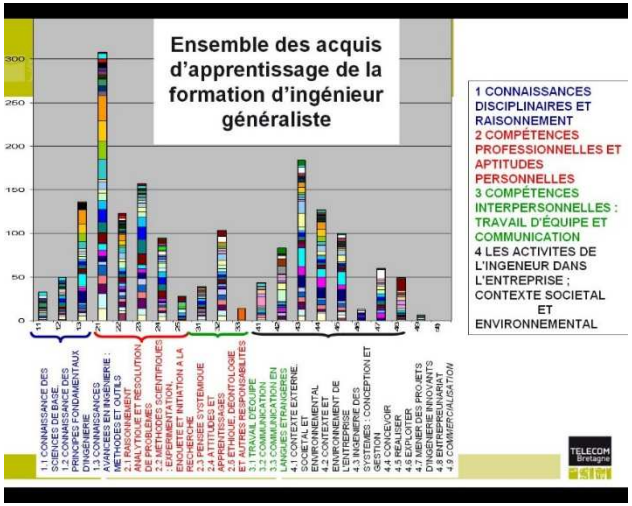


- From that point, standards #3, 4, 5, 7 and 8 relating to educational contents and pedagogical methods were investigated for other courses (done for projects)

- The focus was then on standards #6, 9 and 10 (i.e. workspaces and faculty skills)

- Approximately **15% of the teaching staff is confident** with all the CDIO standards and details
  - 40% are aware on the broad lines, mainly standard #2

- Before further exploring standard #11 (i.e. skills assessment, proficiency matrixes)



ADVICE FOR FUTURE CDIO ADOPTERS

At a programme level:

- Evaluate your program
- What are your strengths and weaknesses with respect to the CDIO Standards?
- Identify some early successes
- Generate buy-in from faculty/staff
- Elaborate action plans & prioritize
- Be ready to assess changes
- Identify resources needed before you embark on large changes
- **Learn and get inspired from others**

ADVICE FOR FUTURE CDIO INCOMING MEMBERS

Networking to share with others:

- … Inspire others

La Commission des titres d'ingénieur renouvelle la démarche de recueil et d'analyse des pratiques entreprises par les écoles d'ingénieurs sur des thématiques ciblées nouvelles, peu évaluées sur le fond, transversales ou qu'il conviendrait de revisiter.

Cette démarche, appelée « FOCUS d'audit », vise à faire le point, à repérer des pratiques remarquables ainsi que des angles morts, à dégager des visions communes, à tirer des enseignements, sur la base de ce qui est réalisé et présenté par un nombre significatif d'écoles. Cette analyse est restituée à l'ensemble des écoles.

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Trois thématiques sont retenues pour la campagne d'accréditation 2018-2019

- Innovation et entrepreneuriat (I&E) p 5-6
- Développement durable et responsabilité sociétale (DD&RS) p 7
- Santé et sécurité au travail (S&ST) p 8-9

Objet : mise en place des FOCUS d'audit de la campagne d'accréditation 2018-2019

- *En complément du chapitre « I.2.4 Les consultations de réseaux » du Livre 1 R&O 2016*
- *Considérant les propositions du Bureau de la CTI, le 14 décembre 2017*

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