Session Objectives

- Explain the CDIO Engineering Education Framework
- Share experiences of engineering education reform
- Identify ways in which the CDIO approach may be useful to your programs
WHAT IS CDIO?

CDIO is an educational framework stressing engineering fundamentals set in the context of Conceive – Design - Implementation – Operation real world product and system.

Overview of CDIO Engineering Education Framework

The key components and activities in the CDIO Framework are based on two key documents

CDIO Syllabus (the ‘what’ of CDIO)
CDIO Standards (the ‘how’ of CDIO)
CDIO Standards

Curriculum

Workspace/Labs

Teaching & Learning Methods

Enhancement of Faculty Competence

Assessment Methods

Standard 1: Adopt CDIO as a Context
Standard 2: CDIO Syllabus Outcomes
Standard 3: Integrated Curriculum
Standard 4: Introduction to Engineering
Standard 5: Design-Build Experiences
Standard 6: CDIO Workspaces
Standard 7: Integrated Learning Experiences
Standard 8: Active Learning
Standard 9: Enhancement of Staff CDIO Skills
Standard 10: Enhancement of Staff Teaching Skills
Standard 11: CDIO Skills Assessment
Standard 12: CDIO Program Evaluation
The 12 CDIO Standards: SP Context

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-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 and system building, disciplinary knowledge, and social learning

The 12 CDIO Standards – cont’d

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

**Description:** CDIO is considered the context for engineering education in that it is the cultural framework, or environment, in which technical knowledge and other skills are taught, practiced and learned. The principle is adopted by a program when there is explicit agreement of faculty to initiate CDIO, a plan to transition to a CDIO program, and support from program leaders to sustain reform initiatives.

*It's what Engineers do*

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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

**Description:** The knowledge, skills, and attitudes intended as a result of engineering education, *i.e.*, the *learning outcomes*, are codified in the *CDIO Syllabus*. These learning outcomes, also called learning objectives, detail what students should know and be able to do at the conclusion of their engineering programs. In addition to learning outcomes for technical disciplinary knowledge, the *CDIO Syllabus* specifies learning outcomes as personal, interpersonal, and product and system building (*i.e.* Conceive-Design-Implement-Operate).

Learning outcomes are reviewed and validated by *key stakeholders*, groups who share an interest in the graduates of engineering programs, for consistency with program goals and relevance to engineering practice. In addition, stakeholders help to determine the expected level of proficiency, or standard of achievement, for each learning outcome.
CDIO Skills: SP-customized CDIO Syllabus

CDIO Syllabus: Customized for SP (sample)

MIT-CDIO syllabus
System Thinking
1. Thinking Holistically
2. Emergence and Interactions in Systems
3. Prioritization and Focus
4. Trade-offs, Judgement and Balance in Resolution

Professional Skills and Attitudes
1. Professional Ethics, Integrity, Responsibility & Accountability
2. Professional Behaviour
3. Proactively Planning for One’s Career
4. Staying Current on World of Engineer

SP-CDIO syllabus
System Thinking
1. Understand the Basis and Methods for System Thinking
2. Analyse the Workings of Systems
3. Use a Range of Relevant System Thinking Tools

Professional Skills and Attitudes
1. Evaluate the Impact of Values and Ethics
2. Demonstrate Professional Behaviour at Work and in Society
1. Technical Knowledge & Reasoning:
   - Knowledge of underlying sciences
   - Core engineering fundamental knowledge
   - Advanced engineering fundamental knowledge

2. Personal and Professional Skills & Attributes
   - 2.1 Engineering reasoning and problem solving
   - 2.2 Experimentation and knowledge discovery
   - 2.3 System thinking
   - 2.4 Personal skills and attributes
   - 2.5 Professional skills and attributes

3. Interpersonal Skills: Teamwork & Communication
   - 3.1 Teamwork
   - 3.2 Communications

   - 4.1 External and societal context
   - 4.2 Enterprise and business context
   - 4.3 Conceiving
   - 4.4 Designing
   - 4.5 Implementing
   - 4.6 Operating
   - 4.7 Leading Engineering Endeavours
   - 4.8 Entrepreneurship

3.2 COMMUNICATIONS

3.2.1 Design appropriate communications strategies

- Analyze the communication situation e.g., in terms of purpose, audience and context (PAC)
- Identify key considerations in communicating across cultures and disciplines
- Identify communications objectives
- Read critically and select relevant content
- Identify and choose appropriate communication structure and style
- Select appropriate multimedia and graphical communication (e.g. email, voicemail, video conferencing, tables and charts, sketching and drawing)

3.2.2 Demonstrate effective written communication

3.2.3 Demonstrate effective oral communication
For any specific learning objective: whether this is knowledge, skill, or attitudinally based – there will be essential knowledge that underpins understanding and/or competence.

In basic terms this is the “stuff” that a teacher needs to know in order to be able to teach the objective.

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The different purposes that may be intended by a communicator (e.g. Convey facts, influence perception and beliefs, change behaviors, etc), How audiences differ (e.g. Gender, ethnicity, competence, belief systems, etc) and the implications for how communication is conducted. How context (e.g. what is occurring now, has recently occurred, time and place, who is present – or not present, physical conditions, etc) may significantly influence the perceived meaning of human communication by audiences.
The programme should ensure that graduates are able to:

a) apply knowledge of mathematics, science and engineering;
b) design and conduct experiments, analyse, interpret data and synthesise valid conclusions;
c) design a system, component, or process, and synthesise solutions to achieve desired needs;
d) identify, formulate, research through relevant literature review, and solve engineering problems reaching substantiated conclusions;
e) use the techniques, skills, and modern engineering tools necessary for engineering practice with appropriate considerations for public health and safety, cultural, societal, and environmental constraints;
f) communicate effectively;
g) recognize the need for, and have the ability to engage in life-long learning;
h) understand the impact of engineering solutions in a societal context and to be able to respond effectively to the needs for sustainable development;
i) function effectively within multi-disciplinary teams and understand the fundamental precepts of effective project management;
j) understand professional, ethical and moral responsibility.

Curriculum Alignment

**Learning Outcomes**

serve as the basis for developing the

**Assessment Approaches** and the

**Teaching and Learning Activities**

Often referred to as

“**Constructive Alignment**”

(Biggs)
A curriculum designed with mutually supporting disciplinary courses, with an explicit plan to integrate personal, interpersonal, and product and system building skills (Standard 2), integrated with the learning of disciplinary content. Disciplinary subjects 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 CDIO skills and multidisciplinary connections are to be made, for example, by mapping CDIO learning outcomes to courses and co-curricular activities that make up the curriculum.
Communication as an integrated competence

As engineers, being able to communicate well, is part of the practice of engineers, as they need to be able to:

• Speak with clarity and confidence
• Explain technical concepts at different levels of complexity to different audiences
• Argue the case for engineering proposals and solutions
• Display good interpersonal communications with a range of stakeholders

The same applies to other CDIO skills, such critical and creative thinking, teamwork, ethical reasoning, etc

Examples in the SP context

Existing modules (courses) were reviewed, reorganised and content areas rationalised and updated

Selected CDIO skills were integrated in modules (some modules were specifically identified as most suitable for selected skill integration)

Integration of CDIO skills across modules through integrated learning experiences

Developing the proficiency of skills, through selected modules, over the course duration

Some modules actually removed and new ones added, resulting in a better sequence for the overall programme structure
Gap Analysis & Skill Mapping

Each school conducted a gap analysis of their courses. From this, it was possible to:

- Identify where such skills are already present in the curriculum (whether explicitly stated or otherwise)
- Identify where there are naturally occurring opportunities to integrate selected CDIO skills.
- Map and integrate the CDIO skills throughout the course (programme), and in terms of proficiency at module (course) level.
- Ensure that the overall structure and sequencing of modules is both effective and efficient in terms of meeting the terminal outcomes of the programme.

Example from Chemical Engineering:

Integration of Communication & Teamwork across 3 years of Study

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Year 1: Exposure to CDIO skills
Year 2: Reinforcement of CDIO skills
Year 3: Demonstration of CDIO skills
Different level of expectations Year 1 to Year 3

Example: Communication

Year 1: To appreciate importance of clear oral communication using walkie-talkie in carrying out the task of ....

Year 1: To be aware of Purpose, Audience & Context (PAC) in preparing a memo to different target audience ....

Year 2: To develop competence in applying good principles in preparing an oral presentation for ....

Year 3: To demonstrate competence in delivering oral presentation to a designated audience in .....
WHY Introduction to Engineering

• “Primacy Effect” (positive first impression) → get student attention, interest and commitment to engineering

• Much of the criticism of engineering education by students is that the intrinsically interesting parts of curriculum typically come in later years. Earlier years tend to focus on foundational knowledge → often experienced by students as dry and de-contextualized

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Year 1: Introduction to Engineering

- Mechanics
- IDEA (creative thinking)
- Machine Practice

Conceive, design and build a model racing car

- Communication skills
- Teamwork skills
- Sketching/CAD
A curriculum that includes two or more design-implement experiences, including one at a basic level and one at an advanced level

*Description:* The term *design-implement experience* denotes a range of engineering activities central to the process of developing new products and systems. Included are all of the activities described in Standard One at the *Design* and *Implement* stages, plus appropriate aspects of conceptual design from the *Conceive* stage. Students develop product and system building skills, as well as the ability to apply engineering science, in design-build experiences integrated into the curriculum. Design-build experiences are considered *basic* or *advanced* in terms of their scope, complexity, and sequence in the program.
Design-Implement Experiences

A framework for students to learn engineering by building things

- Provide authentic real world simulated learning experiences → Add realism to the curriculum
- Illustrate connections between engineering disciplines
- Naturally infuses both technical and CDIO skills (e.g. teamwork, communications, thinking, etc.)
- Foster students’ creative abilities
- Are motivating for students

Introduction to Engineering
(basic conceive, design and implement)

Year 2 project
Conceive, Design (Design Thinking)

Capstone Project
Conceive, Design, Implement and Operate
Standard 6 – Engineering Workspaces

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

Description: The physical learning environment includes traditional learning spaces, for example, classrooms, lecture halls, and seminar rooms, as well as engineering workspaces and laboratories. Workspaces and laboratories support the learning of product and system building skills concurrently with disciplinary knowledge. They emphasize hands-on learning in which students are directly engaged in their own learning, and provide opportunities for social learning, that is, settings where students can learn from each other and interact with several groups. The creation of new workspaces, or remodeling of existing laboratories, will vary with the size of the program and resources of the institution.
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

**Description:** Integrated learning experiences are pedagogical approaches that foster the learning of disciplinary knowledge simultaneously with personal, interpersonal, and product and system building skills. They incorporate professional engineering issues in contexts where they coexist with disciplinary issues. 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.

**Standard 7 – Integrated Learning Experiences**

**Final Year Project**
Description: Active learning methods engage students directly in thinking and problem solving activities. There is less emphasis on passive transmission of information, and more on engaging students in manipulating, applying, analyzing, and evaluating ideas. Active learning in lecture-based courses can include such methods as partner and small-group discussions, demonstrations, debates, concept questions, and feedback from students about what they are learning. Active learning is considered experiential when students take on roles that simulate professional engineering practice, for example, design-build projects, simulations, and case studies.

Learning is not a spectator sport. Students do not learn much just by sitting in class listening to teachers, memorizing pre-packaged assignments, and spitting out answers. They must talk about what they are learning, write about it, relate it to past experiences, apply it to their daily lives. They must make what they learn part of themselves.

(Chickering & Gamson)
### ACTIVE LEARNING
Engages students directly in thinking and problem solving activities  
Emphasis on engaging students in manipulating, applying, analyzing, and evaluating ideas  

**Examples:**  
Pair-and-Share  
Group discussions  
Debates  
Concept questions

### EXPERIENTIAL LEARNING
Active learning in which students take on roles that simulate professional engineering practice

**Examples:**  
Design-implement experiences  
Problem-based learning  
Simulations  
Case studies

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### Standard 9 - Enhancement of Faculty CDIO Skills

*Actions that enhance faculty competence in personal, interpersonal, and product, process and system building skills*

*Description:* CDIO programs provide support for faculty to improve their own competence in the personal, interpersonal, and product and system building skills described in Standard 2. They develop these skills best in contexts of professional engineering practice. The nature and scope of faculty development vary with the resources and intentions of different programs and institutions. Examples of actions that enhance faculty competence include: professional leave to work in industry, partnerships with industry colleagues in research and education projects, inclusion of engineering practice as a criterion for hiring and promotion, and appropriate professional development experiences at the university.
Enhancement of Staff CDIO Skills

What do I need to do for this?

Standard 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

Description: A CDIO program provides support for faculty to improve their competence in integrated learning experiences (Standard 7), active and experiential learning (Standard 8), and assessing student learning (Standard 11). The nature and scope of faculty development practices will vary with programs and institutions. Examples of actions that enhance faculty competence include: support for faculty participation in university and external faculty development programs, forums for sharing ideas and best practices, and emphasis in performance reviews and hiring on effective teaching skills.
Enhancing my Teaching Skills....

I have been teaching for years, why do I need more teaching skills?

Standard 11 - CDIO Skills Assessment

Assessment of student learning in personal and interpersonal skills, and product, process and system building skills, as well as in disciplinary knowledge.

*Description*: 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, interpersonal, and product 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.
Assessment is not separate from the instructional process but an integral part of it. Well used assessment methods and processes significantly enhance learning:

- direct learning towards desired learning outcomes
- provide clear guides to performance criteria & standards

“There have been a number of notable studies over the years which have demonstrated that assessment methods and requirements probably have a greater influence on how and what students learn than any other single factor. This influence may well be of greater significance than the impact of teaching or learning materials” - Boud

Use of Formative Assessment (i.e. to support learning, not grading) provides a means in which students and lecturers can receive important feedback which can facilitate:

- clarifying what good performance is (e.g. goals, criteria, standards)
- identifying gaps in performance and specific learning needs
- closing gap between current and desired performance
- positive beliefs and self-esteem
- development of self-assessment in learning
- appropriate modification of teaching and learning strategy
Program evaluation is a judgment of the overall value of a program based on evidence of a program's progress toward attaining its goals. A CDIO program should be evaluated relative to these 12 CDIO Standards. Evidence of overall program value can be collected with course evaluations, instructor reflections, entry and exit interviews, reports of external reviewers, and follow-up studies with graduates and employers. The evidence can be regularly reported back to instructors, students, program administrators, alumni, and other key stakeholders. This feedback forms the basis of decisions about the program and its plans for continuous improvement.

Standard 12 - CDIO 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.

You like it, but what have you learned?
Implementation: Overview

- **SP Customized CDIO SKILLS** (Competency areas with underpinning Knowledge)
- **Infuse CDIO Skills Into Course & Module structure**
- **Produce Learning Designs and Activities for developing competence**
- **Produce Assessment Items for assessing competence**

Q & A
ONE DOES NOT SIMPLY WALK INTO THE BATCAVE.
THANK YOU

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