A model for engineering education

“Scientists investigate that which already is. Engineers create that which has never been.”

- Albert Einstein
We envision an education that stresses the fundamentals, set in the context of **Conceiving – Designing – Implementing – Operating** systems and products:

- A curriculum organised around mutually supporting disciplines, but with CDIO activities highly interwoven
- Rich with student design-build projects
- Integrated approach to learning “non-technical” skills
- Featuring active and experiential learning
- Set in both the classroom and a modern learning laboratory/workspace
- Continuously improved through a robust assessment/evaluation process

**Bring forward the role of design and implementation in the education - from paper (computer) designs to physical prototypes**

**Bridge theory and practice - more authentic, realistic**

**Improve learning of non-technical skills**
OK ...but what was the need for change?

Industry needs a new kind of engineer

Focus of yesterday
- Context: Engineering science
- Reduced, “pure” problems (with right and wrong answers)
- Design phase
- Individual effort

Desired focus
- Context: Product & system development
- Systems view; problems across disciplines are complex, ill-defined, and contain societal and business aspects
- Understand the whole cycle: CDIO
- Teamwork, communication
THE 12 CDIO STANDARDS – THE GUIDELINES FOR PROGRAM DESIGN

Program focus 1,2,3
- CDIO as Context
- CDIO Syllabus
- Integrated Curriculum

CDIO 4,5,6
- Introduction to Engineering
- Design-Build Experiences
- CDIO Workspaces

Teaching & Learning 7,8
- Integrated Learning Experiences
- Active Learning

Faculty development 9,10
- Enhancement of Faculty CDIO Skills
- Enhancement of Faculty Teaching Skills

Evaluation 11,12
- CDIO Skills Assessment
- CDIO Program Evaluation
The "Civilingenjör" program in Mechanical Engineering aims to develop the knowledge, skills and attitudes that are needed to be able to

Lead and participate in the design and operation of industrial products, processes and systems

This includes the entire lifecycle from identifying needs, creating solutions, design, manufacturing, marketing, operating, maintaining, recycling to eliminating
STANDARD 2

- a long list of desired competences

1. **Technical Knowledge & Reasoning:**
   1.1 Knowledge of underlying sciences
   1.2 Core engineering fundamental knowledge
   1.3 Advanced engineering fundamental knowledge

2. **Personal and Professional Skills**
   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**
   3.1 Multi-disciplinary teamwork
   3.2 Communications
   3.3 Communication in a foreign language

4. **CDIO of Complex Systems**
   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

- Program specific (1) and general (2-4)
- Created and validated by alumni, faculty and students
- Complete
### STANDARD 3

#### INTEGRATED CURRICULUM

<table>
<thead>
<tr>
<th>Learning objective/topic</th>
<th>Course 1</th>
<th>Course 2</th>
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<td>2 Personal and professional knowledge, skills and attributes</td>
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Planned learning sequences
# STANDARD 3 FOR CHALMERS MECHANICAL ENGINEERING PROGRAM

## Intro Mathematics
7.5 ECTS

- Single-variable Calculus 7.5 ECTS
- Linear Algebra 7.5 ECTS
- Several-variable Calculus 7.5 ECTS

## Programming
4.5 ECTS

- Programming in Matlab 4.5 ECTS
- Intro to Mechanical Eng 7.5 ECTS

## Mechanics and Solid Mechanics I
7.5 ECTS

- Mechanics and Solid Mechanics I 7.5 ECTS
- Mechanics and Solid Mechanics II 7.5 ECTS

## Machine Elements
7.5 ECTS

- Machine Elements 7.5 ECTS
- Materials B 7.5 ECTS
- Manufacturing Tech 7.5 ECTS

## Materials A
7.5 ECTS

- Materials A 7.5 ECTS
- Machine Elements 7.5 ECTS
- Manufacturing Tech 7.5 ECTS

## Fluid Mechanics
7.5 ECTS

- Fluid Mechanics 7.5 ECTS
- Control Engineering 7.5 ECTS
- Elective I 7.5 ECTS

## Control Engineering
7.5 ECTS

- Control Engineering 7.5 ECTS
- Elective II 7.5 ECTS
- Mathematical Statistics 7.5 ECTS

## Bachelor Thesis Project
15 ECTS

- Bachelor Thesis Project 15 ECTS
- Manufacturing Production & Org 6 ECTS
- Industrial Economics 4 ECTS

## Common computation labs in mathematics, programming & engineering science

## Communications

## Teamwork

## Sustainability

## Integrative project in design & manufacturing

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**Year 1**

- Intro Mathematics 7.5 ECTS
- Single-variable Calculus 7.5 ECTS
- Linear Algebra 7.5 ECTS
- Several-variable Calculus 7.5 ECTS
- Programming in Matlab 4.5 ECTS
- Intro to Mechanical Eng 7.5 ECTS
- Mechanics and Solid Mechanics I 7.5 ECTS
- Mechanics and Solid Mechanics II 7.5 ECTS

**Year 2**

- Mechanics and Solid Mechanics I II 7.5 ECTS
- Machine Elements 7.5 ECTS
- Integrated Design and Manufacturing Project 7.5 ECTS
- Materials A 7.5 ECTS
- Materials B 7.5 ECTS
- Mechatronics 7.5 ECTS
- Manufacturing Tech 7.5 ECTS

**Year 3**

- Fluid Mechanics 7.5 ECTS
- Control Engineering 7.5 ECTS
- Bachelor Thesis Project 15 ECTS
- Elective I 7.5 ECTS
- Elective II 7.5 ECTS
- Mathematical Statistics 7.5 ECTS

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**INTERGRALED CURRICULUM**
INTRODUCTION TO ENGINEERING

Motivation

Common grounds for understanding of technical concepts

Introduce the process of engineering: Conceive-design-implement-operate

Basic project management- communication - teamwork
A product is developed or improved, from need to physical prototype as a vehicle for learning engineering.

- Integrated learning:
  - Teamwork and communication
  - Design and manufacturing
  - Analysis and simulation

- Industrial projects
- Industrial project model
- At least one DBE project in each year:
  - Systematic progression and variation

Year 2 projects

Integriterad konstruktion och tillverkning M2
Exempel på genomförda projekt:

självgående gräsklippare för golfbanor
Motivation
Self-efficacy
Self-expression, ownership
Involves unexpected events
Concrete technical knowledge

Chalmers EcoMarathon 2006
STANDARD 6: THE PROTOTYPING LABORATORY AT CHALMERS

CDIO WORKSPACES

• 450 m² facility where students can build prototypes

• Metal machining, woodworking, FFF, welding, electronics, …

• Used in courses and projects from year 1 to master thesis projects
Communication in engineering means being able to

► use the technical concepts comfortably,
► discuss a problem at different levels,
► determine what is relevant to the situation,
► argue for or against conceptual ideas and solutions,
► develop ideas through discussion and collaborative sketching,
► explain the technical matters for different audiences,
► show confidence in expressing yourself within the field...

Communication skills as contextualized competences are embedded in, and inseparable from, students’ application of technical knowledge.

The same kind of reasoning can be made for teamwork, ethics (etc...) as well.

Practising CDIO competences in the disciplinary context means expressing and applying technical knowledge. Training for the competences will therefore at the same time reinforce students’ understanding of disciplinary content – they will acquire a deeper working knowledge of engineering fundamentals.
• Reformed mathematics emphasizing simulations
• Motivate importance of mathematics and applied mechanics courses
• Realistic engineering problems
• Working method based on modelling, simulation & analysis
• MATLAB programming
• Visualization of mechanical behaviour

Year 1 lab example

Analys av plan elastiska skiva med fyra hål

Beräkna spänningskoncentrationsfaktorn. Avgör om spänningshojningarna vid hålen samverkar. Symmetrier skall utnyttjas.
Organised faculty workshops

Courses in group dynamics

Systematic faculty development

Coaching to facilitate implementation of perspectives of sustainable development
STANDARD 11

Integration of CDIO competencies into:

- Objectives
- Activities
- Assessment

CONSTRUCTIVE ALIGNMENT (Biggs 1999)

What should the student be able to do as a result of the course?

What work is appropriate for the student to do to reach the objectives?

What should the student do to demonstrate that they reached the objectives in e.g. communication?
A system that evaluates programs against the twelve standards, provides feedback to students, faculty, and other stakeholders for the purposes of continuous improvement.
"Rethinking Engineering Education - The CDIO Approach",
CDIO-Initiative

ORIGINAL COLLABORATORS

- Chalmers
- KTH
- Linköping
- MIT

EUROPE

N. AMERICA

REST OF WORLD

SOME OF THE NEW COLLABORATORS

- Denmark Tech. U.
- Queen’s U., Belfast
- US Naval Academy
- Queen’s U. Ontario
- U. Auckland
- U. Pretoria
- Bristol
- U. Liverpool
- Wismar
- École Poly., Montréal
- Daniel Webster College
- Singapore Poly.
- Hogeschool Gent
- Lancaster
- University of Colorado
- University of Sydney
- Shantou