# Rethinking Engineering Education
## The CDIO Approach

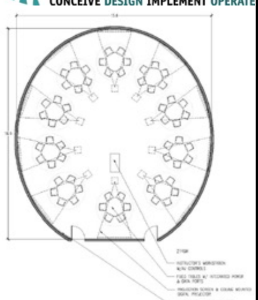
Kristina Edström
KTH Royal Institute of Technology, Stockholm, Sweden

1

# Kristina Edström


## Engineer & Educational developer

- Associate Professor in *Engineering Education Development* at KTH Royal Institute of Technology, Stockholm, Sweden
- 1000+ participants in courses on *Teaching and Learning in Higher Education* and *Doctoral Supervision*, customized for KTH faculty
- CDIO Initiative for reform of engineering education since 2001
- Editor-in-Chief of the *European Journal of Engineering Education,* 2018-
- M. Sc. in Engineering (Chalmers) and PhD in Technology and Learning (KTH)
- The KTH prize for outstanding educational achievements, 2004



### Some publications


- Edström, K. (2020). Integrating the academic and professional values in engineering education – ideals and tensions. In Geschwind, L. Broström, A. & Larsen, K. (Eds.) *Technical Universities - Past, present and future*. Springer Higher Education Dynamics.
- Edström, K. (2020). The role of CDIO in engineering education research: Combining usefulness and scholarliness. *European Journal of Engineering Education, 45*(1), 113–127.
- Edström,K. (2018). Academic and professional values in engineering education: Engaging with the past to explore a persistent tension. *Engineering Studies*, *10*(1), 38–65.
- Crawley, E.F., Malmqvist, J., Östlund, S., Brodeur, D.R., & Edström, K. (2014). *Rethinking Engineering Education: The CDIO Approach*, 2nd ed., Springer Verlag.
- Edström, K., & Kolmos, A. (2014). PBL and CDIO: complementary models for engineering education development. *European Journal of Engineering Education*, *39*(5), 539–555.
- Edström, K. (2008). Doing course evaluation as if learning matters most, *Higher Education Research & Development*, *27*(2), 95–106.


2

## What is CDIO?

1. A community to develop the concept & share experiences
   **The CDIO Initiative**
2. An idea that we should educate
   **engineers who can actually engineer**
3. A methodology for curriculum development
   **The 12 CDIO Standards**

cdio
CONCEIVE DESIGN IMPLEMENT OPERATE

3

## CDIO is a community for developing engineering education

**The CDIO Initiative**

cdio
CONCEIVE DESIGN IMPLEMENT OPERATE

4


- **The CDIO Initiative** started in 2000 with four partners: MIT, KTH Royal Institute of Technology, Chalmers, and Linköping University
- Soon other institutions expressed an interest in joining
- Today some **200 CDIO Collaborators** worldwide

5

# CDIO collaborators

See www.cdio.org

## North America

- Arizona State University
- California State University, Northridge
- Duke University
- École Polytechnique de Montréal
- Embry-Riddle Aeronautical University
- Laspau
- Massachusetts Institute of Technology
- Naval Postgraduate School (U.S.)
- Pennsylvania State University
- Queen's University (Canada)
- Sheridan College
- Stanford University
- United States Naval Academy
- University of Arkansas
- University of Calgary
- University of Colorado
- University of Manitoba
- University of Michigan
- University of Notre Dame

## Latin America

- CESUPA - Pará State University Center
- Escola de Engenharia de Lorena (EEL-USP)
- Instituto Nacional de Telecomunicações (Inatel)
- Military Institute of Engineering (IME)
- Pontificia Universidad Javeriana
- Santo Tomás University
- School of Engineering of Antioquia (EIA)
- UNISAL – Salesian University Center of Sao Paulo
- UNITEC Laureate International Universities
- Universidad Autónoma del Caribe (UAC)
- Universidad Católica de la Santísima Concepción
- Universidad de Chile
- Universidad de Los Lagos
- Universidad de Santiago de Chile
- Universidad del Quindío
- Universidad ICESI, Cali
- Universidad Nacional de Colombia, Bogota
- Universidad Tecnológica de Chile INACAP
- Universidade Federal da Grande Dourados (UFGD)
- Universidade Estadual Paulista Júlio de Mesquita Filho-UNESP
- Universidad Federico Santa Maria (UFSM)
- University center toledo araçatuba - UNITOLEDO
- University of Vale do Taquari - Univates

## Africa

- University of Johannesburg
- University of Pretoria
- ESPRIT, Tunisia

## Australia/New Zealand

- Australasian Association for Engineering Education (Affiliated organization)
- Chisholm Institute, Centre for Integrated Engineering & Science
- Curtin University
- Queensland University of Technology
- Royal Melbourne Institute of Technology - RMIT
- University of Auckland
- University of Sydney
- University of the Sunshine Coast

## Asia

- Australian College of Kuwait
- Beijing Institute of Petrochemical Technology (BIPT)
- Beijing Jiaotong University
- Bulacan State University
- Chengdu University of Information Technology
- Chulalongkorn University (Faculty of Engineering)
- Dalat University
- Dalian Neusoft University of Information
- Dong Nai Technology University (DNTU)
- Duy Tan University
- Feng Chia University
- FPT University
- Hokkaido Information University
- Inje University
- Institute of Engineering and Technology (IET)
- International College of Technology, Kanazawa
- Kanazawa Institute of Technology
- Mongolian University of Science and Technology
- Nanyang Polytechnic
- National University of Civil Engineering (NUCE)
- NIT Anan College, National Institute of Technology
- NIT Ibaraki College, (NITIC)
- NIT Kisarazu, National Institute of Technology, Kisarazu College
- NIT Kumamoto College, National Institute of Technology (KOSEN)
- NIT Nagano, National Institute of Technology Nagano College
- NIT Nagaoka, National Institute of Technology, Nagaoka College
- NIT Sendai, National Institute of Technology, Sendai College
- NIT Tsuruoka College
- NIT Tsuyama, National Institute of Technology, Tsuyama College
- Politeknik Ibrahim Sultan
- Politeknik Ungku Omar
- Rajamangala University of Technology Isan (RMUTI)
- Rajamangala University of Technology Thanyaburi (RMUTT)
- Sathyabama Institute of Science and Technology
- Shantou University
- Singapore Polytechnic
- SRM Institute of Science and Technology
- Suzhou Industrial Park Institute of Vocational Technology
- Taylor's University, School of Engineering
- Thiagarajar College of Engineering (TCE)
- Thu Dau Mot University
- Tra Vinh University, TVU
- Tsinghua University
- Universiti Teknologi MARA (UiTM)
- University of Electronic Science and Technology of China (UESTC)
- University of Science and Technology of Southern Philippines, Cagayan de Oro Campus (USTP CDO)
- Vel Tech Dr.RR & Dr.SR Technical University
- Vietnam National University
- Vinh University
- Yanshan University

## UK-Ireland

- Aston University
- Birmingham City University
- Canterbury Christ Church University.
- Lancaster University
- Nottingham Trent University (NTU)
- Queen's University (Belfast)
- South Eastern Regional College (SERC)
- South West College
- Trinity College Dublin
- Ulster University
- University of Bristol
- University of Chichester
- University of Hertfordshire
- University of Leeds
- University of Leicester
- University of Limerick
- University of Liverpool
- University of Strathclyde

## Europe

- Aalborg University
- Aarhus University
- AFEKA Tel Aviv Academic College of Engineering
- Arts et Métiers Institute of Technology (Ecole Nationale Supérieure d'Arts et Métiers)
- Astrakhan State University
- Bauman Moscow State Technical University
- Blekinge Institute of Technology
- Chalmers University of Technology
- Cherepovets State University
- Delft University of Technology
- Don State Technical University
- Eindhoven University of Technology
- Ernst-Abbe-University of Applied Sciences Jena (EAH Jena)
- Escola Tecnica Superior d'Enginyeria Quimica (ETSEQ)
- ESPRIT
- Gdansk University of Technology
- Ghent University
- Graduate School of Engineering CESI
- Group T - International University College Leuven
- Hague University of Applied Sciences
- Hochschule Wismar
- IMT Atlantique (formerly Telecom Bretagne & EMN)
- Instituto Superior de Engenharia do Porto
- Israel Institute for Empowering Ingenuity
- Jönköping University
- Kazan Federal University
- Kristianstad University
- KTH Royal Institute of Technology
- Kuban State Technological University
- LAB University of Applied Sciences
- Lapland University of Applied Sciences
- Linköping University
- Linnaeus University
- Luleå University of Technology
- Metropolia University of Applied Sciences
- Moscow Aviation Institute
- Moscow Institute of Physics and Technology (MIPT)
- National Research Nuclear University - NRNU MEPhI
- North-Eastern Federal University
- Novia University of Applied Sciences
- NTNU - Norweigian University of Science and Technology
- Orel State University
- Politecnico di Milano
- Reykjavik University
- RWTH Aachen
- Saint Petersburg State University of Aerospace Instrumentation
- Savonia University of Applied Sciences
- Seinäjoki University of Applied Sciences
- Siberian Federal University
- Skolkovo Institute for Science and Technology
- Surgut State University, SurSU
- Tallinn University of Technology (TalTech)
- Tampere University of Applied Sciences (TAMK)
- Technical University of Denmark
- Technical University of Madrid
- Tomsk Polytechnic University
- Tomsk State University of Control Systems and Radioelectronics (TUSUR)
- Turku University of Applied Sciences
- Umeå University
- Universitat Politècnica de Catalunya (Telecom BCN)
- University of Navarra. TECNUN – School of Engineering
- University of Skövde
- University of Turku
- University of Twente
- University West
- Ural Federal University
- Ural State University of Railway Transport, USURT
- VIA University College
- Vilniaus Kolegija/University of Applied Sciences
- Wageningen University & Research
- Østfold University College

6

"If you want to learn about a system, try to change it"

(attributed to Kurt Lewin; cf. Le Chatelier's principle)

7

# Annual International CDIO Conference

**European Regional meeting,**
*8-9 January 2024*
*KTH Royal Institute of Technology*
*Open for registration*

**20th International CDIO Conference**
June 2024, Tunis, Tunisia
*Deadline for abstracts 15 Nov 2023*

2005 Queen's University, Kingston, Canada
2006 Linköping University, Linköping, Sweden
2007 Hogeschool Gent, Gent, Belgium
2008 MIT, Cambridge MA, USA
2009 Singapore Polytechnic, Singapore
2010 École Polytéchnique, Montreal, Canada
2011 Denmark Technical University, Copenhagen, Denmark
2012 QUT, Brisbane, Australia
2013 Harvard/MIT, Cambridge MA, USA
2014 UPC, Barcelona, Spain
2015 CUIT, Chengdu, China
2016 Turku UAS, Turku, Finland
2017 University of Calgary, Canada
2018 Kanazawa, Japan
2019 Aarhus University, Denmark
2020 Chalmers University of Technology, Sweden
2021 Chulalongkorn University & RMUTT, Bangkok, Thailand
2022 Reykjavik University, Iceland
2023 NTNU, Trondheim, Norway

8

## CDIO is based on an idea of what students should learn to become good engineers

**Engineers who can engineer**

Or in other words: who can Conceive, Design, Implement and Operate products, processes, systems and services

cdio
CONCEIVE DESIGN IMPLEMENT OPERATE

9

## The dual nature of engineering education

Higher engineering education is *simultaneously*

**Academic**
emphasising theory in a range of disciplines

**Professional**
preparing students for engineering practice

These are not merely two separate components that need to be balanced in appropriate proportions, but they should also be in **meaningful relationship** in the curriculum.

10

## This creates a dual challenge

We want to educate students with

- **a deeper working knowledge** of technical fundamentals, **AND**
- **professional competences**

**not one at the expense of the other!**

cdio

CONCEIVE DESIGN IMPLEMENT OPERATE

11

## LET'S START WITH TWO EXAMPLES FROM CDIO EDUCATION

12

# Let’s go to Chalmers for an example

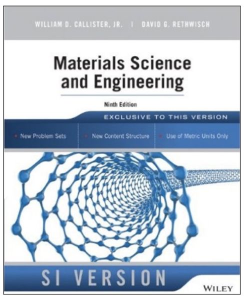
## COURSE LEVEL

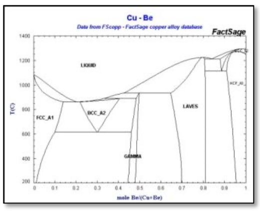
- A course in basic materials science

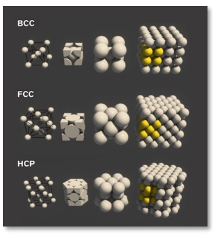
13

# A course in Basic Materials Science

- Standard lecture based course
- Focus on disciplinary knowledge (“content”)




Hypoeutectoid steel was quenched from austenite to martensite which was tempered, spheroidized and hardened by dislocation pinning..

[Professor Maria Knutson Wedel, Chalmers]

14

**A course in Basic Materials Science**

## Two ways of seeing materials science

**From the inside - out**

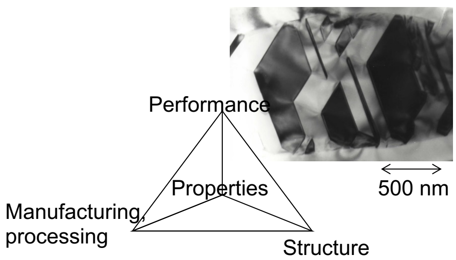
"Materials engineers distinguish themselves from mechanical engineers by their focus on the internal structure and processing of materials, specifically at the micro- and nano-scale."

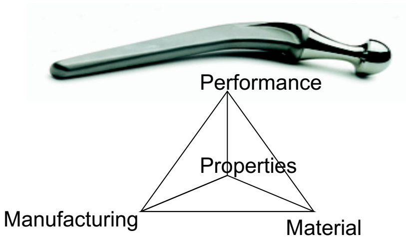
Flemings & Cahn

**From the outside - in**

"Materials have a supportive role of materializing the design. The performance is of primary concern, followed by considerations of related materials properties…."

Östberg



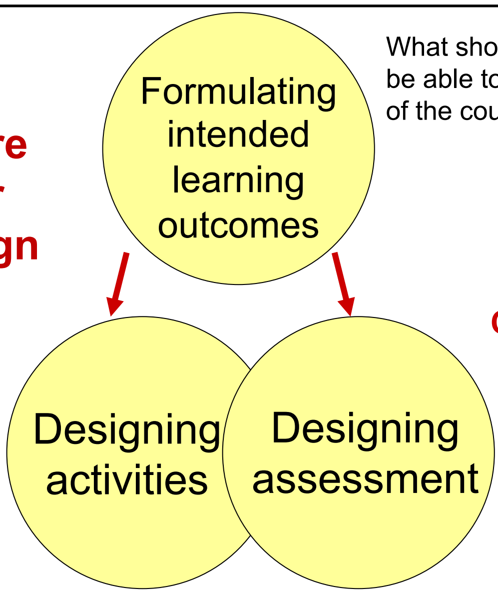




[Professor Maria Knutson Wedel, Chalmers]

15

## Intended learning outcomes are the basis for course design

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



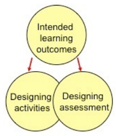

**Constructive alignment** [Biggs]

What work is appropriate for the students to do, to reach the learning outcomes?

How should the students demonstrate that they fulfil the learning outcomes?

16

A course in Basic Materials Science




# 1. Changing the learning objectives

**Before**
**disciplinary knowledge in itself**

…describe crystal structures of some metals…

…interpret phase diagrams…

…explain hardening mechanisms…

...describe heat treatments…

**Now**
**performances of understanding**

…select materials based on considerations for functionality and sustainability

...explain how to optimize material dependent processes (e.g. casting, forming, joining)

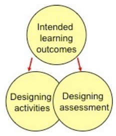
...discuss challenges and trade-offs when (new) materials are developed

...devise how to minimise failure in service (corrosion, creep, fractured welds)

[Professor Maria Knutson Wedel, Chalmers]

17

A course in Basic Materials Science




# 2. Changing the learning activities

Still lectures and still the same book, but framed differently:
- from product to atoms
- focus on engineering problems

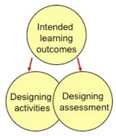
And…
- Study visit in industry, assessed by written reflection
- Material selection class (CES)
- Active lecturing: buzz groups, quizzes
- Test yourself on the web
- Students developed animations to visualize

[Professor Maria Knutson Wedel, Chalmers]

18

A course in Basic Materials Science

# 3. Redesigning assessment




2011:

**New type of exam, aimed at deeper working understanding**

- More **open-ended questions** - many solutions possible, the quality of **reasoning** is assessed
- **Interconnected knowledge** – integrating the parts of the course

2012:

**Added formative midterm exam, with peer assessment**

- Communicates expectations on the required **level and nature of understanding** (Feedback / Feed forward)
- Generates **appropriate learning activity**
- **Early engagement in the basics** of the course (a basis for further learning)

[Professor Maria Knutson Wedel, Chalmers]

19

**What view of knowledge is the teaching in your programmes and courses based on?**

**The disciplinary knowledge in itself** **or** **What an engineer can do with that understanding**

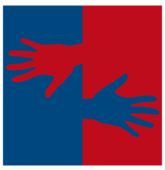
20

”” ”” ””

**How can subject courses contribute to both academic and professional preparation?**

21

## Every learning experience sets a balance and relationship



### Discipline-led learning

- Well-structured knowledge base
- Evidence/theory, Model/reality
- Methods to further the knowledge frontier

**CONNECTING WITH PROBLEM/PRACTICE**

- Deep working understanding = ability to apply
- Seeing the knowledge through the lens of problems, interconnecting the disciplines
- Integrating skills, e.g. communication and collaboration

### Problem/project-led learning

- Integration and application, synthesis
- Open-ended problems, ambiguity, trade-offs
- Real problems, in a context
- Professional work processes
- ”Creating that which has never been”

**CONNECTING WITH DISCIPLINARY KNOWLEDGE**

- Discovering how the disciplinary knowledge is useful
- Reinforcing disciplinary understanding
- Motivational context

22

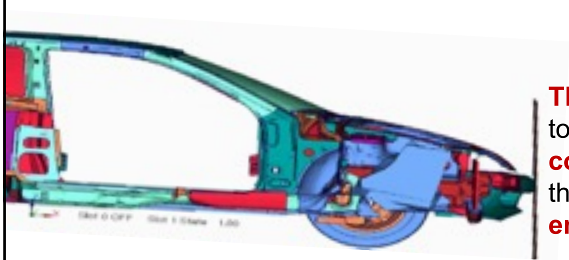
## Let's go to Chalmers for another example

### PROGRAMME LEVEL

- How computational mathematics was integrated

24

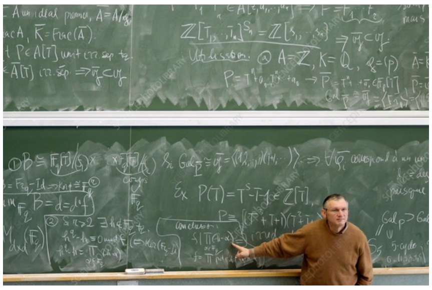
## Integrating computational mathematics
## Mechanical Engineering at Chalmers, Sweden



**THE AIM**
to **modernize the mathematical content** while also strengthening the **connection between engineering and mathematics**

25

## Analysis of the problem



Students need to:

- learn to solve more **general, real-world problems**
- spend less time *"solving oversimplified problems that can be expressed analytically and with solutions that are already known in advance"*
- work on **complete problems**
  - setting up a mathematical **model** and solving it,
  - **simulation** of the system,
  - using **visualisation** to assess the correctness of the model and the solution and compare with physical reality

(Enelund et al. 2011)

26

### Computational mathematics

## Integrated curriculum approach

Interventions to *infuse the programme* with computational mathematics

- **new basic math courses** including a an introduction to programming in a technical computing language and environment (Matlab)
- production of **new teaching materials** (since few textbooks take advantage of the development in computing)
- **integration of relevant mathematics topics in fundamental engineering courses** such as mechanics and control theory
- **cross-cutting exercises, assignments and team projects** shared between the mechanics and strengths of materials courses and mathematics courses

27

### Computational mathematics

## Integrated curriculum approach

*These kinds of problems are often framed as a task for mathematics teachers to solve within the mathematics courses – sometimes with an accusatory tone and ensuing conflict!*

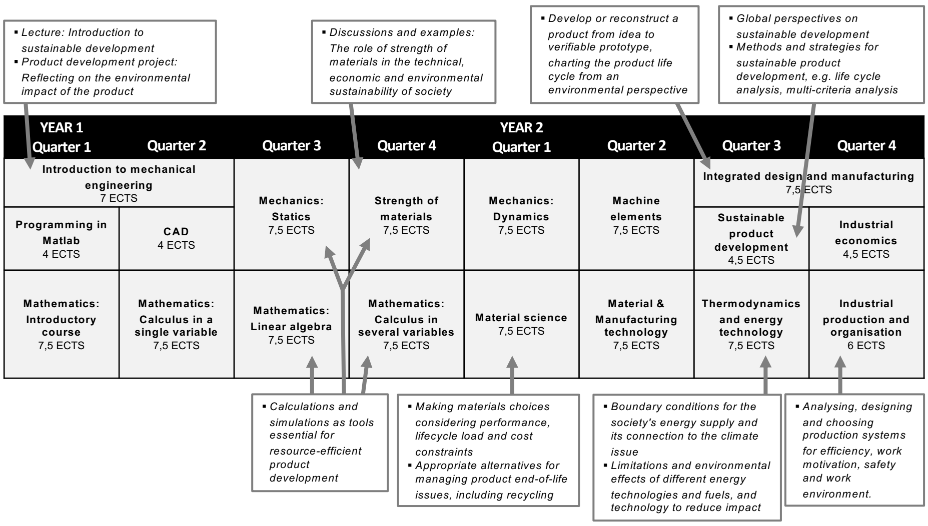
Instead, at Chalmers:

- The **programme-driven approach** was applied, with all relevant courses contributing to the common goal
- The work was done in a **respectful dialogue and collaboration** between the mathematics and engineering colleagues
- Making **connections to mathematics in engineering subjects** was at least as important as **making connections to engineering in mathematics**

28

### Program driven development

## Integration of sustainable development




29

## Integration across the curriculum...

### ...makes it meaningful for teachers and students

- Sustainability is addressed **where it is relevant** and **meaningfully related to course content**
- Teachers are drawing on their **strengths**
- Students are equipped to address sustainability with **increasing technical knowledge and tools**

30

” ” ”

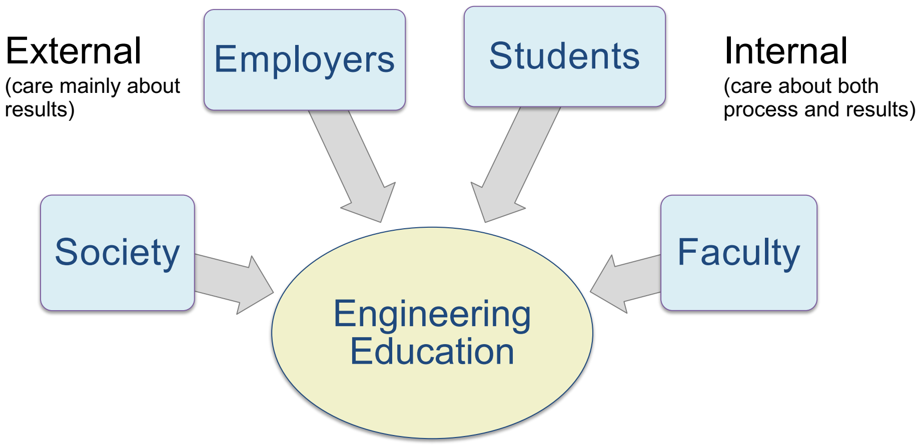
**What kinds of improvements can be addressed with a programme level approach?**

31

## WHAT WERE THESE EXAMPLES OF?

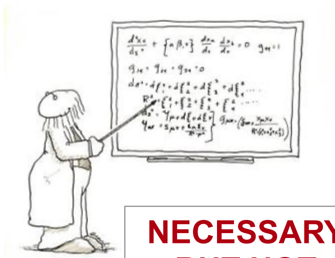
32

## Stakeholder perspectives




35

## Disciplinary theory applied to "problem-solving"



**NECESSARY BUT NOT SUFFICIENT**

## Theory and judgement applied to <u>real</u> problems

"Real" problems

- cross disciplinary boundaries
- sit in contexts with societal and business aspects
- contain values and interests
- are complex, ill-defined and contain tensions
- need interpretations and estimations (seldom 'one right answer')
- require systems view

Jonassen, D., Strobel, J., & Lee, C. B. (2006). Everyday problem solving in engineering: Lessons for engineering educators. Journal of Engineering Education, 95(2), 139.

36

## Individual approach

**NECESSARY BUT NOT SUFFICIENT**

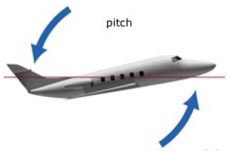
## Communicative and collaborative approach

- Crucial for all engineering work processes
- Much more than working in project teams with well-defined tasks
- Engineering is a social activity involving customers, suppliers, colleagues, citizens, authorities, competitors
- Networking within and across organizational boundaries, over time, in a globalised world

37

## CDIO Standard 1: The context
### Educating for the context of engineering

**An education *about* technology**




**NECESSARY BUT NOT SUFFICIENT**

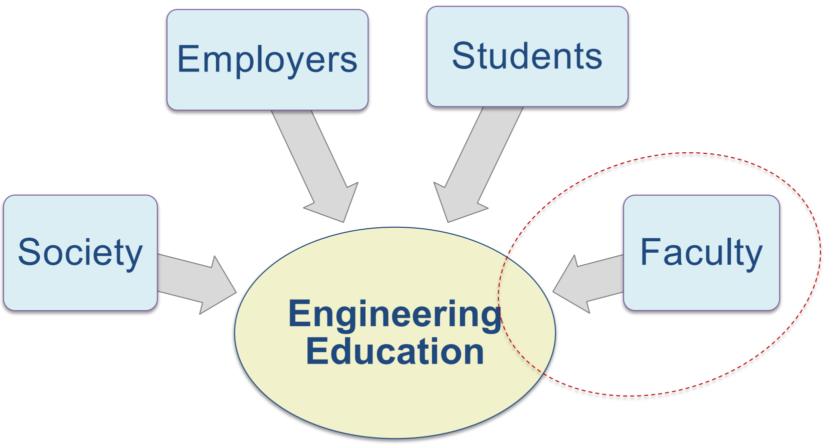
**An education in engineering – becoming an engineer**

**CDIO Standard 1 – The context**
Adoption of the principle that sustainable product, process, system, and service lifecycle development and deployment – Conceiving, Designing, Implementing and Operating – are the context for engineering education.

*Engineers who can engineer!*

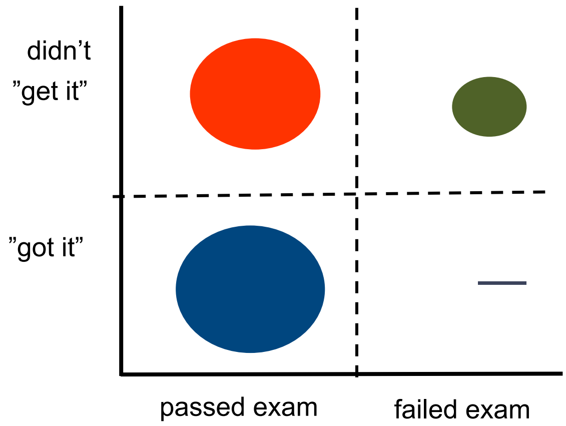
38

## And when we do ask faculty?




39

## Deeper working knowledge of disciplinary fundamentals




- Functional knowledge
- Not just reproduction of known solutions to known problems
- Conceptual understanding
- Being able to explain what they do and why

See for instance Mazur, E. (1997) Peer Instruction, and Kember & McNaught (2007) Enhancing University Teaching.

40

## Quality of student learning
### Feisel-Schmitz Technical Taxonomy

| | |
|---|---|
| Judge | To be able to critically evaluate multiple solutions and select an optimum solution |
| Solve | Characterize, analyze, and synthesize to model a system (provide appropriate assumptions) |
| Explain | Be able to state the process/outcome/concept in their own words |
| Compute | Follow rules and procedures (substitute quantities correctly into equations and arrive at a correct result, "plug & chug") |
| Define | State the definition of the concept or describe in a qualitative or quantitative manner |

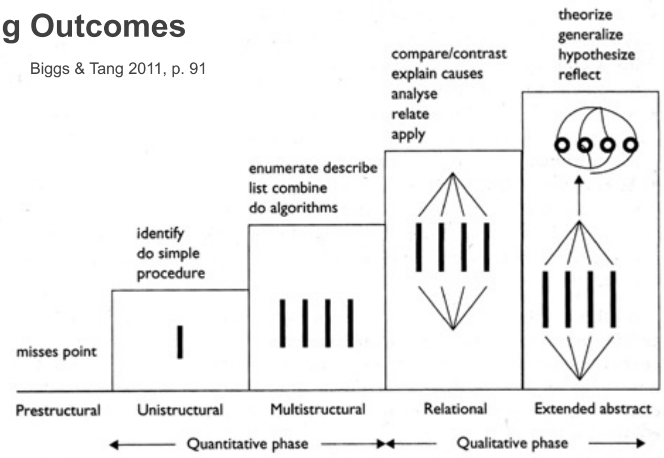
[Feisel, L.D., Teaching Students to Continue Their Education, Proceedings of the Frontiers in Education Conference, 1986.]

41

# Quality of student learning
## The SOLO Taxonomy

**Structure of Observed Learning Outcomes**

Biggs & Tang 2011, p. 91




42

# CDIO is a <u>methodology</u> for developing engineering education

## The 12 CDIO Standards

cdio

CONCEIVE DESIGN IMPLEMENT OPERATE

44

### The working definition of CDIO:
## The 12 CDIO Standards – aligned strategies

**Context:**
- Recognise that we educate for the practice of engineering [1]

**Curriculum development:**
- Formulate explicit program learning outcomes (including engineering skills) in dialogue with stakeholders [2]
- Map out responsibilities to courses – negotiate intended learning outcomes [3]
- Evaluation and continuous programme improvement [12]

**Course development, discipline-led and project-based learning experiences:**
- Introduction to engineering [4]
- Design-implement experiences and workspaces [5, 6]
- Integrated learning experiences [7]
- Active and experiential learning [8]
- Learning assessment [11]

**Faculty development**
- Engineering skills [9]
- Skills in teaching & learning , and assessment [10]

45

# Success

**is never inherent in a method;**
**it always depends on**
**good implementation.**

46

## CDIO Standard 2: Learning Outcomes
### Recognising the *dual nature* of learning

**Understanding of technical fundamentals** and **Professional engineering skills**

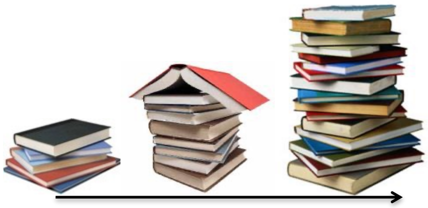
**CDIO Standard 2 – Learning Outcomes**
Specific, detailed learning outcomes for personal and interpersonal skills, and product, process, system, and service building skills, as well as disciplinary knowledge, consistent with program goals and validated by program stakeholders.

47

The strategy of CDIO is **integrated learning** of knowledge and skills !

50

## Standard 3 – Integrated curriculum
### Integrating the two learning processes



Acquisition of technical knowledge

Development of engineering skills

The CDIO strategy is the **integrated curriculum** where knowledge & skills give each other meaning!

**CDIO 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, system, and service building skills.

51

## Design-Implement Experiences
**student teams design and implement actual products, processes, or systems**

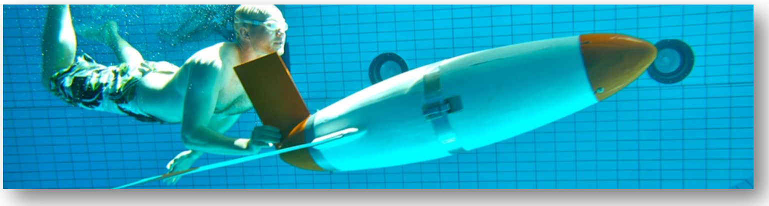
- Projects take different forms in various engineering fields
- The essential aim is to learn through near-authentic engineering tasks, working in modes resembling professional practice
- Progression in several dimensions
  - engineering knowledge (breadth and depth)
  - size of student teams
  - length of project
  - increasingly complex and open-ended problems
  - tensions, contextual factors
  - student and facilitator roles

**CDIO 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.

52

## Learning in Design-Implement Experiences

- How to improve student learning in projects
- How to assess students individually in group projects
- How to teach and assess project courses sustainably



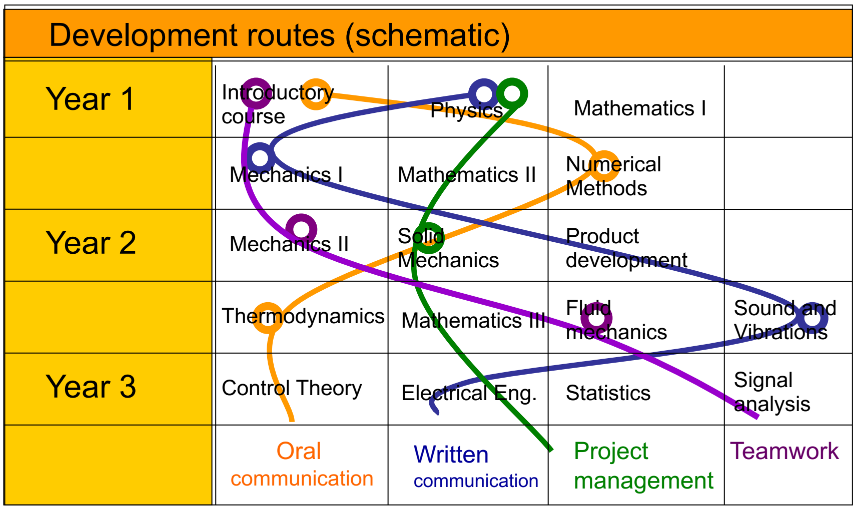
**The purpose is not to build things,**
**but to learn from building things**

53

# INTEGRATION & PROGRESSION

54

## Systematic assignment of responsibilities for program learning objectives - negotiating the contribution of courses




55

## Example: Communication skills in Lightweight design & FEM modelling

In this course, **communication** means being able to

- Use the technical concepts comfortably
- Discuss a problem of different levels
- Determine what factors are relevant to the situation
- Argue for, or against, conceptual ideas and solutions
- Develop ideas through discussion and collaborative sketching
- Explain technical matters to different audiences
- Show confidence in expressing oneself within the field

The skills are **embedded** in, and **inseparable** from, students' application of technical knowledge.

The same interpretation should be made for teamwork, problem solving, professional ethics, and other engineering skills.

**"It's about educating engineers who can actually engineer!"**

56

What does communication skills mean in the specific professional role or subject area?

[Barrie 2004]

57


## Dimensions of progression

- Subject content
- Personal, professional and engineering skills
- Theoretical maturity – not just ”more” theory, but to make connections and apply
  (integration, synthesis & modelling)
- Understanding context
  (“real” problems, sustainable development, ethics, etc)
- Selecting and applying methods, understanding limitations
- Professional “eye” and language
  (see and interpret situations, discuss with others and relate to knowledge)
- Academic writing, professional writing
- Personal development
  (feedback, reflection, etc)
- View on knowledge (not just black and white)
- Degree of independence as a learner
  (pedagogical red threads)

58

# Enhancing progression through the curriculum

THE BLACK-BOX EXERCISE

INPUT:
Previous knowledge and skills → **Course (black box)**

OUTPUT:
→ Contribution to final learning outcomes
→ Input to later course
→ Input to later course
→ Input to later course

All faculty formulate their course only as input/output:

Input: "When students come to my course I want them to be able to…"
Output: "When students leave my course they will be able to… because I think this is necessary input for course X…"

59

# 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

During the discussions:
- Document which course takes responsibility for what learning outcomes
- Identify redundancies or gaps
- Check chronological order
- Is it easy for the students to make the connections between courses?

60

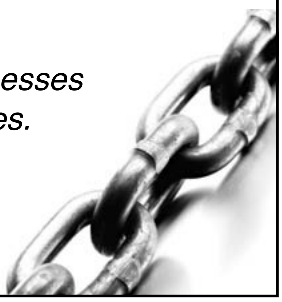
## Our curriculum system has 2 logical links

The strength of the chain – the extent to which graduates will actually meet the program learning objectives – hinges on:

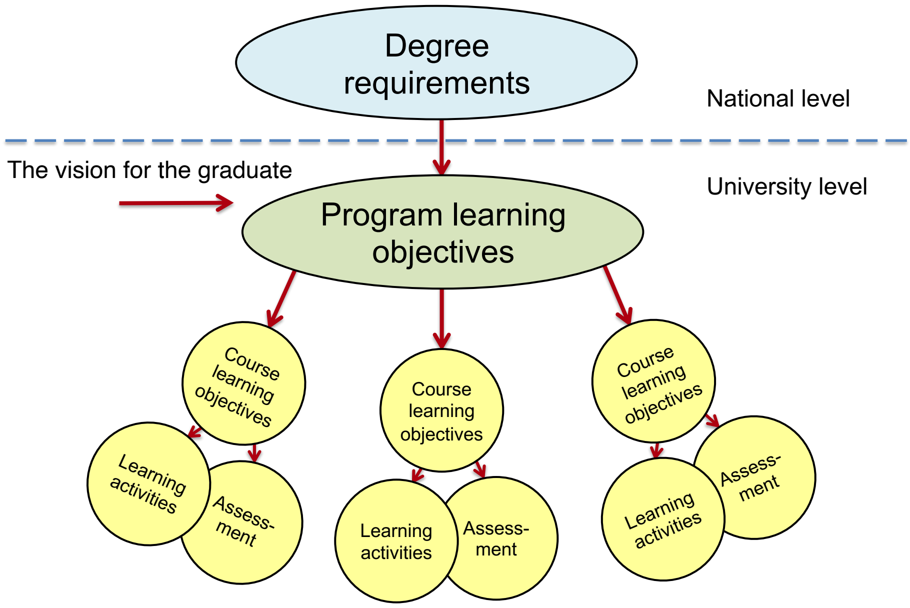
- **the connection between courses and programs**
  *that the sum of course learning objectives actually equals the program objectives,*

*and*

- **the constructive alignment**
  *that each course actually teaches and assesses students according to its learning objectives.*

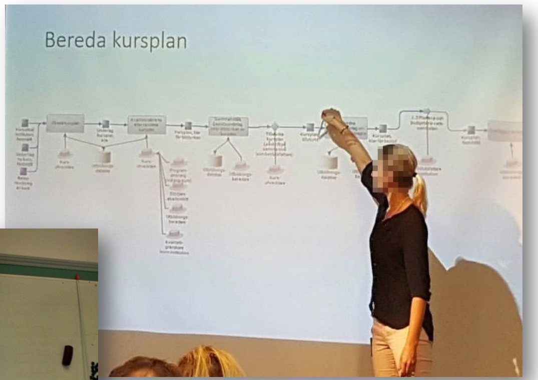


61




62

# Bureaucracy warning




- Just because it looks perfect on paper, does it work?
- When are we developing the programme and when are we feeding the control systems?
- How are we using our capacity for development?
- How should our best teachers spend their time?

63

Anyone can improve a course if it means that the teacher works 100 hours more

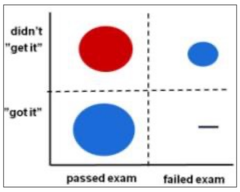
That is not a valid solution…

**This is about how to get better student learning from the same teaching resources**

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

64

## Constructive alignment - applied




Formulating intended learning outcomes

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

Designing activities

Designing assessment

What work is appropriate for the students to do, to reach the learning outcomes?

How should the students demonstrate that they fulfil the learning outcomes?

65

## Constructive alignment - applied

| | |
|---|---|
| Judge: | To be able to critically evaluate multiple solutions and select an optimum solution |
| Solve: | Characterize, analyze, and synthesize to model a system (provide appropriate assumptions) |
| Explain: | Be able to state the process/outcome/concept in their own words |
| Compute: | Follow rules and procedures (substitute quantities correctly into equations and arrive at a correct result, "plug & chug") |
| Define: | State the definition of the concept or is able to describe in a qualitative or quantitative manner |

Formulating intended learning outcomes

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


| | |
|---|---|
| Judge: | To be able to critically evaluate multiple solutions and select an optimum solution |
| Solve: | Characterize, analyze, and synthesize to model a system (provide appropriate assumptions) |
| Explain: | Be able to state the process/outcome/concept in their own words |
| Compute: | Follow rules and procedures (substitute quantities correctly into equations and arrive at a correct result, "plug & chug") |
| Define: | State the definition of the concept or is able to describe in a qualitative or quantitative manner |


Designing activities

Designing assessment


| | |
|---|---|
| Judge: | To be able to critically evaluate multiple solutions and select an optimum solution |
| Solve: | Characterize, analyze, and synthesize to model a system (provide appropriate assumptions) |
| Explain: | Be able to state the process/outcome/concept in their own words |
| Compute: | Follow rules and procedures (substitute quantities correctly into equations and arrive at a correct result, "plug & chug") |
| Define: | State the definition of the concept or is able to describe in a qualitative or quantitative manner |


What work is appropriate for the students to do, to reach the learning outcomes?

How should the students demonstrate that they fulfil the learning outcomes?

66

## Constructive alignment -

CDIO 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, system, and service building skills.

Formulating intended learning outcomes

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

Designing activities

Designing assessment

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

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

67

### The working definition of CDIO:
## The CDIO Standards – aligned strategies

**Context:**
- Recognise that we educate for the practice of engineering [1]

**Curriculum development:**
- Formulate explicit program learning outcomes (including engineering skills) in dialogue with stakeholders [2]
- Map out responsibilities to courses – negotiate intended learning outcomes [3]
- Evaluation and continuous programme improvement [12]

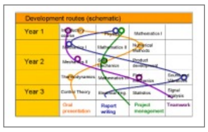
**Course development, discipline-led and project-based learning experiences:**
- Introduction to engineering [4]
- Design-implement experiences and workspaces [5, 6]
- Integrated learning experiences [7]
- Active and experiential learning [8]
- Learning assessment [11]

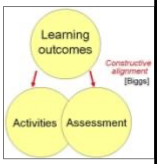
**Faculty development**
- Engineering skills [9]
- Skills in teaching & learning , and assessment [10]

68

# Integrated curriculum development - the process in a nutshell

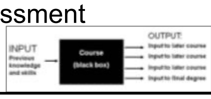
- **Set program learning outcomes**
  in dialogue with stakeholders
- **Design an integrated curriculum**
  mapping out responsibilities to courses
  – negotiate intended learning outcomes
  (both knowledge and engineering skills)



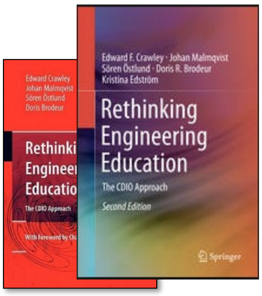



- **Create integrated learning experiences**
  course development with constructive alignment
  - ✓ mutually supporting **subject courses**
  - ✓ applying **active learning methods**
  - ✓ an **introductory course**
  - ✓ a sequence of **design-implement experiences**

- **Faculty development**
  - ✓ Engineering skills
  - ✓ Skills in teaching, learning and assessment
- **Evaluation** and continuous **improvement**




69




# In the book shelf

**Book in 2nd edition**

- Crawley, E., Malmqvist, J., Östlund, S., Brodeur, D., Edström, K., *Rethinking Engineering Education, The CDIO Approach*. Springer, 2014.

(Also in Chinese, Russian, Vietnamese)

**Shorter introduction**

- Edström, K., & Kolmos, A. (2014). PBL and CDIO: complementary models for engineering education development. *European Journal of Engineering Education*, 39(5), 539-555.

**Chalmers program development**

- Malmqvist, J., Bankel, J., Enelund, M., Gustafsson, G., & Knutson Wedel, M. (2010). Ten Years of CDIO - Experiences from a Long-term Education Development Process. *Proceedings of the 6th International CDIO Conference*. École Polytechnique de Montréal, Québec, Canada.
- Enelund, M., Larsson, S., & Malmqvist, J. (2011). Integration of Computational Mathematics Education in the Mechanical Engineering Curriculum. *Proceedings of the 7th International CDIO Conference*, Copenhagen, Denmark.
- Enelund, M., Knutson Wedel, M., Lundqvist, U., & Malmqvist, J. (2013). Integration of education for sustainable development in the mechanical engineering curriculum. *Australasian Journal of Engineering Education*, 19(1), 51-62.

**See also**

- Edström, K. (2017). The role of CDIO in engineering education research: Combining usefulness and scholarliness, *European Journal of Engineering Education*.
- Edström, K. (April 2018). Academic and professional values in engineering education: Engaging with history to explore a persistent tension. *Engineering Studies*, 10(1), 38-65.
- Edström, K. (2019). Integrating the academic and professional values in engineering education – ideals and tensions. In Geschwind, L., Larsen, K., & Broström, A. (Eds.) *Technical Universities - Past, present and future*. Springer Higher Education Dynamics.

72

”

**Which ideas from CDIO could be most useful for you right now?**

73

## Notes

74

## How to become a CDIO Collaborator

1. Express an interest (answer a few questions)
   - Why does your university want to join the CDIO initiative?
   - Which of your programs do you plan to initially apply CDIO? How do you expect CDIO to influence these programs?
   - What goals do you hope to achieve?
   - What are your plans for participating with the other CDIO collaborating schools?
   - What experience do you have in engineering educational reform at your university, which might contribute to the effort and form a foundation for the work as a collaborator?
   - What level of commitment and support do you have from your university's Dean and Central Leadership?
   - Who will be the key two to five participants in your effort?
2. Make introductions at a CDIO meeting
3. The CDIO Council will grant collaborator status

- Contact the leader of your region to get started. (see www.cdio.org)

77

## Comparing CDIO with other communities

**PBL (problem based and/or project organised learning)**

- Starting point of PBL is *how* to learn – CDIO starts with *what* to learn
- PBL is a pedagogical approach not specific to engineering, but there is also a strong community for PBL in engineering education
- PBL is a component of CDIO (Standard 5 and 8)
- PBL focuses exclusively on project and problem-based learning – CDIO also aims to improve discipline-led learning and subject courses
- PBL can be applied on course, program or university level (while CDIO is programme-led)
- Several conferences, long research tradition

**SEFI, Société Européenne pour la Formation des Ingénieurs**

- SEFI is European – CDIO is global
- SEFI discusses all issues related to engineering education – CDIO is more focused
- Both have annual conferences
- SEFI has a research community, and the journal *European Journal of Engineering Education*

79