CONCEIVE DESIGN IMPLEMENT OPERATE

CDIO as an idea, a methodology for program development, and a community

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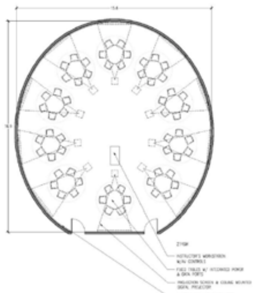
Engineer & Educational developer

- M. Sc. in Engineering, Chalmers
- PhD in Technology and Learning, KTH
- Associate Professor in *Engineering Education Development* at KTH Royal Institute of Technology, Stockholm, Sweden
  - 700 participants in the course for KTH faculty: *Teaching and Learning in Higher Education*, 7.5 ECTS
  - 190 participants in the course for KTH faculty: *Doctoral Supervision*, 3 ECTS
- Director of Educational Development at Skolkovo Institute of Science and Technology, Moscow, 2012-2013
- CDIO Initiative for reform of engineering education since 2001
- Editor-in-Chief of the *European Journal of Engineering Education*

CONCEIVE DESIGN IMPLEMENT OPERATE



Some publications

- Crawley, E.F., Hegarty, J., Edström, K., & Garcia Sanchez, C. (2020). *Universities as Engines of Economic Development: Making Knowledge Exchange Work.* Springer, Cham.
- 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.
- 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.

LET'S START WITH TWO EXAMPLES

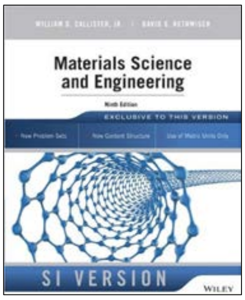
Let's go to Chalmers for an example

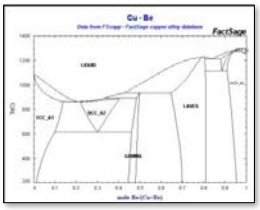
COURSE LEVEL

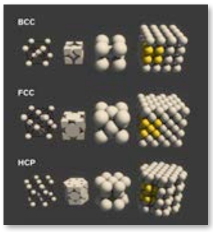
- A course in basic materials science

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]

A course in Basic Materials Science

Two ways of seeing materials science

From the inside - out

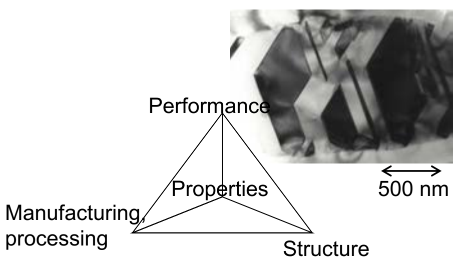
“Materials engineers distinguish themselves from mechanical engineers by their focus on the internal structure and processing of materials, specifically at the micro- and nano-scale.”

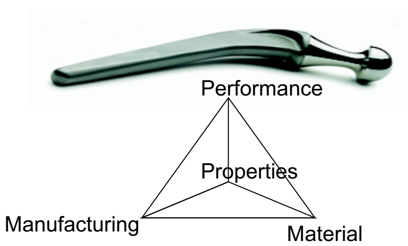
Flemings & Cahn

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….”

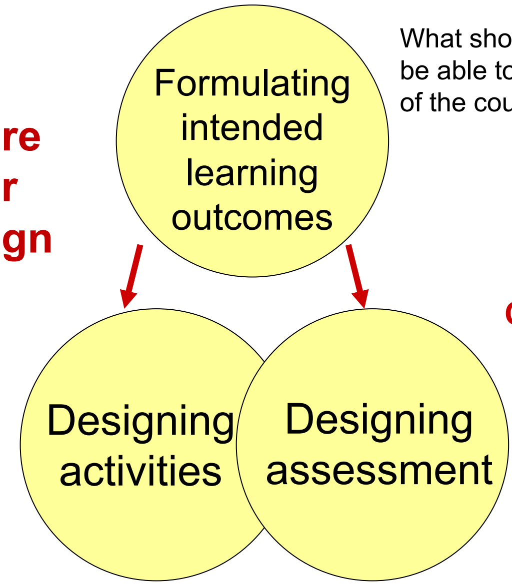
Östberg





[Professor Maria Knutson Wedel, Chalmers]

Intended learning outcomes are the basis for course design



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

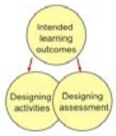
Constructive alignment [Biggs]

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?

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

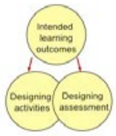
...explain how to optimize material dependent processes (e.g. casting, forming, joining)

...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]

A course in Basic Materials Science



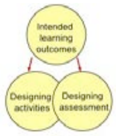
2. Changing the learning activities

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]

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]

” ” ”

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

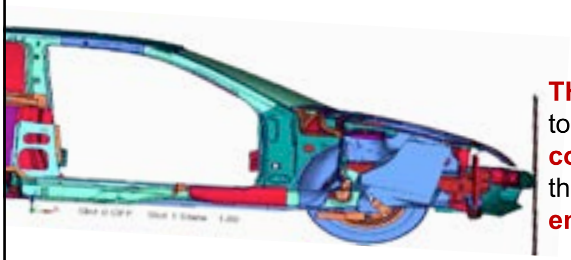
How can subject courses contribute to both academic and professional preparation?

Let’s go to Chalmers for another example

PROGRAMME LEVEL

- How computational mathematics was integrated

Integrating computational mathematics
Mechanical Engineering at Chalmers, Sweden



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

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)

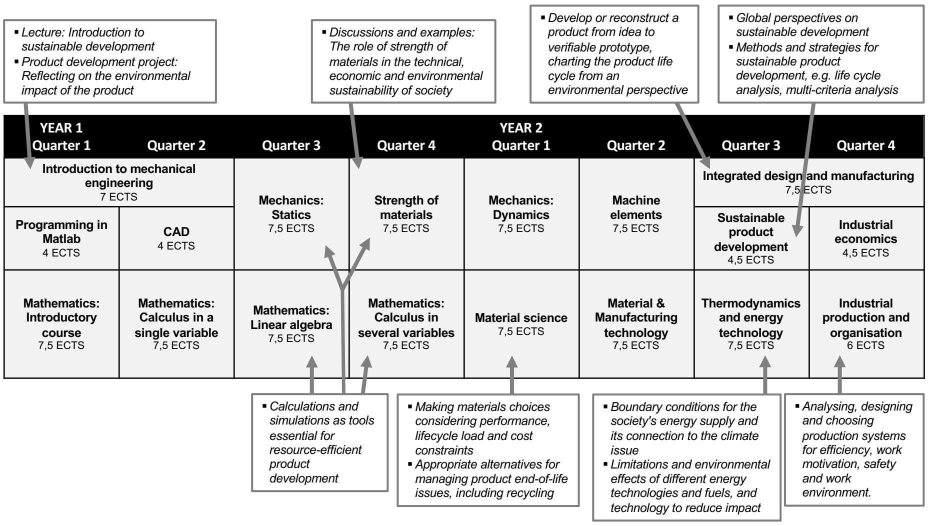
Computational mathematics
Integrated curriculum approach

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

Instead of framing this as a task for mathematics teachers to solve within the mathematics courses, the **programme-driven approach** was applied, where **making connections to mathematics in engineering subjects** was at least as important as **making connections to engineering in mathematics**

Program driven development

Integration of sustainable development



Integrated curriculum

Start by forming a vision

- Form a vision for the graduate in dialogue with stakeholders
- Prioritise and translate to learning outcomes for the programme

Integrated learning

- Develop knowledge and understanding together with skills, approaches and judgment
- Learning in the logic of disciplines (theory) and the logic of problems (practice)

Connection and progression

- The contribution of the course is made explicit (connection between course and program)
- Connection between courses, progression
- Program driven course development

” ” ”

What kinds of improvements / problems are best addressed with a programme level approach?

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

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CONCEIVE DESIGN IMPLEMENT OPERATE

CDIO is a community for developing engineering education

The CDIO Initiative

CONCEIVE DESIGN IMPLEMENT OPERATE

- **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**180 CDIO Collaborators** worldwide

The international CDIO community

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
- Pontificia Universidad Javeriana
- Santo Tomás University
- School of Engineering of Antioquia (EIA)
- UNISAL – Salesian University Center of Sao Paulo
- UNITEC Laureate International Universities
- Universidad Católica de la Santísima Concepción
- Universidad de Chile
- Universidad de Los Lagos
- Universidad de Santiago de Chile
- Universidad del Quindio
- Universidad ICESI, Cali
- Universidad Nacional de Colombia, Bogota
- Universidad Tecnológica de Chile INACAP

Sweden
- Blekinge tekniska högskola
- Chalmers tekniska högskola*
- Högskolan i Jönköping
- Högskolan Kristianstad
- Kungl. Tekniska högskolan*
- Linköpings universitet*
- Linnéuniversitetet
- Luleå tekniska universitet
- Umeå universitet
- Högskolan i Skövde
- Högskolan Väst

See www.cdio.org

Asia
- 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
- Duy Tan University
- Feng Chia University
- FPT Education
- Inje University
- Kanazawa Institute of Technology
- Kanazawa Technical College
- Mongolian University of Science and Technology
- Nanyang Polytechnic
- National Institute of Technology, Kisarazu College
- Politeknik Ungku Omar
- Rajamangala University of Technology Thanyaburi (RMUTT)
- Shantou University
- Singapore Polytechnic
- Suzhou Industrial Park Institute of Vocational Technology
- Taylor's University, School of Engineering
- Thu Dau Mot University
- Tsinghua University
- Universiti Teknologi MARA (UiTM)
- Vel Tech Dr.RR & Dr.SR Technical University
- Vietnam National University
- Yanshan University

Australia:
- 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

Africa
- University of Pretoria
- ESPRIT, Tunisia

Europe
- Aalborg University
- Aarhus University
- AFEKA Tel Aviv Academic College of Engineering
- Astrakhan State University
- Bauman Moscow State Technical University
- Cherepovets State University
- Delft University of Technology
- Don State Technical University
- 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
- Kazan Federal University
- Lahti University of Applied Sciences
- Lapland University of Applied Sciences
- 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
- 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
- Universitat Politècnica de Catalunya (Telecom BCN)
- University of Turku
- University of Twente
- Ural Federal University
- Vilniaus Kolegija/University of Applied Sciences
- Østfold University College

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

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

Annual International CDIO Conference

- **17th International CDIO Conference**
  21-24 June 2021, Bangkok, Thailand (online)
- **18th International CDIO Conference**
  June 2022, Reykjavik, Iceland

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 Queensland University of Technology, 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 (online)

CDIO is a community for developing engineering education

It is based on an **idea** of what students should learn to become good engineers
(who can develop technology, or Conceive, Design, Implement and Operate products, processes and systems)

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CONCEIVE DESIGN IMPLEMENT OPERATE

The dual nature of engineering education

Higher engineering education is simultaneously
- **academic**, emphasising theory in a range of disciplines, and
- **professional**, preparing students for engineering practice.

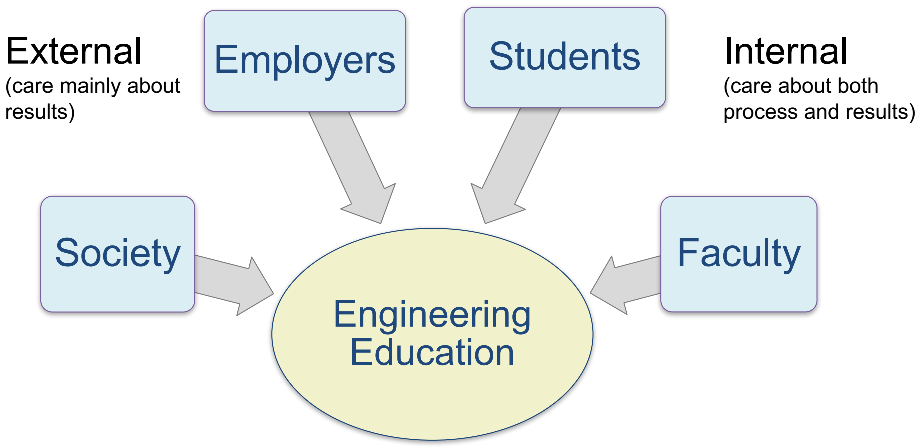
These are not merely two separate components that need to be balanced in appropriate proportions, but they should also be in **meaningful relationship** in the curriculum.

…creates a dual challenge

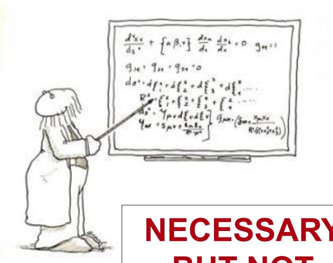
We want to educate students with
- **a deeper working knowledge** of technical fundamentals, and
- **professional competences**

not one at the expense of the other!

Stakeholder perspectives



Disciplinary theory applied to "problem-solving"



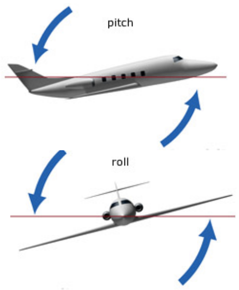
NECESSARY BUT NOT SUFFICIENT

Theory and judgement applied to real 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 ('one right answer' are exceptions)
- 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.

An education *about* technology



NECESSARY BUT NOT SUFFICIENT

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

Conceive customer needs, technology, enterprise strategy, regulations; and conceptual, technical, and business plans…

Design plans, drawings, and algorithms that describe what will be implemented…

Implement transformation of the design into the product, process, or system, including manufacturing, coding, testing and validation…

Operate the implemented product or process delivering the intended value, including maintaining, evolving and retiring the system…

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

CDIO Standard 1: The context

Educating for the context of engineering

Education set in *Engineering science*

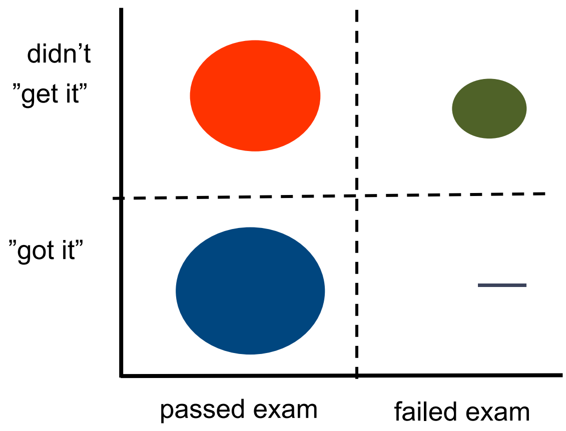
NECESSARY BUT NOT SUFFICIENT

Educate for the context of *Engineering*

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!

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.

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.]

CDIO is a community for developing engineering education

It is a methodology

The 12 CDIO Standards

CONCEIVE DESIGN IMPLEMENT OPERATE

Success

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

CDIO is open source – do whatever you want

Civil Engineering

Investigate – Plan – Design – Construct – Operate and maintain

Martin Nilsson

Catrin Edelbro

Luleå University of Technology

Nilsson, M., Edelbro, C., & Edström, K. (2016). Adapting CDIO to Civil Engineering: Investigate - Plan - Design - Construct - Operate and Maintain.

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.

The CDIO Syllabus
Support in formulating learning outcomes

Each institution formulates program goals considering their own stakeholder needs, national and institutional context, level and scope of programs, subject area, etc

The CDIO Syllabus

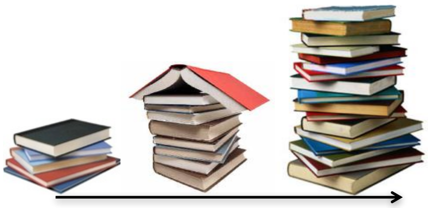
- is not prescriptive (not a CDIO Standard)
- is offered as an instrument for specifying local program goals by selecting topics and making appropriate additions in dialogue with stakeholders
- lists and categorises desired qualities of engineering graduates
- is based on stakeholder input and validation

- Crawley, E. F. 2001. The CDIO Syllabus: A Statement of Goals for Undergraduate Engineering Education: see www.cdio.org/framework-benefits/cdio-syllabus-report
- for version 2.0, see Crawley, Malmqvist, Lucas, and Brodeur. 2011. “The CDIO Syllabus v2.0. An Updated Statement of Goals for Engineering Education.” Proceedings of the 7th International CDIO Conference

The strategy of CDIO is integrated learning of knowledge and skills

!

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.

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/practice-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

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

How to teach these courses sustainably

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.

Learning in Design-Implement Experiences

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

- it is key that students bring their designs and solutions to an **operationally testable state**.
- To turn practical experiences into learning, students are continuously guided through **reflection and feedback exercises** supporting them to evaluate their work and identify potential improvement of results and processes.
- **Assessment and grading** should reflect the quality of attained **learning outcomes**, rather than the product performance in itself

INTEGRATION & PROGRESSION

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

Development routes (schematic)				
Year 1	Introductory course	Physics	Mathematics I	
	Mechanics I	Mathematics II	Numerical Methods	
Year 2	Mechanics II	Solid Mechanics	Product development	
	Thermodynamics	Mathematics III	Fluid mechanics	Sound and Vibrations
Year 3	Control Theory	Electrical Eng.	Statistics	Signal analysis
	Oral communication	Written communication	Project management	Teamwork

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

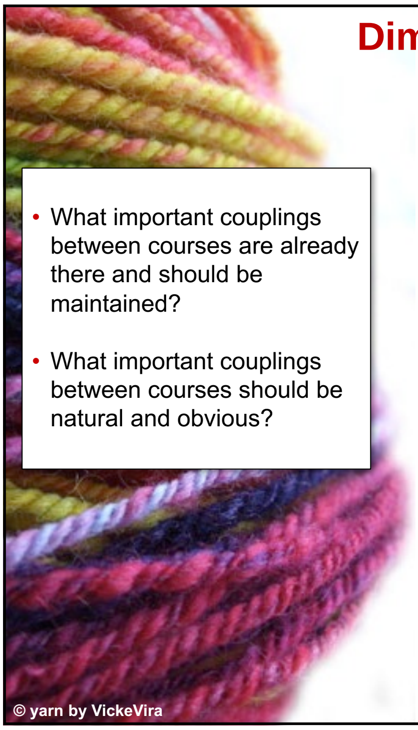
The skills are **embedded** in, and **inseparable** from, students' application of technical knowledge.

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!"

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

[Barrie 2004]



© yarn by VickeVira

- What important couplings between courses are already there and should be maintained?
- What important couplings between courses should be natural and obvious?

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)

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?

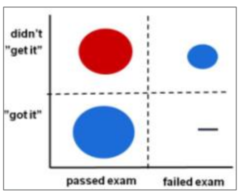
Anyone can improve a course if it means that the teacher works 100 hours more

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.

Constructive alignment - applied



Formulating intended learning outcomes

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

Designing activities

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

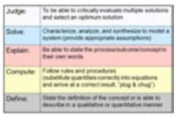
Designing assessment

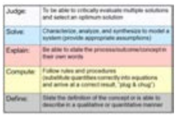
How should the students demonstrate that they fulfil the learning outcomes?

Constructive alignment - applied

Formulating intended learning outcomes

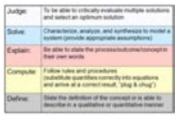
What should the students be able to do as a result of the course?





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?

Constructive alignment -

Formulating intended learning outcomes

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

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.

Designing activities

Designing assessment

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.

CDIO Standard 8 – Active Learning

Teaching and learning based on active and experiential learning methods

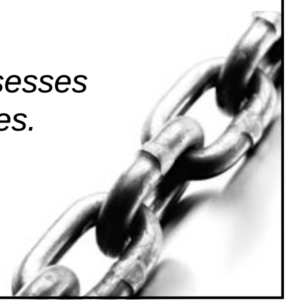
Our curriculum system has 2 logical links

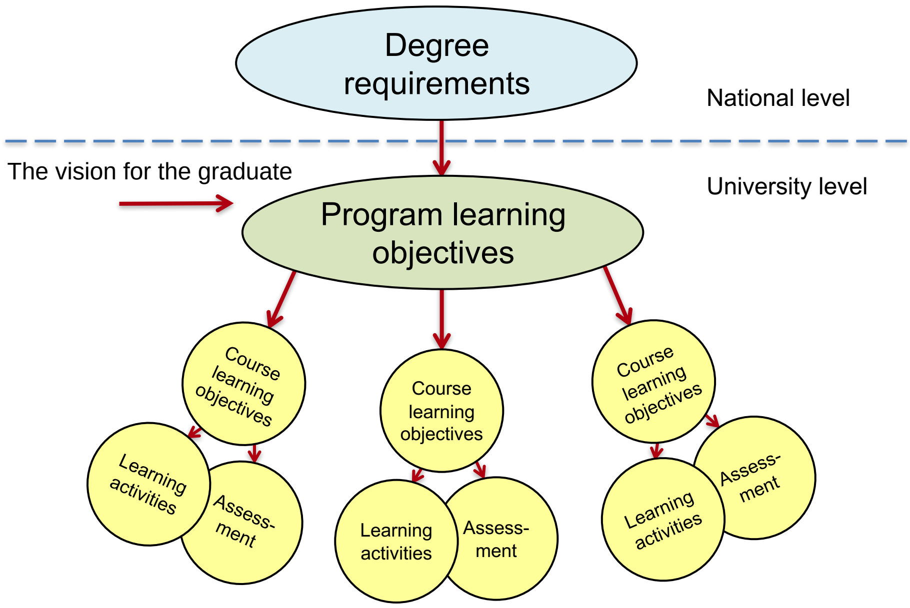
The strength of the chain – the extent to which graduates will actually meet the program learning objectives – hinges on:

- **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.





The working definition of CDIO:

The CDIO Standards – aligned strategies

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

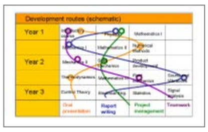
Curriculum development:
- Formulate explicit program learning outcomes (including engineering skills) in dialogue with stakeholders [2]
- Map out responsibilities to courses – negotiate intended learning outcomes [3]
- Evaluation and continuous programme improvement [12]

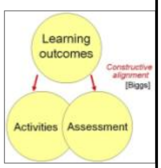
Course development, discipline-led and project-based learning experiences:
- Introduction to engineering [4]
- Design-implement experiences and workspaces [5, 6]
- Integrated learning experiences [7]
- Active and experiential learning [8]
- Learning assessment [11]

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

Integrated curriculum development - the process in a nutshell

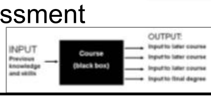
- **Set program learning outcomes** in dialogue with stakeholders
- **Design an integrated curriculum** mapping out responsibilities to courses – negotiate intended learning outcomes (both knowledge and engineering skills)



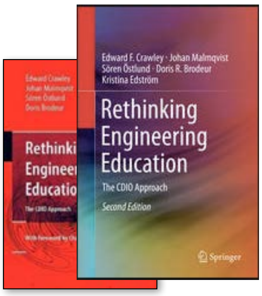


- **Create integrated learning experiences** course development with constructive alignment
  - ✓ mutually supporting **subject courses**
  - ✓ applying **active learning methods**
  - ✓ an **introductory course**
  - ✓ a sequence of **design-implement experiences**

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



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*.
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