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CONCEIVE DESIGN IMPLEMENT OPERATE

An approach to engineering education development

Kristina Edström
KTH Royal Institute of Technology, Stockholm, Sweden

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LET'S START WITH TWO EXAMPLES

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Let’s go to Chalmers for an example

COURSE LEVEL

- A course in basic materials science

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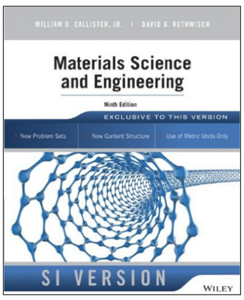
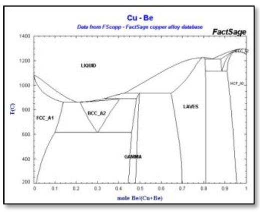
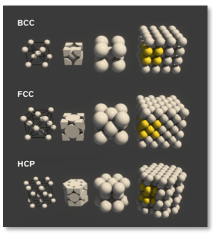
A course in Basic Materials Science

- 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]

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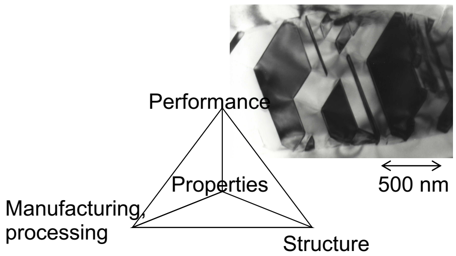
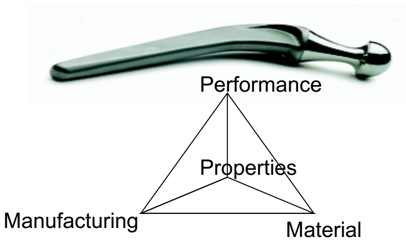
A course in Basic Materials Science

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]

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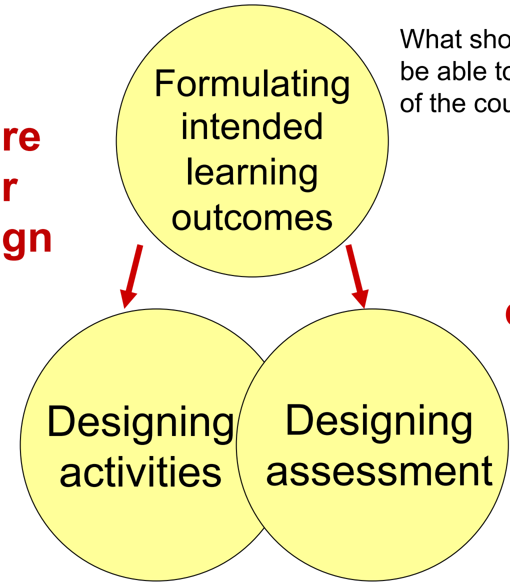
Intended learning outcomes are the basis for course design



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?

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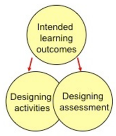
A course in Basic Materials Science

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]

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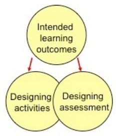
A course in Basic Materials Science

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]

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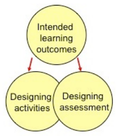
A course in Basic Materials Science

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]

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> > > > > > > > > > > > > > > >

- **The course content in itself**
- **What an engineer can do *with that understanding***

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What view of knowledge is your teaching based on?

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

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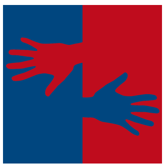
Every learning experience sets a balance and relationship


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

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Let's go to Chalmers for another example

PROGRAMME LEVEL

- How computational mathematics was integrated

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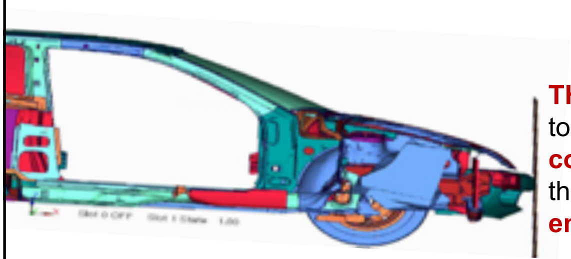
Integrating computational mathematics
Mechanical Engineering at Chalmers, Sweden



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)

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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**

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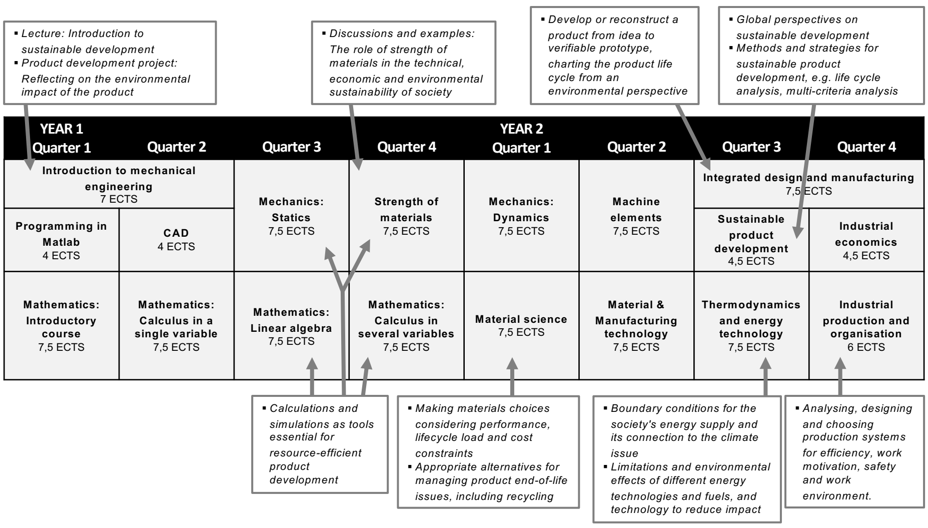
Program driven development

Integration of sustainable development



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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

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” ” ”

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

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WHAT WERE THESE EXAMPLES OF?

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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

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CDIO is a <u>community</u> for developing engineering education

The CDIO Initiative

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- **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

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CDIO collaborators

Se 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 Quindio
- 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
- Universidade Federal de 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

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Annual International CDIO Conference

18th International CDIO Conference

13-15 June 2022, Reykjavik, Iceland

Call for papers open now, deadline for abstracts is 15 November!

Tracks:

- CDIO Implementation
- Advances in CDIO
- Engineering Education Research
- Projects-in-Progress

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
2021 Chulalongkorn University & RMUTT, Bangkok, Thailand

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

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

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CDIO is based on an <u>idea</u> 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

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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!

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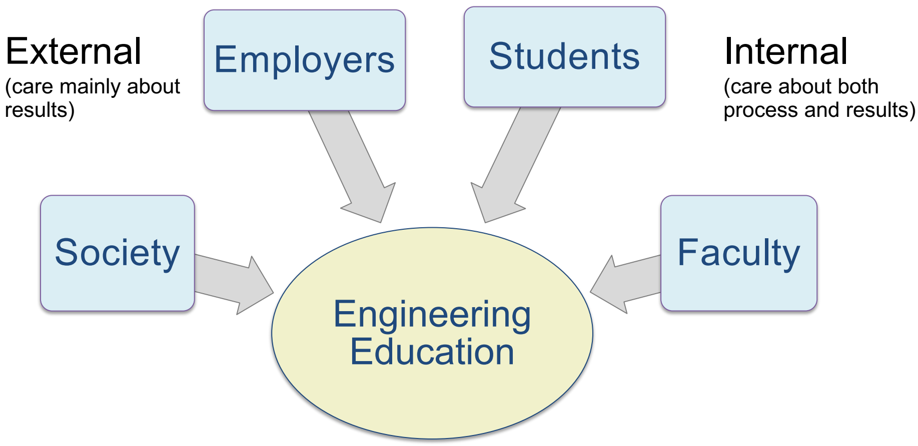
Stakeholder perspectives



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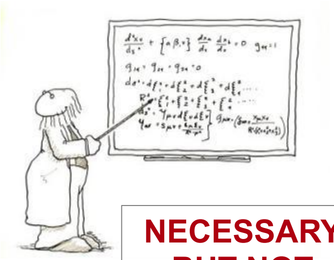
Disciplinary theory applied to "problem-solving"



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 ('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.

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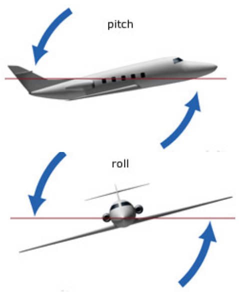
An education *about* technology



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…

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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

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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!

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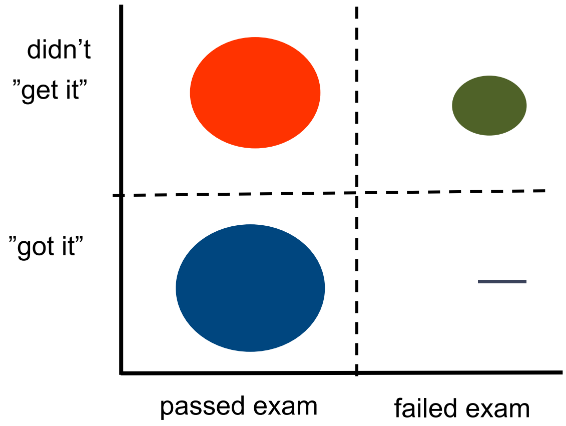
Deeper working knowledge of disciplinary fundamentals



- 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.

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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.]

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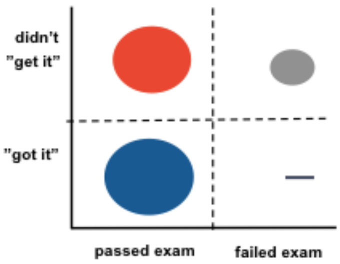
”” ”

What tools or language do you normally use for discussing the quality of learning?



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CDIO is a methodology for developing engineering education

The 12 CDIO Standards

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Success

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

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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.

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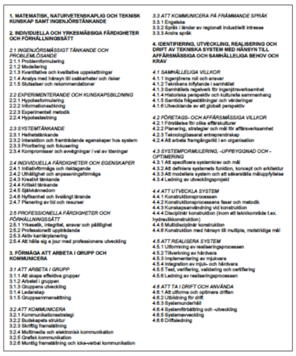
The CDIO Syllabus
Support in formulating learning outcomes

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



1. MATEMATISK, NATURVETENSKAPLIG OCH TEKNISK KUNSKAP SAMT INGENJÖRSTÄNKANDE

2. INDIVIDUELLA OCH YRKESMÄSSIGA FÄRDIGHETER OCH FÖRHÅLLNINGSSÄTT

2.1 INGENJÖRSMÄSSIGT TÄNKANDE OCH PROBLEMLÖSANDE
2.1.1 Problemformulering
2.1.2 Modellering
2.1.3 Kvantitativa och kvalitativa uppskattningar
2.1.4 Analys med hänsyn till osäkerheter och risker
2.1.5 Slutsatser och rekommendationer

2.2 EXPERIMENTERANDE OCH KUNSKAPSBILDNING
2.2.1 Hypotesformulering
2.2.2 Informationssökning
2.2.3 Experimentell metodik
2.2.4 Hypotestestning

2.3 SYSTEMTÄNKANDE
2.3.1 Helhetstänkande
2.3.2 Interaktion och framträdande egenskaper hos system
2.3.3 Prioritering och fokusering
2.3.4 Kompromisser och avvägningar i val av lösningar

2.4 INDIVIDUELLA FÄRDIGHETER OCH EGENSKAPER
2.4.1 Initiativförmåga och risktagande
2.4.2 Uthållighet och anpassningsförmåga
2.4.3 Kreativt tänkande
2.4.4 Kritiskt tänkande
2.4.5 Självkännedom
2.4.6 Nyfikenhet och livslångt lärande
2.4.7 Planering av tid och resurser

2.5 PROFESSIONELLA FÄRDIGHETER OCH FÖRHÅLLNINGSSÄTT
2.5.1 Yrkesetik, integritet, ansvar och pålitlighet
2.5.2 Professionellt uppträdande
2.5.3 Aktiv karriärplanering
2.5.4 Att hålla sig a jour med professionens utveckling

3. FÖRMÅGA ATT ARBETA I GRUPP OCH KOMMUNICERA

3.1 ATT ARBETA I GRUPP
3.1.1 Att skapa effektiva grupper
3.1.2 Arbetet i gruppen
3.1.3 Gruppens utveckling
3.1.4 Ledarskap
3.1.5 Gruppsammansättning

3.2 ATT KOMMUNICERA
3.2.1 Kommunikationsstrategi
3.2.2 Budskapets struktur
3.2.3 Skriftlig framställning
3.2.4 Multimedia och elektronisk kommunikation
3.2.5 Grafisk kommunikation
3.2.6 Muntlig framställning och icke-verbal kommunikation

3.3 ATT KOMMUNICERA PÅ FRÄMMANDE SPRÅK
3.3.1 Engelska
3.3.2 Språk i länder av regionalt industriellt intresse
3.3.3 Andra språk

4. IDENTIFIERING, UTVECKLING, REALISERING OCH DRIFT AV TEKNISKA SYSTEM MED HÄNSYN TILL AFFÄRSMÄSSIGA OCH SAMHÄLLELIGA BEHOV OCH KRAV

4.1 SAMHÄLLELIGA VILLKOR
4.1.1 Ingenjörens roll och ansvar
4.1.2 Teknikens inflytande i samhället
4.1.3 Samhällets regelverk för ingenjörsverksamhet
4.1.4 Historiska perspektiv och kulturella sammanhang
4.1.5 Samtida frågeställningar och värderingar
4.1.6 Utvecklande av ett globalt perspektiv

4.2 FÖRETAGS- OCH AFFÄRSMÄSSIGA VILLKOR
4.2.1 Förståelse för olika affärskulturer
4.2.2 Planering, strategier och mål för affärsverksamhet
4.2.3 Teknologibaserat entreprenörskap
4.2.4 Att arbeta framgångsrikt i en organisation

4.3 SYSTEMFORMULERING, -UPPBYGGNAD OCH -OPTIMERING
4.3.1 Att specificera systemkrav och mål
4.3.2 Att definiera systemets funktion, koncept och arkitektur
4.3.3 Att modellera system och att säkerställa måluppfyllelse
4.3.4 Ledning av utvecklingsprojekt

4.4 ATT UTVECKLA SYSTEM
4.4.1 Konstruktionsprocessen
4.4.2 Konstruktionsprocessens faser och metodik
4.4.3 Kunskapsanvändning vid konstruktion
4.4.4 Disciplinär konstruktion (inom ett teknikområde t.ex. hydraulikkonstruktion)
4.4.5 Multidisciplinär konstruktion
4.4.6 Konstruktion med hänsyn till multipla, motstridiga mål

4.5 ATT REALISERA SYSTEM
4.5.1 Utformning av realiseringsprocessen
4.5.2 Tillverkning av hårdvara
4.5.3 Implementering av mjukvara
4.5.4 Integration av mjuk- och hårdvara
4.5.5 Test, verifiering, validering och certifiering
4.5.6 Ledning av realiseringsprocessen

4.6 ATT TA I DRIFT OCH ANVÄNDA
4.6.1 Att utforma och optimera driften
4.6.2 Utbildning för drift
4.6.3 Systemunderhåll
4.6.4 Systemförbättring och -utveckling
4.6.5 Systemavveckling
4.6.6 Driftsledning

- 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

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The strategy of CDIO is
integrated learning
of knowledge and skills

!

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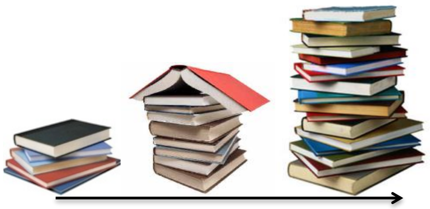
Standard 3 – Integrated curriculum
Integrating the two learning processes



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.

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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.

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Learning in Design-Implement Experiences

How to improve student learning in projects

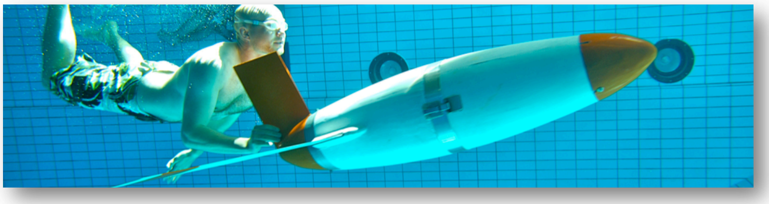
- The purpose is not to build things, but to learn from building things

How to assess students individually in group projects

- Assessment reflects the quality of learning, rather than the product

How to teach and assess project courses sustainably

- Tried-and-tested approaches



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INTEGRATION & PROGRESSION

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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

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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!"

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

[Barrie 2004]

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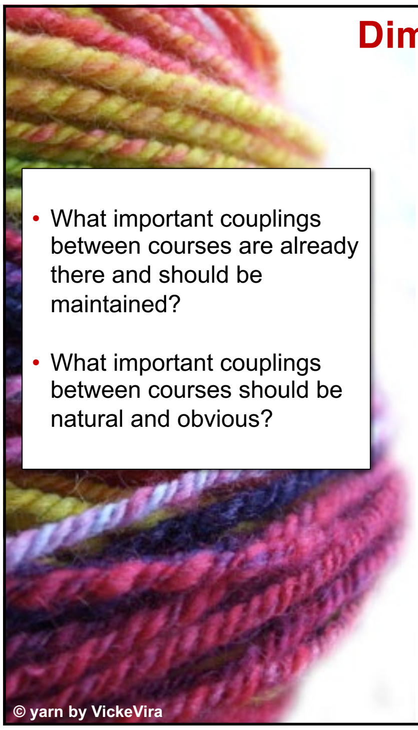

Dimensions of progression

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

- 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)

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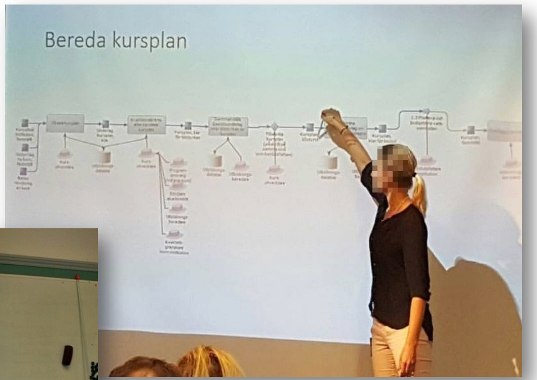
Bureaucracy warning



- 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?

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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.

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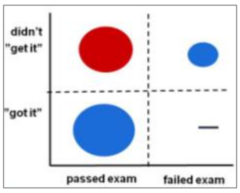
Constructive alignment - applied



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?

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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

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Designing assessment

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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?

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Constructive alignment -

Formulating intended learning outcomes

What should the <u>students</u> 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 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.

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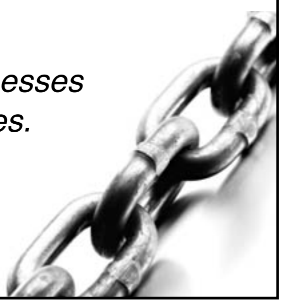
Our curriculum system has 2 logical links

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 <u>actually</u> equals the program objectives,

and

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



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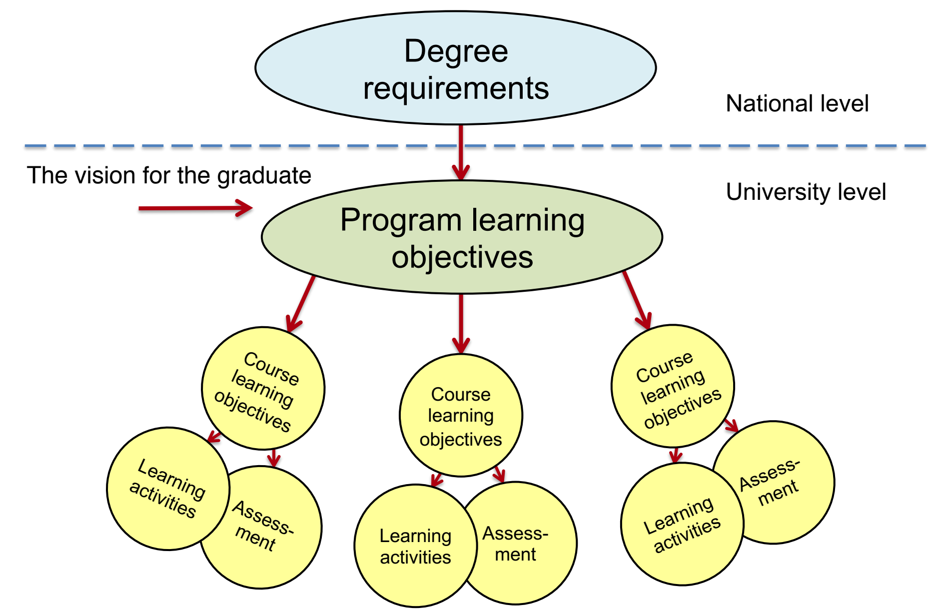

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The working definition of CDIO:
The CDIO Standards – aligned strategies

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]

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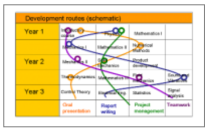
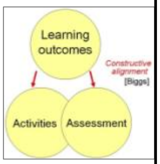
Integrated curriculum development - the process in a nutshell

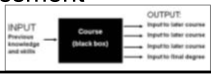
- **Set program learning outcomes** in dialogue with stakeholders
- **Design an integrated curriculum** mapping out responsibilities to courses
  – negotiate intended learning outcomes
  (both knowledge and engineering skills)





- **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**



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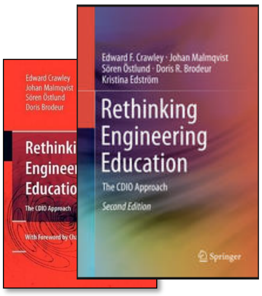
In the book shelf



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.

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

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So I brought another trick...

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