Developing the Integrated Curriculum

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Who is Kristina Edström?

- **Engineer & Educational developer**
  - M. Sc. in Engineering, Chalmers
  - Associate Professor in *Engineering Education Development* at KTH Royal Institute of Technology, Sweden
- **Strategic educational development in Sweden and internationally**
  - CDIO Initiative for reform of engineering education since 2001, Contributor to *Rethinking Engineering Education* (2007, 2014), member of the CDIO Council
  - SEFI Administrative Council 2010-2013
- **Faculty development at KTH**
  - During 2004-2012, more than 600 participants passed the course *Teaching and Learning in Higher Education* (7.5 ECTS credits) customized for faculty at KTH

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Designing the CDIO curriculum
– the CDIO Standards

Now:

- Designing an integrated curriculum

After lunch:

- Course design for integrated learning

Success

is not inherent in a method;
it always depends on
good implementation.

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1. Designing an Integrated Curriculum

The educational development process is the working definition of CDIO:

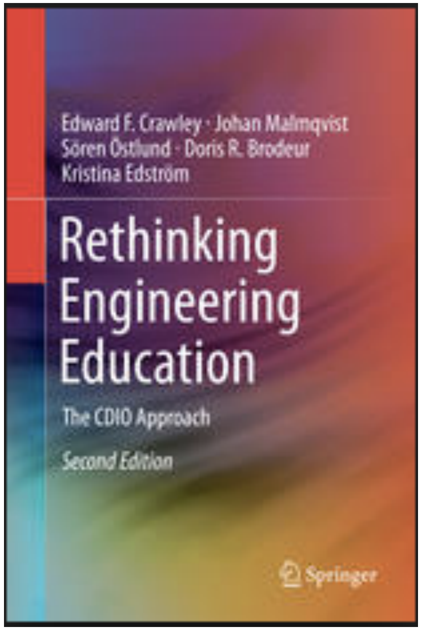
The CDIO Standards

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]

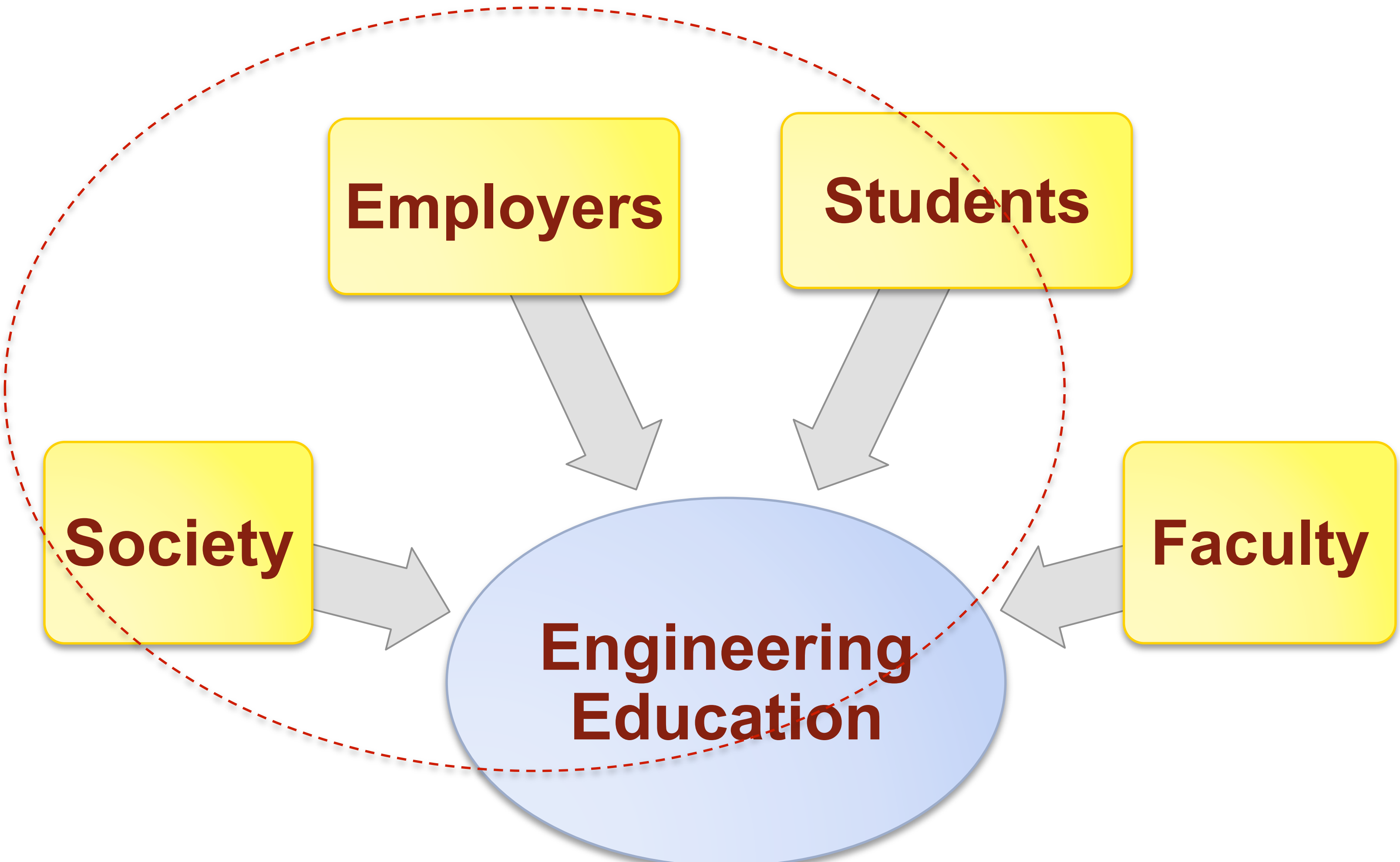
Course development, discipline-led and project-based learning experiences:
- Introduction to engineering [4]
- Design-implement experiences and workspaces [5, 6]
- Integrated learning experiences [7]
- Active and experiential learning [8]
- Learning assessment [11]

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



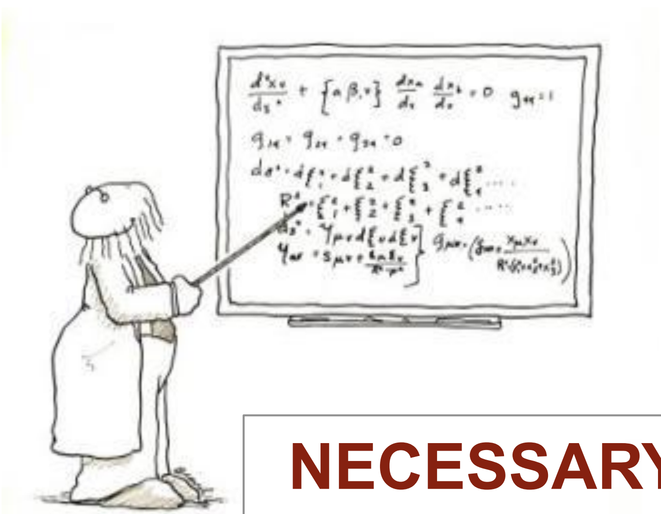
Crawley, et al (2007, 2014) *Rethinking Engineering Education: The CDIO Approach*, Springer.

Step 1
Find out your stakeholder perspectives



Work life skills

"Problem-solving"



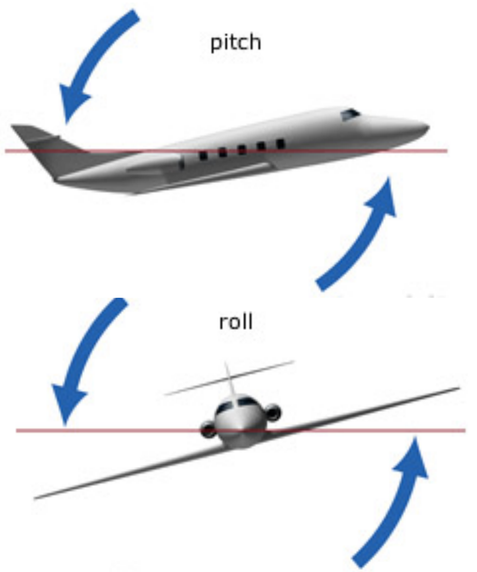
NECESSARY BUT NOT SUFFICIENT

Real problems

- Cross disciplinary boundaries
- Sit in contexts with societal and business aspects
- Complex, ill-defined and contain tensions
- Need interpretations and estimations ('one right answer' are exceptions)
- Require systems view

Work life skills

Technology in itself



NECESSARY BUT NOT SUFFICIENT

Working in the engineering process:

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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Work life skills

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 based in
Engineering science

NECESSARY BUT NOT SUFFICIENT

Educate for the context of
Engineering

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

Engineers who can engineer!

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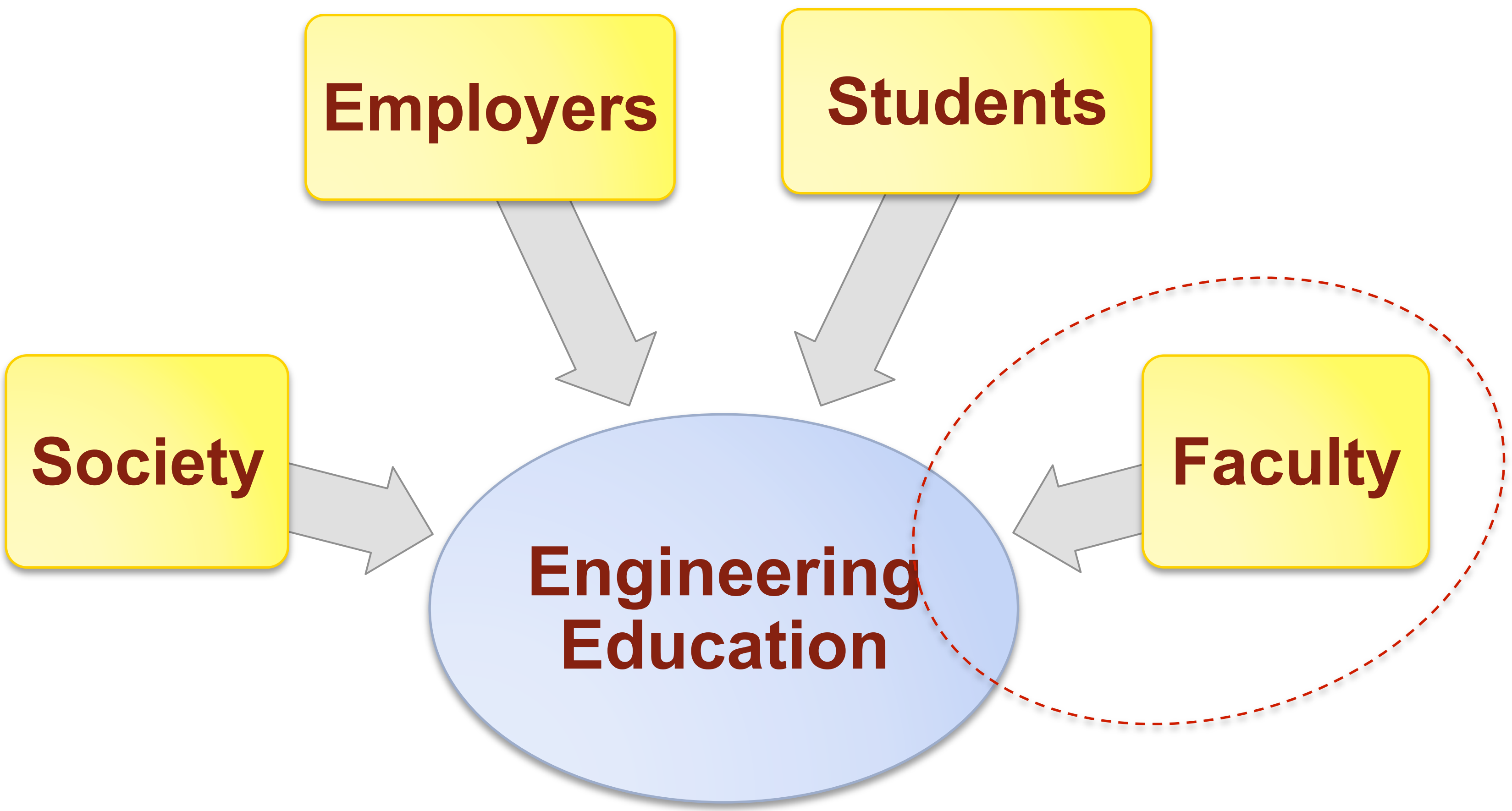
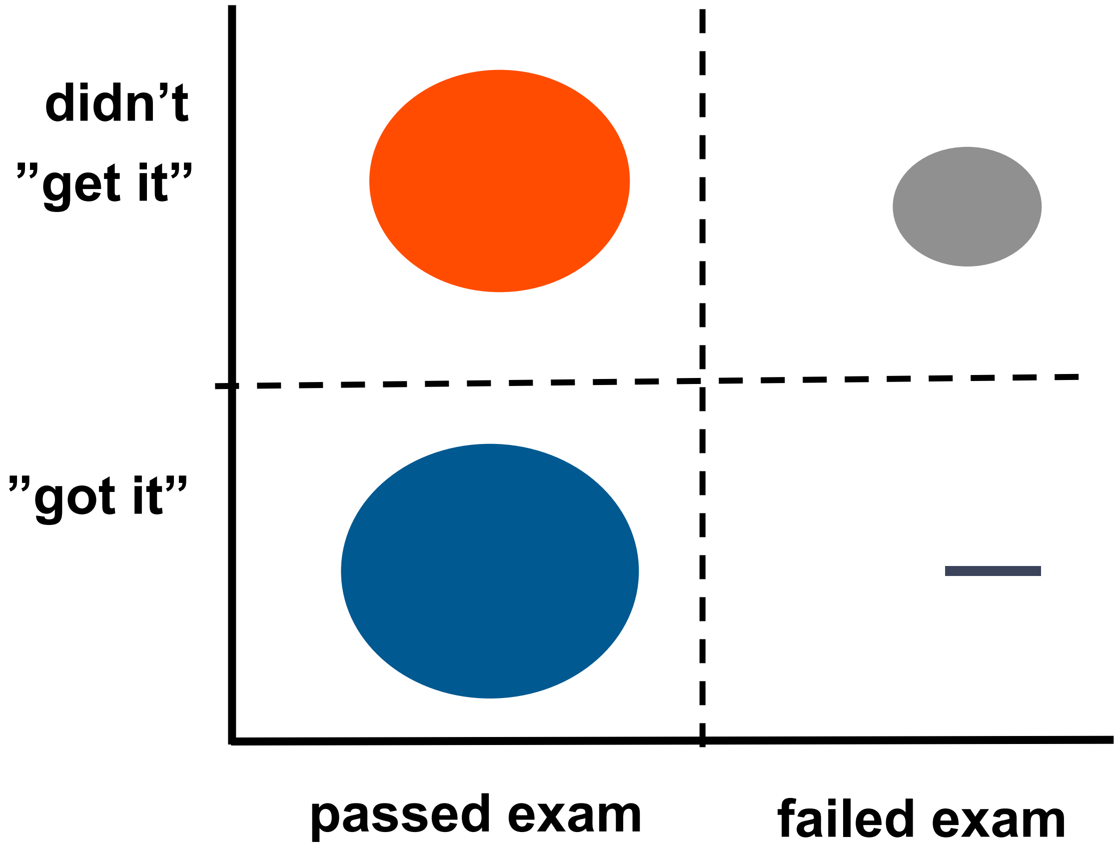
But what if we do ask faculty?



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

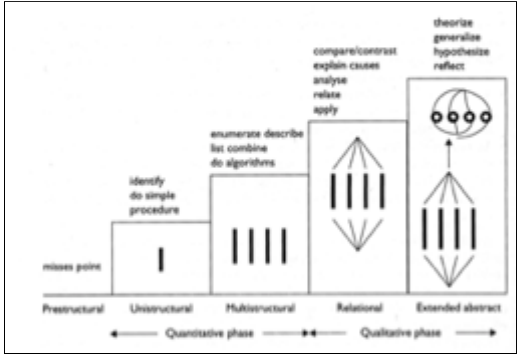
See for instance Mazur, E. (1997) *Peer Instruction*, and Kember & McNaught (2007) *Enhancing University Teaching.*

Quality of student learning – more useful classifications

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

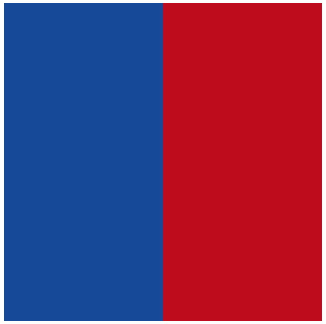
The SOLO Taxonomy



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

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, and system 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 based on stakeholder input and validation
- 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

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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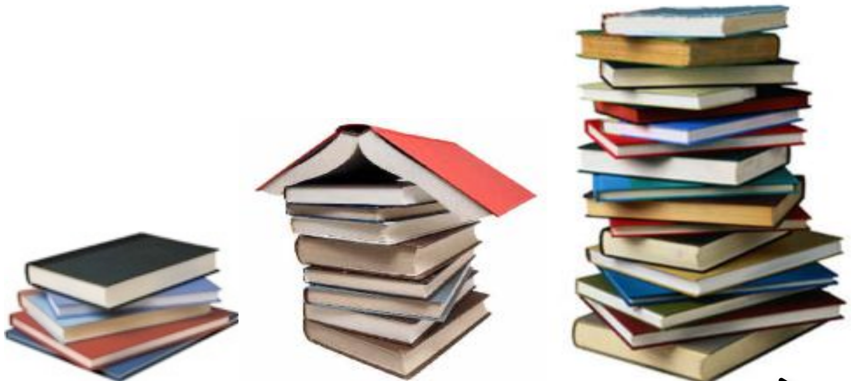
The strategy of CDIO is integrated learning of knowledge and skills

!

Standard 3 – Integrated curiculum
Integrating the two learning processes



Acquisition of technical knowledge

Development of engineering skills

The CDIO strategy is the **integrated curriculum**

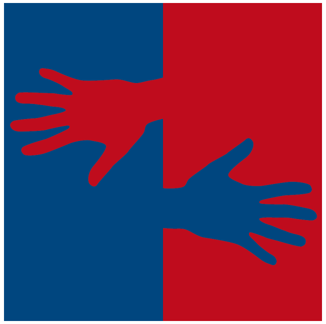
…because we need to improve both learning processes – not one at the expense of the other

…because 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, interpersonal, and product, process, and system building skills.

Every learning experience sets a balance and relationship



Discipline-led learning

- Well-structured knowledge base (”content”)
- What is known and what is not
- Evidence/theory, Model/reality
- Methods to further the knowledge frontier

CONNECTING WITH PROFESSIONAL SKILLS

- Working understanding = capability to apply, functioning knowledge
- Seeing the knowledge through the lense of problems, interconnecting the disciplines
- Integrating skills, e.g. communication and collaboration

Problem/practice-led learning

- Integration and application, synthesis
- Open-ended problems, ambiguity, conflicting interests, trade-offs
- Working under conditions of specific contexts
- Professional skills (work processes)
- ”Creating that which has never been”
- Knowledge building of the practice

CONNECTING WITH DISCIPLINARY KNOWLEDGE

- Drawing on the disciplinary knowledge
- Reinforcing disciplinary understanding
- Creating a motivational context

Design Matrix

– a tool for allocating and documenting responsibility

Kurskod	Kursnamn	1 1	1 2	1 3	2 1	2 2	2 3	2 4	2 5	3 1	3 2	3 3	4 1	4 2	4 3	4 4	4 5	4 6
TNIU70	Analys i en variabel	IUA		U	IU	I		A		A		A						
TND001	Programkonstruktion		U	U	U	I		I		A	A					I	I	
TND002	Objektorienterad prog.		U		U	I		I		A					I	I	I	
TNIU01	Ingenjörsprojekt		U		U	I		I		UA	UA				U	U	U	
TNMK30	Elektronisk publicering		IUA		U		U	IU		I	IU	A			U	U	U	
TNIU11	Databaser		U		U	I	I	I		A	I				I	I	I	
TNIUI75	Linjär algebra	IUA		U	IU	I		A		A	A							
TNDE24	Transformer	IUA		U	IU	I	IU	A		A	A							
TNIU81	Matlab för ingenjörer	A	U		U	U		UA		A					IU	IU		
TNMK31	Användbarhet		IUA	IU	IUA	IU	IU	IU	U	IA	UA	IU	IU	I	I			
TNIU66	Statistik och sannolik.	A	A		A	U				A	A				UA	IUA	IU	I
TNMK32	Distribuerade tjänster	A	I	U	UA	UA	UA	IUA	A	A	UA	UA	UA		A	A	A	A
TNIU13	Datorgrafik	A	IUA	IUA	A	UA	A	UA	UA	A	A							
TNIU14	Datornät	A	UA	I	UA	UA	U			A	UA					U	U	
TNIU08	GIS och applikation...																	
TNIU09	Ingenjörsprojekt f.k.																	
TNMK24	Mobilprogrammering...		U	I	IU	I	A	A	A	A					A	A	A	
TNIU16	Signalbehandling	A	A	I	IU	I	IU	I		U	IU	IU			U	I		
TNIU04	Telekommunikation	A	A	UA	UA	A	UA	U		A								
TNM021	Programvaruutveckling		U	U	U	I	U	UA		UA	A	A		I	U	U	U	U
TPIU01	Industriell ekonomi				A			A	UA				U	IUA				
TNIU07	Mobil kommunikation	A	UA	IU	UA		U			A	UA				U	U	U	I
	Examensarbete	A	A	A	A	U	A	U	U	A	A							
TDDI01	Datastrukturer och alg.	UA	A	UA	A	A	A	A		A	A					A		
THIU01	Engelska											IU						
TNGE11	Digitalteknik	U	U		U			U		U								
TMIU01	Människa, teknik, org.		A				UA	A	U	UA	A		U	U	U			
TNIU17	Flervariabelanalys	A	A		A													
TEIO08	Ledarskap för ing.		A		UA	A		IUA	IUA	IUA				IU	IU			
TNIU18	Vektoranalys	A	A		A													
TSIT01	Datasäkerhetsmetoder		IUA	IU	UA			U	A	A			U	U	U			

	Kurs 1	Kurs 2	Kurs 3	Kurs 4	Kurs 5
Kunskap och förståelse: För civilingenjörsexamen skall studenten					
visa kunskap om det valda teknikområdets vetenskapliga grund och beprövade erfarenhet samt insikt i aktuellt forsknings- och utvecklingsarbete					
visa såväl brett kunnande inom det valda teknikområdet, inbegripet kunskaper i matematik och naturvetenskap, som väsentligt fördjupade kunskaper inom vissa delar av området.					
Färdighet och förmåga: För civilingenjörsexamen skall studenten					
visa förmåga att med helhetssyn kritiskt, självständigt och kreativt identifiera, formulera och hantera komplexa frågeställningar samt att delta i forsknings- och utvecklingsarbete och därigenom bidra till kunskapsutvecklingen,					
visa förmåga att skapa, analysera och kritiskt utvärdera olika tekniska lösningar,					
visa förmåga att planera och med adekvata metoder genomföra kvalificerade uppgifter inom givna ramar,					
visa förmåga att kritiskt och systematiskt integrera kunskap samt visa förmåga att modellera, simulera, förutsäga och utvärdera skeenden även med begränsad information,					
visa förmåga att utveckla och utforma produkter, processer och system med hänsyn till människors förutsättningar och behov och samhällets mål för ekonomiskt, socialt och ekologiskt hållbar utveckling,					
visa förmåga till lagarbete och samverkan i grupper med olika sammansättning, och					
visa förmåga att i såväl nationella som internationella sammanhang muntligt och skriftligt i dialog med olika grupper klart redogöra för och diskutera sina slutsatser och den kunskap och de argument som ligger till grund för dessa.			?		
Värderingsförmåga och förhållningssätt: För civilingenjörsexamen skall studenten					
visa förmåga att göra bedömningar med hänsyn till relevanta vetenskapliga, samhälleliga och etiska aspekter samt visa medvetenhet om etiska aspekter på forsknings- och utvecklingsarbete,					
visa insikt i teknikens möjligheter och begränsningar, dess roll i samhället och människors ansvar för hur den används, inbegripet sociala och ekonomiska aspekter samt miljö- och arbetsmiljöaspekter, och					
visa förmåga att identifiera sitt behov av ytterligare kunskap och att fortlöpande utveckla sin kompetens.					

Systematic assignment of programme learning outcomes to courses

- negotiating the contribution

SYSTEMATIC PROGRESSION OF SKILLS DEVELOPMENT				
Year 1	Course A	Course B	Course C	Course D
Year 2	Course E	Course F	Course G	Course H
Year 3	Course I	Course J	Course K	Course L
Year 4	Course M	Course N	Course O	Course P
Year 5	Course Q	Course R	Course S	Course T
	Oral communi-cation	**Teamwork**	**Project planning**	**Written communi-cation**

(Schematic)

Example:

Embedding communication skills in the course 'Lightweight structures and Finite Element Modelling'

Communication in lightweight structures 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]

Engineering skills - implications

- **It's not about "soft skills"**

  Personal, interpersonal, product, process, and system building skills are **intrinsic to engineering** and we should recognise them as **engineering skills**.

- **It' s not about "adding more content"**

  Students must be given opportunities to develop communication skills, teamwork skills, etc. This is best achieved through **practicing, reflecting, giving and receiving feedback** (rather than lecturing on psychological and social theory).

- **It' s not about "wasting credits"**

  When students practice engineering skills they apply and express their technical knowledge. As they expose their understanding among peers, doing well will also matter more to them. Students will develop **deeper working knowledge**.

- **It' s not about appending "skills modules"**

  Personal, interpersonal, product, process, and system building skills must be practiced and assessed **in the technical context**, it cannot be done separately.

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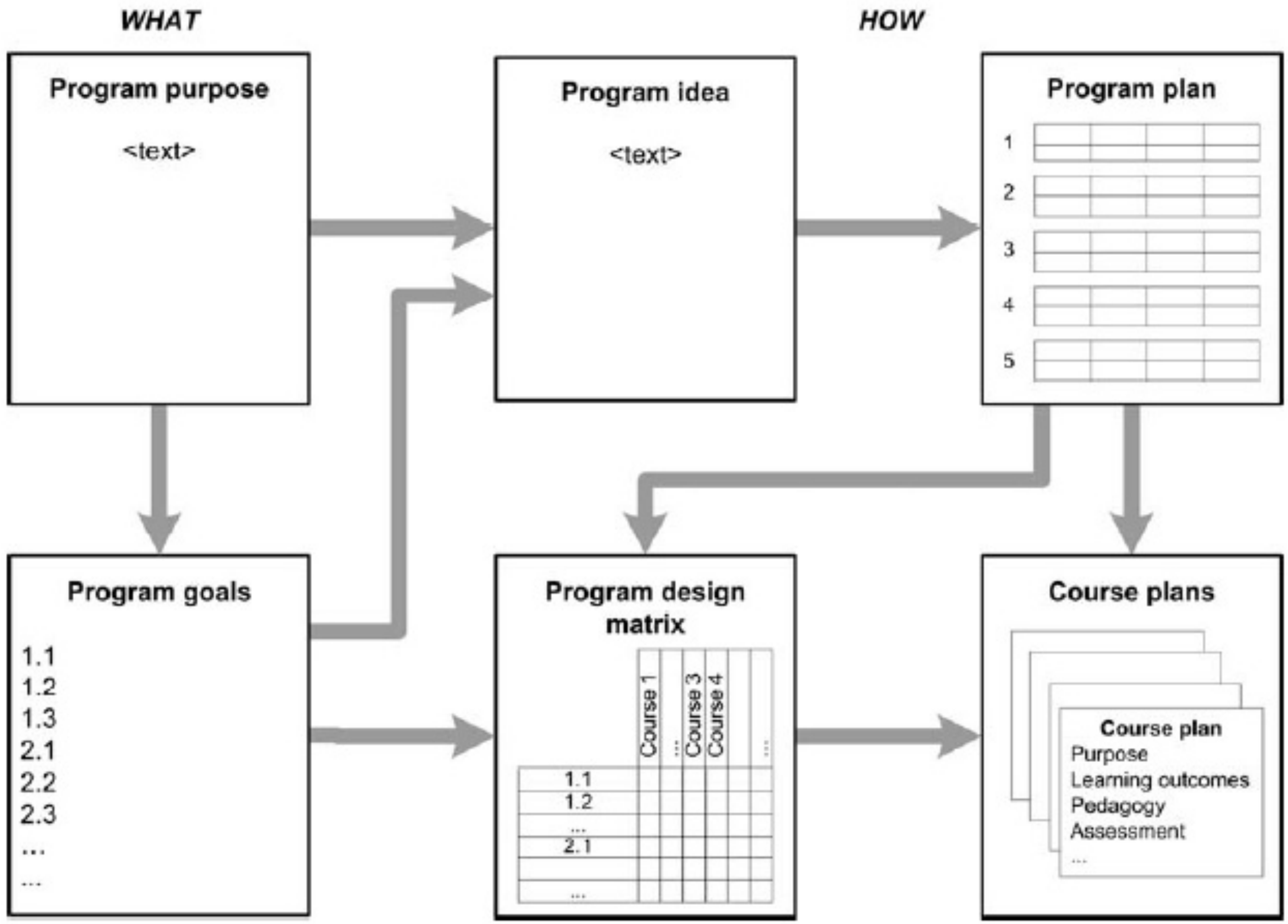
Place in curriculum	Faculty perception of generic skills and attributes
Integral	They are integral to disciplinary knowledge, infusing and **ENABLING** scholarly learning and knowledge.
Application	They let students make use of or apply disciplinary knowledge, thus potentially changing and **TRANSFORMING** disciplinary knowledge through its application. Skills are closely related to, and parallel, discipline learning outcomes.
Associated	They are useful additional skills that **COMPLEMENT** or round out discipline knowledge.They are part of the university syllabus but separate and secondary to discipline knowledge.
Not part of curriculum	They are necessary basic **PRECURSOR** skills and abilities. We may need remedial teaching of such skills at university.

Barrie, S. (2004) A research-based approach to generic graduate attributes policy, *Higher Education Research and Development*. 23 (3), 261-275

Integrated program descriptions



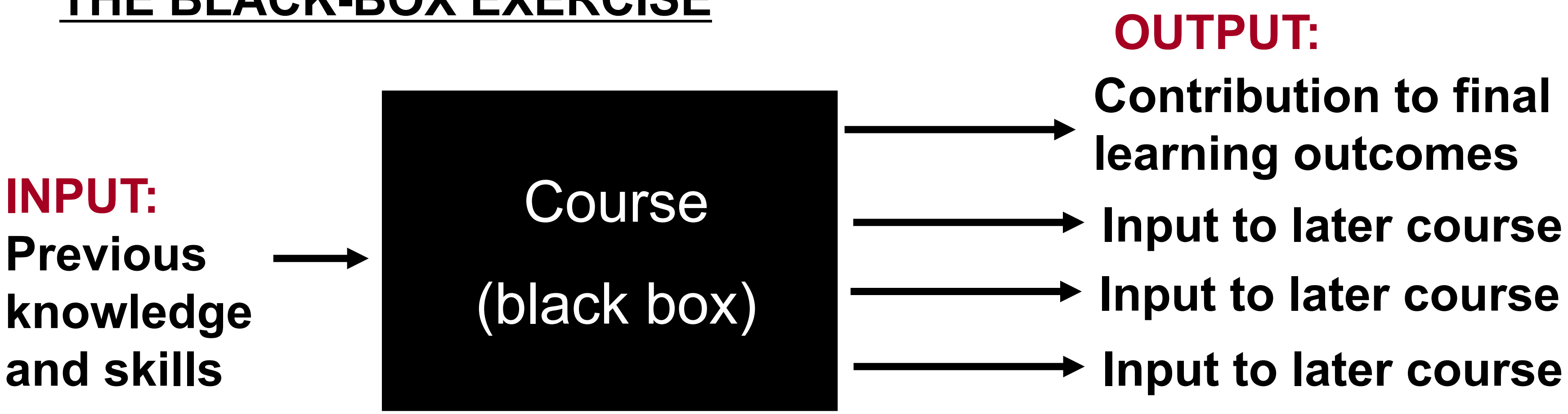
Malmqvist, J., Östlund, S., Edström, K., "Using integrated program descriptions to support a CDIO programme design process", World Transactions on Engineering and Technology Education 5(2), 259-262, 2006.

PROGRESSION

through the programme

Enhancing progression through the curriculum

THE BLACK-BOX EXERCISE



Black-box exercise for faculty

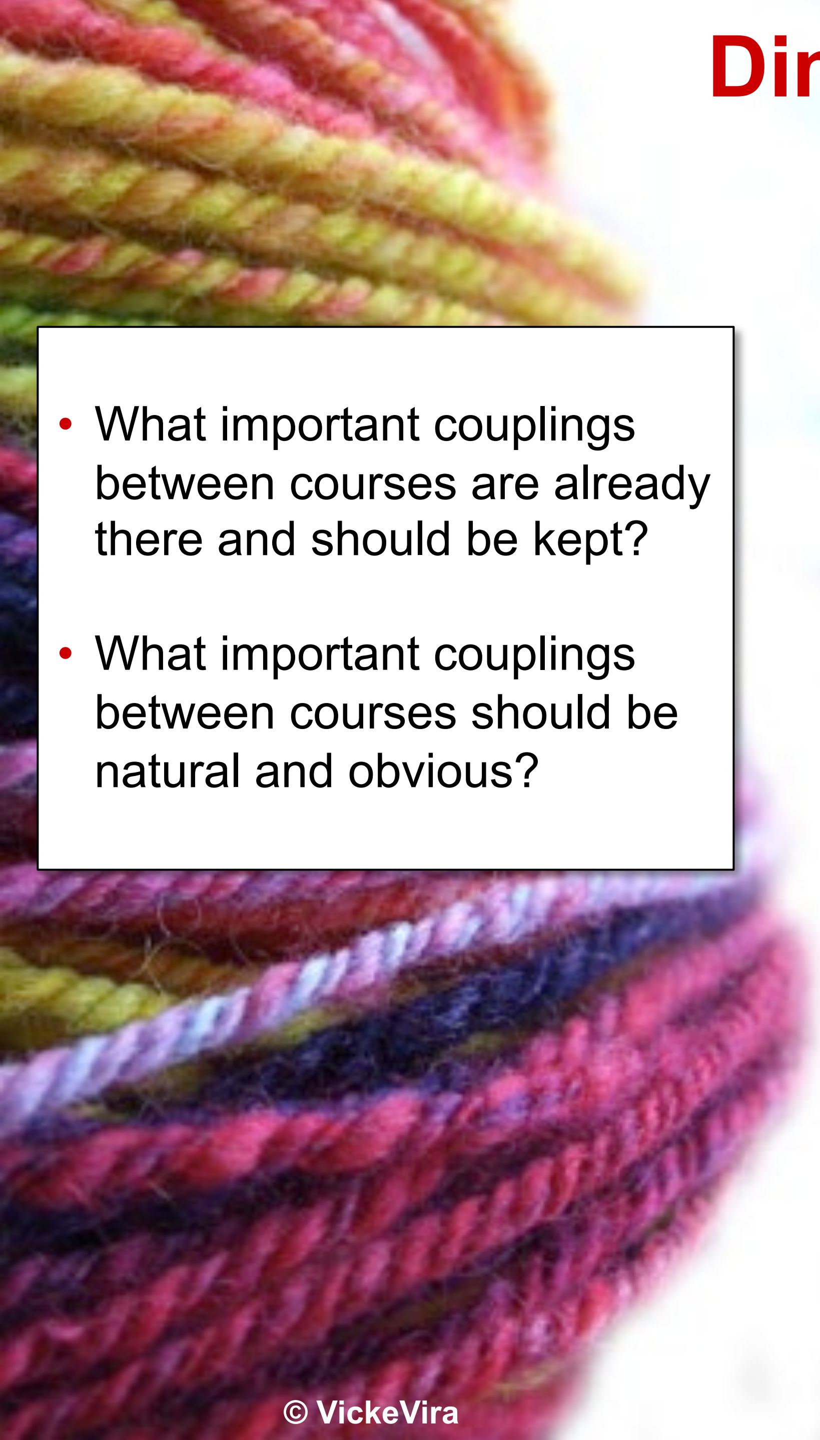
All courses are presented through input and output only:

- 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?

Dimensions of progression



- What important couplings between courses are already there and should be kept?
- 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, synthetis & 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 (pedagogiska röda trådar)

Program description – sample


FARKOSTTEKNIKPROGRAMMET

Måldokument

Version 1.0
December 2004

VEHICLE ENGINEERING – KTH

Table of contents

Introduction

Program goals

Engineering skills (CDIO Syllabus to second level of detail and associated expected proficiencies)

<u>Program structure</u>

Program plan

Explicit disciplinary links between courses

Program design matrix

Sequences for selected engineering skills

<u>All courses in program</u>

Intended learning outcomes

Contribution to engineering skills

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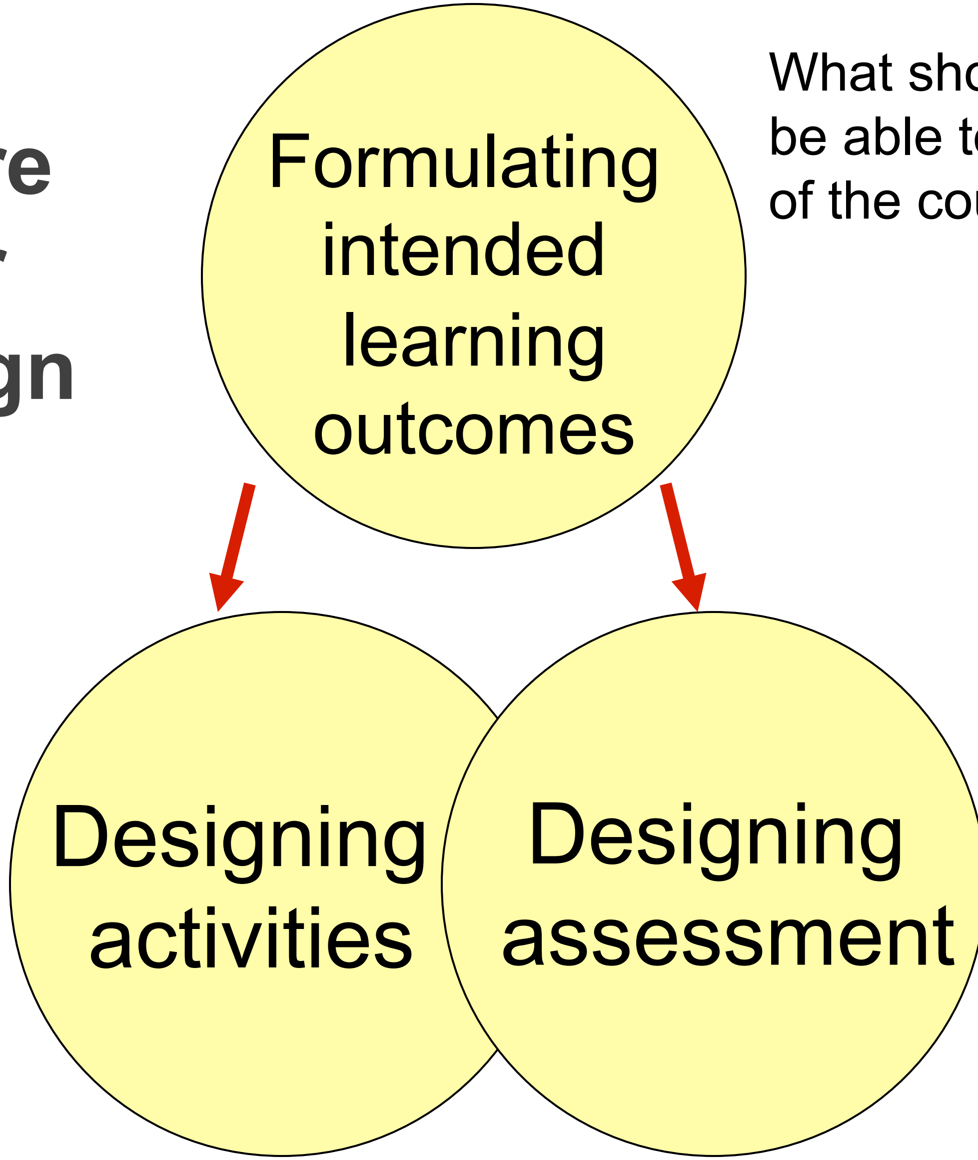
Course Design for Integrated Learning

Learning outcomes are the basis for course design

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

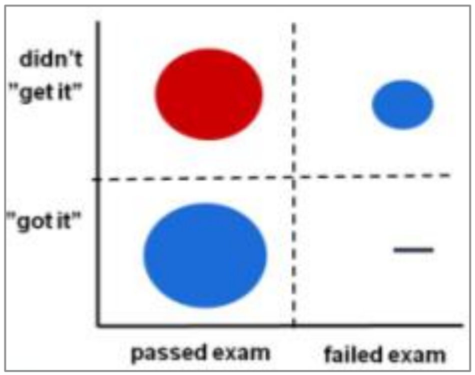


Constructive alignment
[Biggs]

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

What should the students do to demonstrate that they fulfil the learning outcomes?

Constructive alignment - applied



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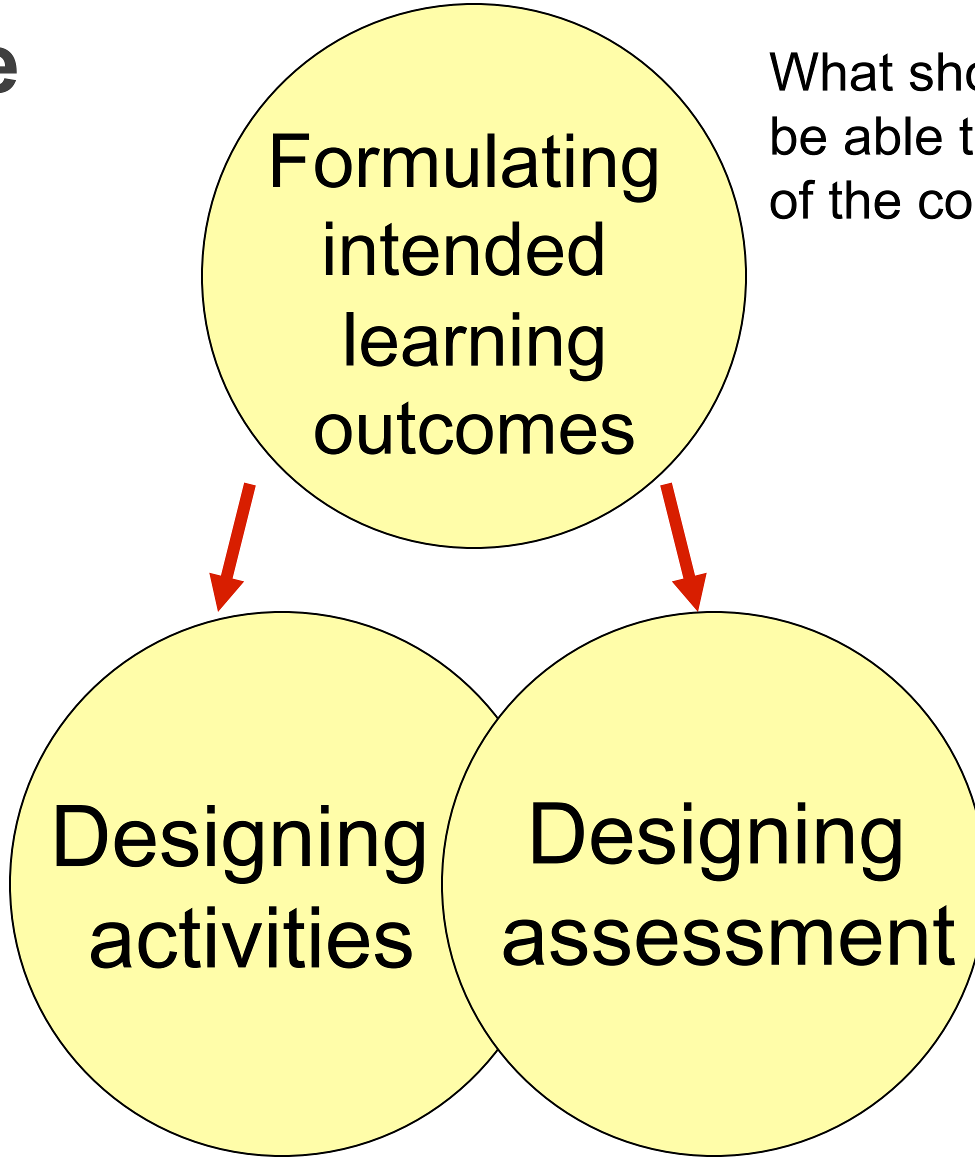

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Constructive alignment - applied

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

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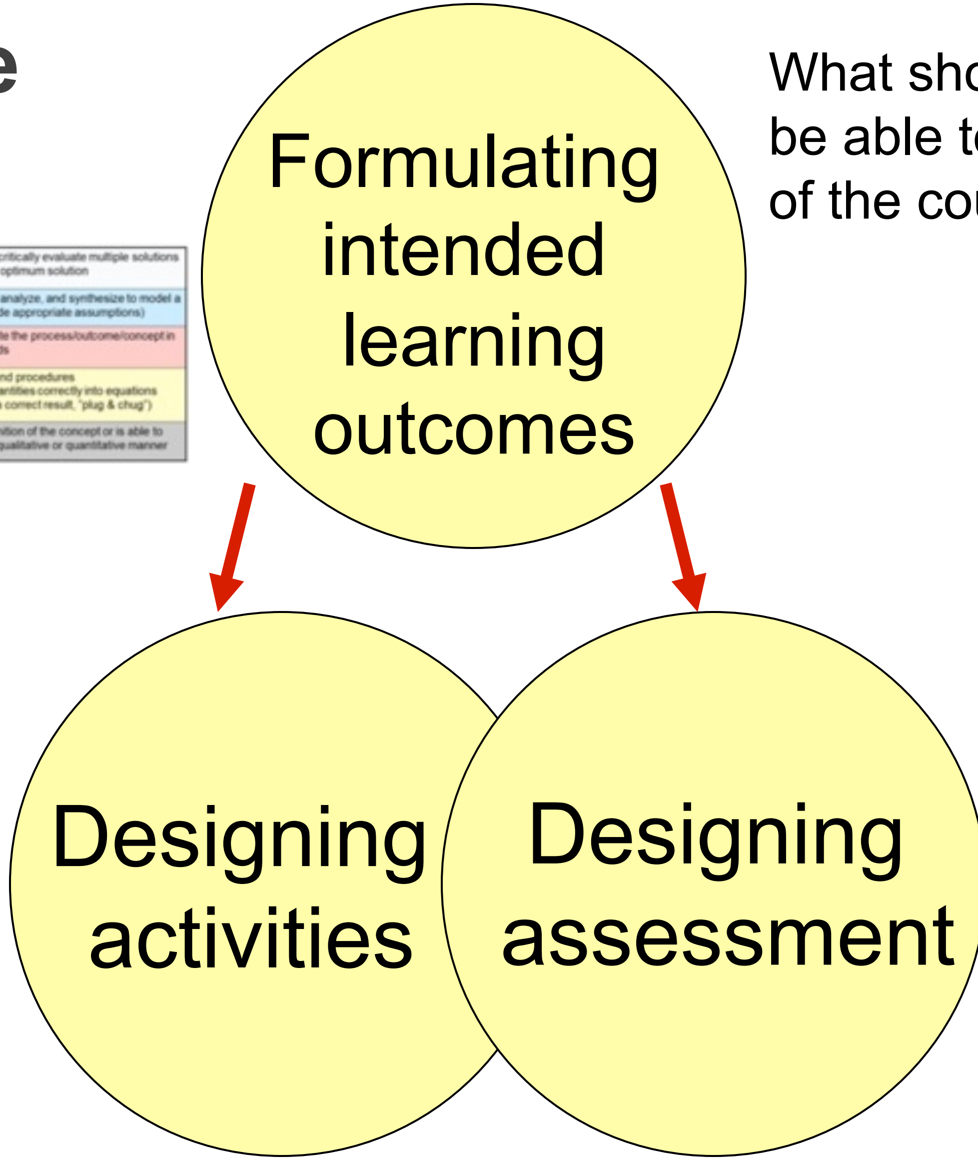

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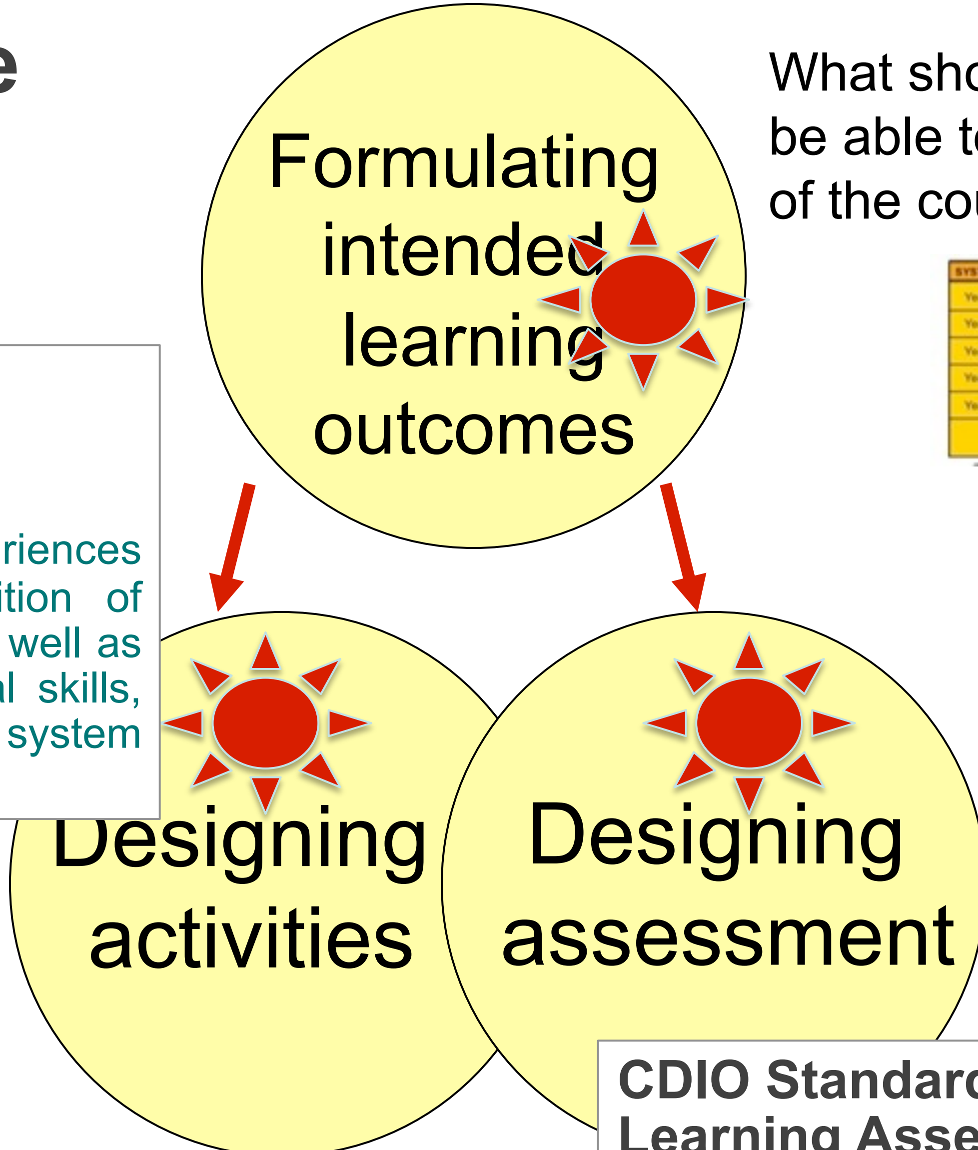


What should the students be able to do as a result of the course?

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, and system building skills.

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, and system building skills, as well as in disciplinary knowledge.

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 (finite) teaching resources

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

Remember that we are
developing people
as much as we are
developing programs.

The first strategy is to use existing resources better

- re-task the space you already have
- re-task the time you already have

If you can not control the resources you have, how can you ever justify why you should get more resources – it would only result in ”more of the same”

Examples are illustrations of principles

A specific **example**

will **illustrate**

generic principles

to **inspire**

applications - of many different kinds.

Educational development in CDIO

Improving discipline-led learning

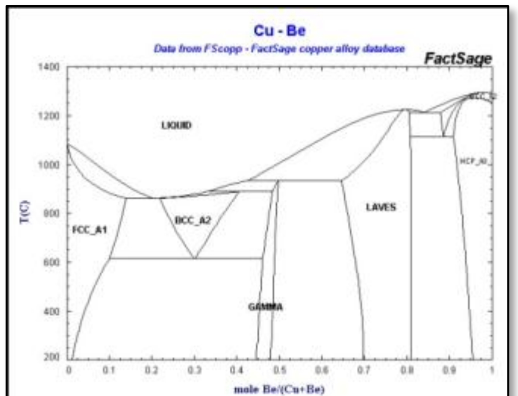
- Improving the quality of understanding
- Knowledge prepared for use: seeing the knowledge through the lense of problems
- Ability to communicate and collaborate
- Interconnecting the disciplines

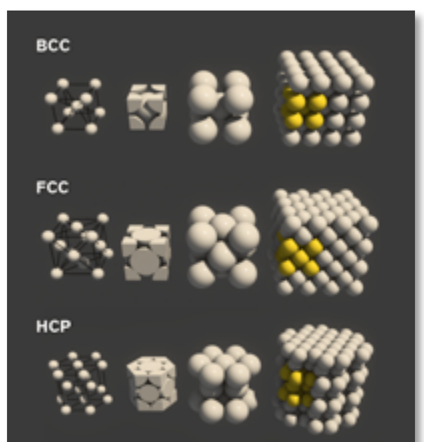
Improving problem/practice-based learning

- Adding problem/practice-based learning experiences
  - Early engineering experience
  - A sequence of Design-Implement Experiences
- Improving reflection and learning
- Improving cost-effectiveness of teaching

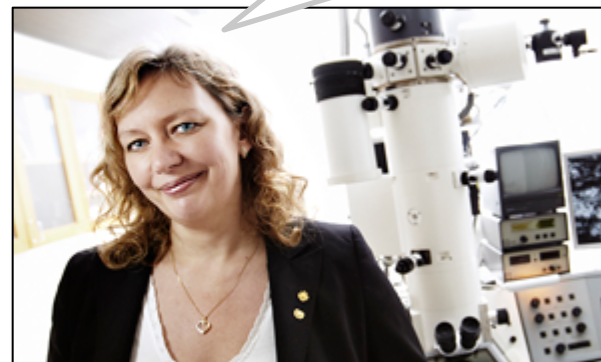
A course in Basic Materials Science

- 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]

Two ways of seeing materials science

From the inside - out

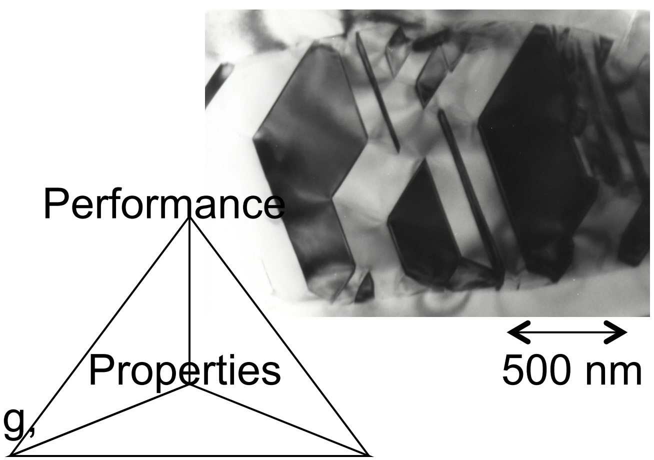
"Materials engineers distinguish themselves from mechanical engineers by their focus on the internal structure and processing of materials, specifically at the micro- and nano-scale."

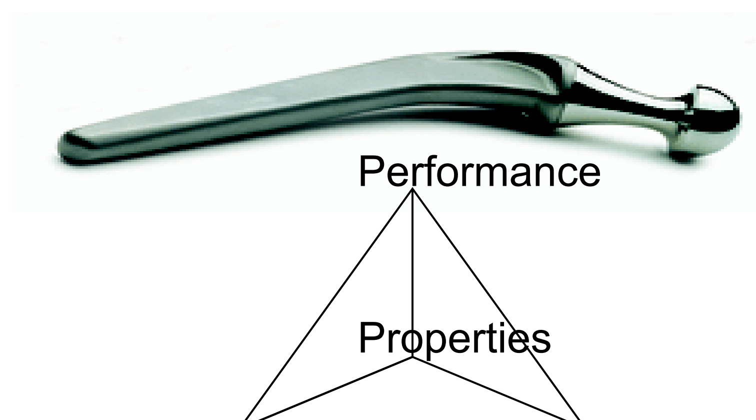
Flemings & Cahn

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





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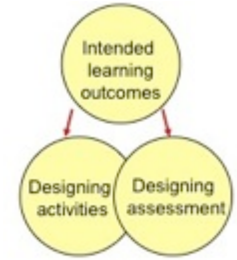


Implications I - formulating intended learning outcomes

Old learning objectives:
the disciplinary knowledge in itself

…describe crystal structures of some metals…

…interpret phase diagrams…

…explain hardening mechanisms…

...describe heat treatments…

New learning objectives:
performances of understanding

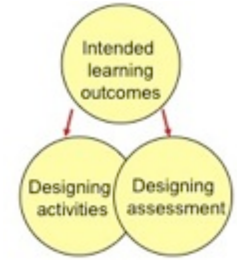
…select materials based on considerations for functionality and sustainability

...explain how to optimize material dependent processes (eg 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]

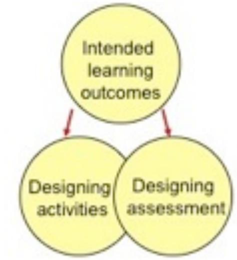


Implications II
- design of learning activities

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]



Implications III
- design of 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** – several aspects need to be integrated

➢ *Very good results on the exam but some students were scared and there were many questions beforehand…*

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]

Educational development in CDIO

In disciplinary courses

- Improving the quality of understanding
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In problem/practice-based courses

- Adding problem/practice-based learning experiences
  - Early engineering experience
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- Improving cost-effectiveness of teaching

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

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.

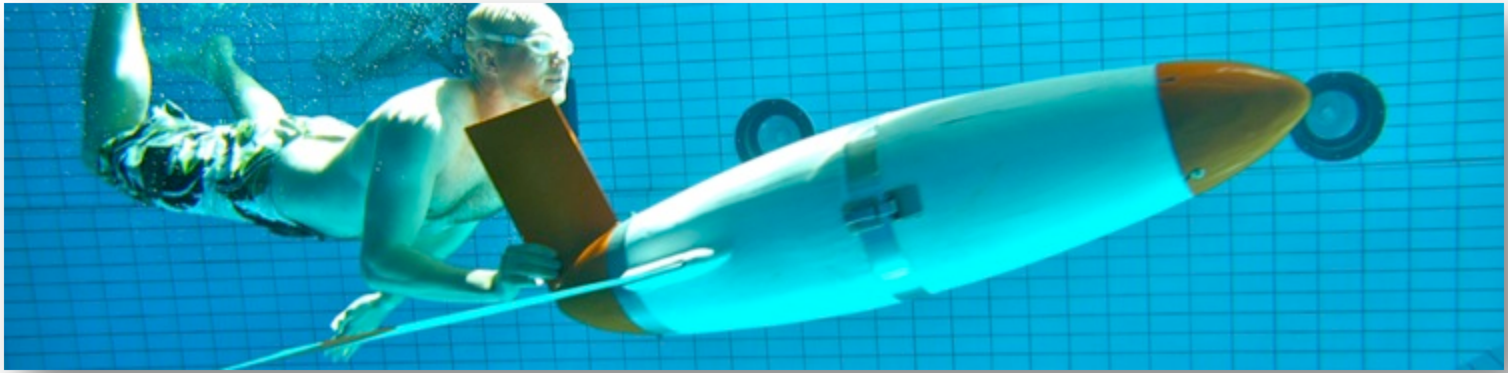
Progression in several dimensions

- 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

Learning in Design-Implement Experiences

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

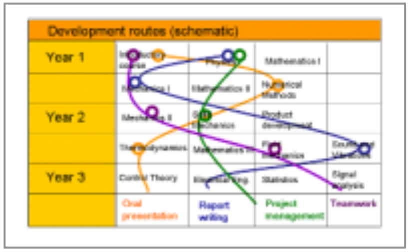
- it is key that students bring their designs and solutions to an **operationally testable state**.
- To turn practical experiences into learning, students are continuously guided through **reflection and feedback exercises** supporting them to evaluate their work and identify potential improvement of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



CDIO integrated curriculum development

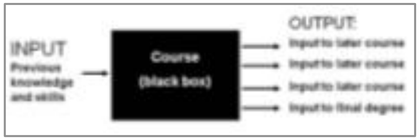
- the process in a nutshell

- **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**



The educational development process is the working definition of CDIO:

The CDIO Standards

Context:

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

Curriculum development:

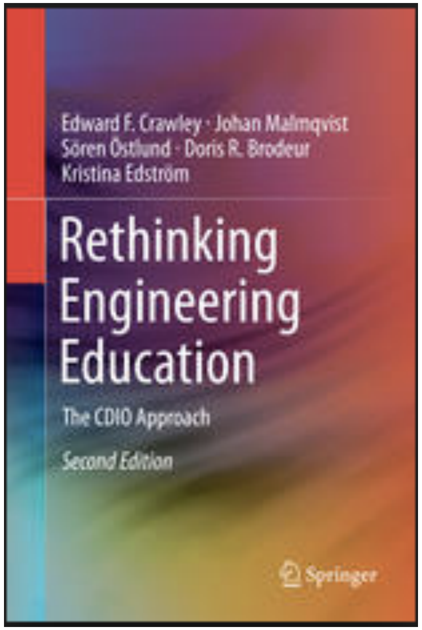
- Formulate explicit program learning outcomes (including engineering skills) in dialogue with stakeholders [2]
- Map out responsibilities to courses – negotiate intended learning outcomes [3]
- Evaluation and continuous programme improvement [12]

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]



Crawley, et al (2007, 2014) *Rethinking Engineering Education: The CDIO Approach*, Springer.