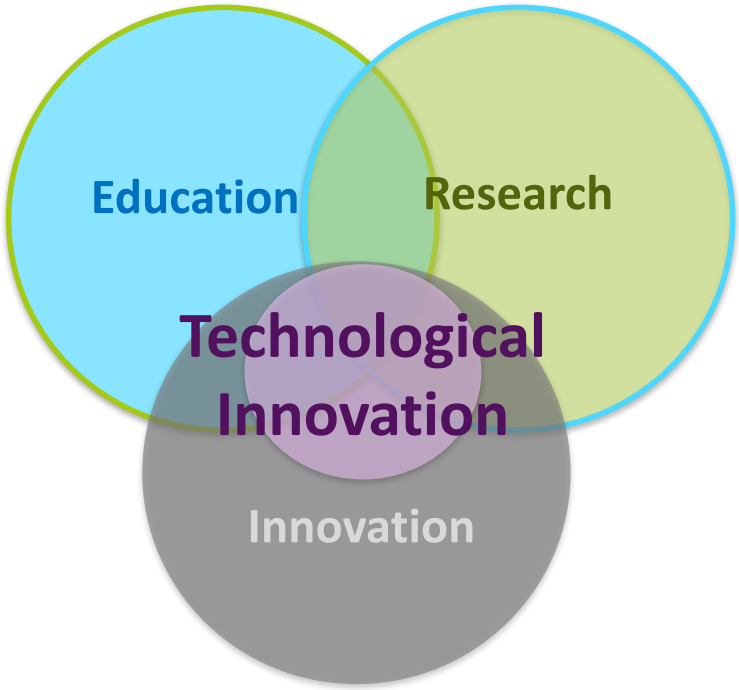
Ed Crawly:



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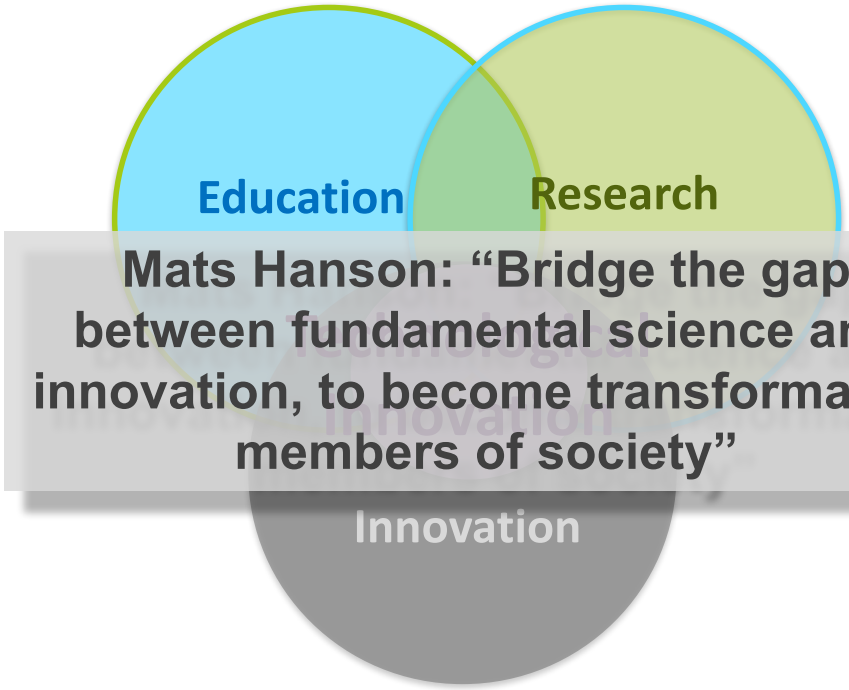

Mats Hanson: "Bridge the gap between fundamental science and innovation, to become transformative members of society"

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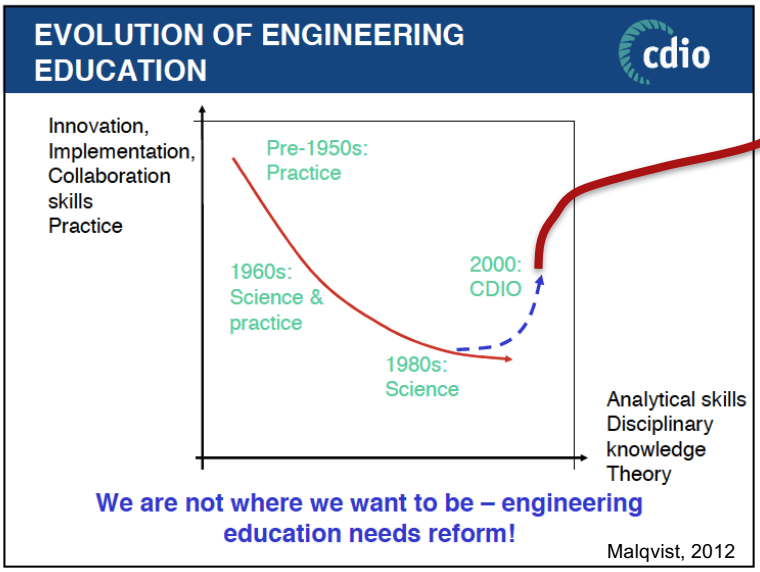
Observation late 90's by MIT …



?

E-edu in 2040?

+ … skills ? + … theory + …?

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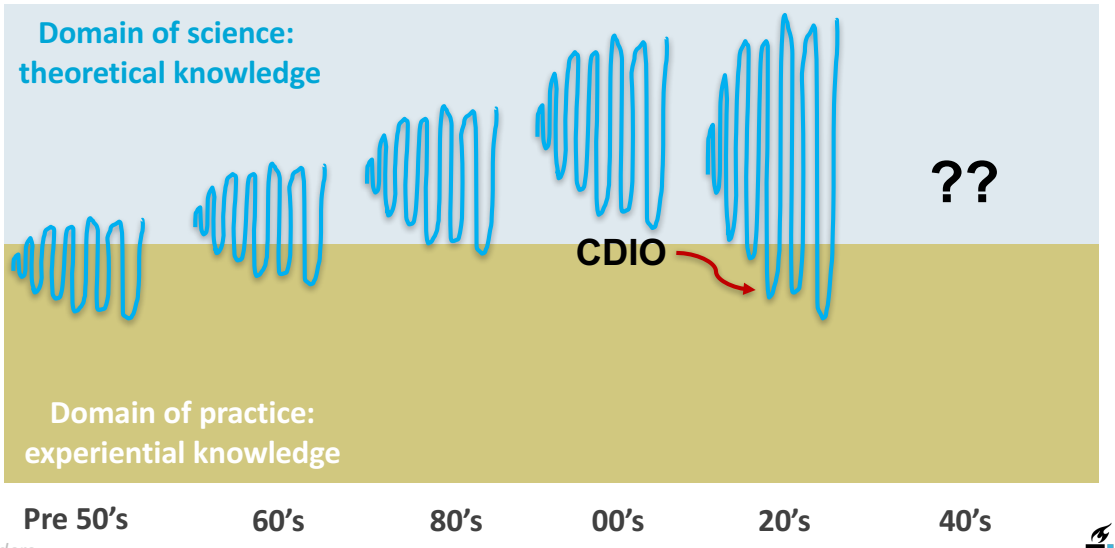
What range are we teaching?



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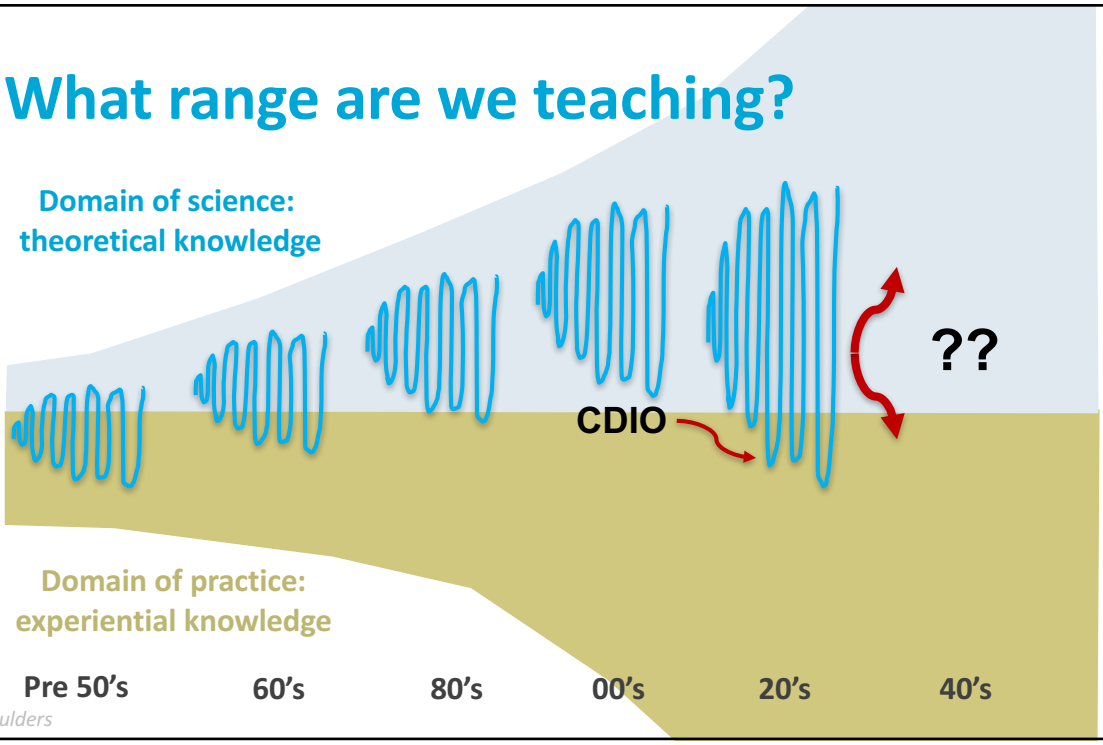
What range are we teaching?



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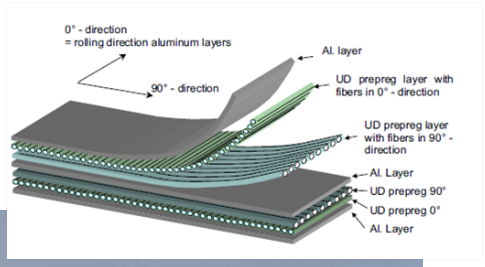
Engineering background



Aerospace materials:

- New hybrid material ARALL
- Fibre composite + aluminium
- Fuselage application: Fibre failure!

My MSc research:

- Explaining fibre failure mechanism
- Change Kevlar fibre to Glass => GLARE!
- Fuselage Airbus A380

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My research: Identifying the 'atoms' of Design, innovation & entrepreneurship

Creative scientist

Micro foundations of innovating

Theories 4 practice and 4 science!

Connecting engineering & social sciences

Engaged scholar

Interdisciplinary research

Industry is my living lab

Intensive collaboration with industry

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Insights presented today are based on:

- Smulders ('88, '89, '91, '92, '94, '96, '97, '02, '03, '06, '09, '14, '15 a+b, '17)
- Smulders, Dorst & Vermaas (2014 & 2017?)
- Smulders & De Bont (2013)
- Van Bruinessen, Hopman & Smulders (2012, 2013 a+b & 2015)
- Van Bruinessen (2016)
- Van Oorschot, Smulders & Hultink (2016, 2017?)
- Buijs, Smulders, Van der Meer (2009)
- My practice as innovation management consultant… +

My research & practice over the past 30 years

Frido Smulders

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Insights presented today are based on:

… 'experiments' aimed at … understanding & explaining the verb of innovating by design …

My research & practice over the past 30 years

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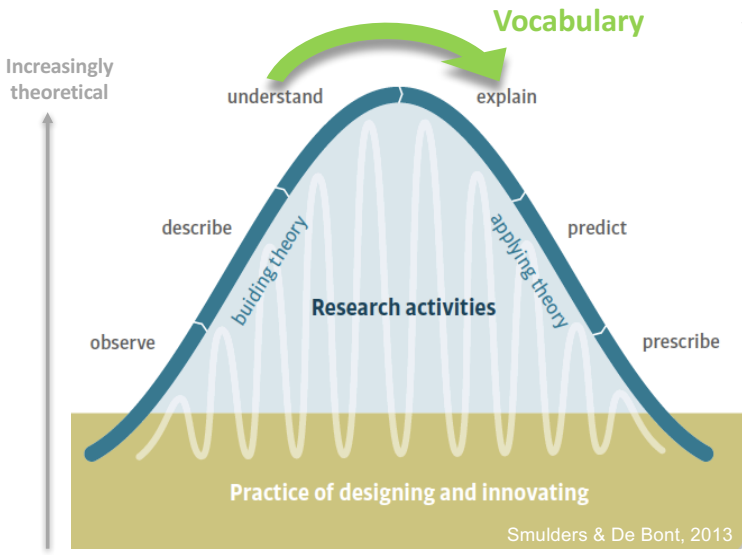
Research



Scientific inquiry:

- Observe
- Describe
- Understand
- Explain
- Predict
- Prescribe

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Dominant work field for engineers …?

- All engineers are involved in processes of renewal, be it:

buildings dikes experiments roads infrastructures
planes bridges ships systems
satelites materials products circuits

- Any process that aims to renew anything might be seen as a process of innovating …
- Innovating … **'successful' introduction of something new in existing environment**
- Newness ranges from: Incremental to breakthrough +

Our engineers find a natural habitat in innovation processes!

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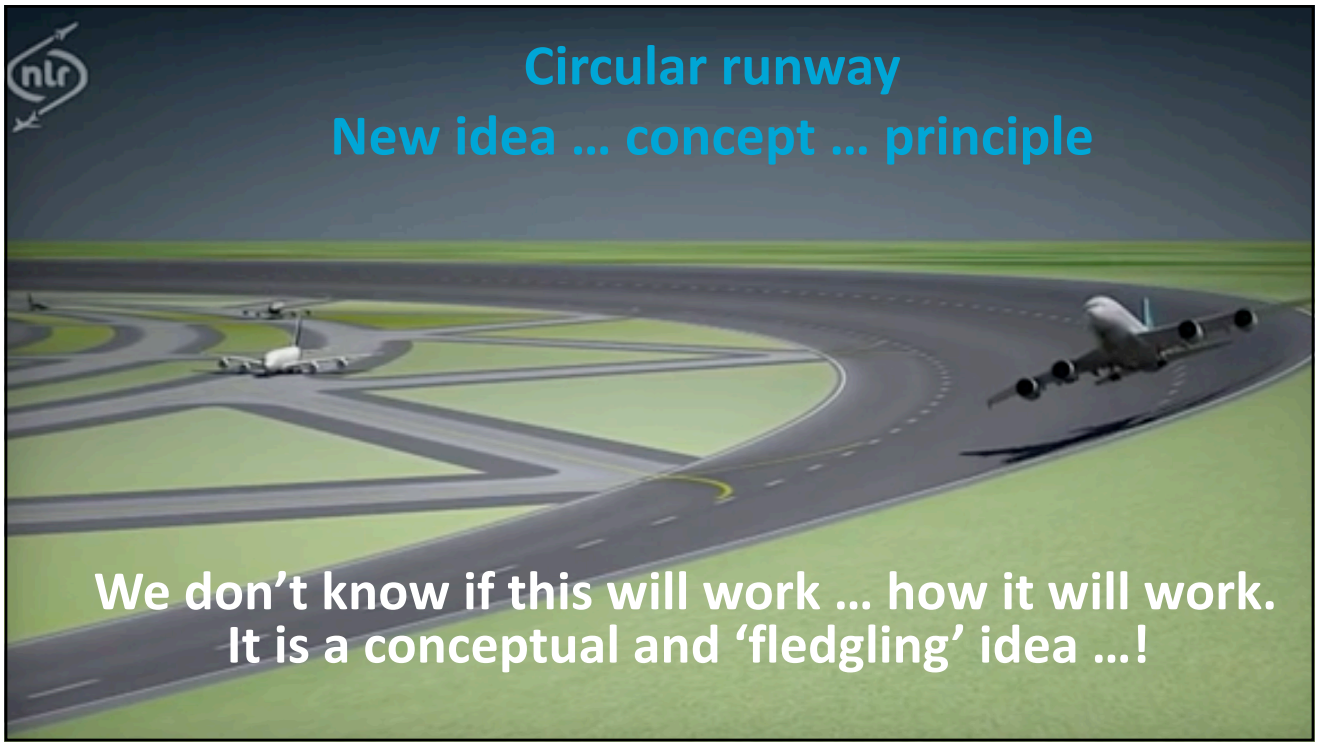

Generic innovation process …?

… describing 'introduction of something new in existing environment'

- Generic model for all 'somethings' …

- Product innovation processes treat large range of 'somethings'
- Structure of product innovation (Roozenburg & Eekels 1995)

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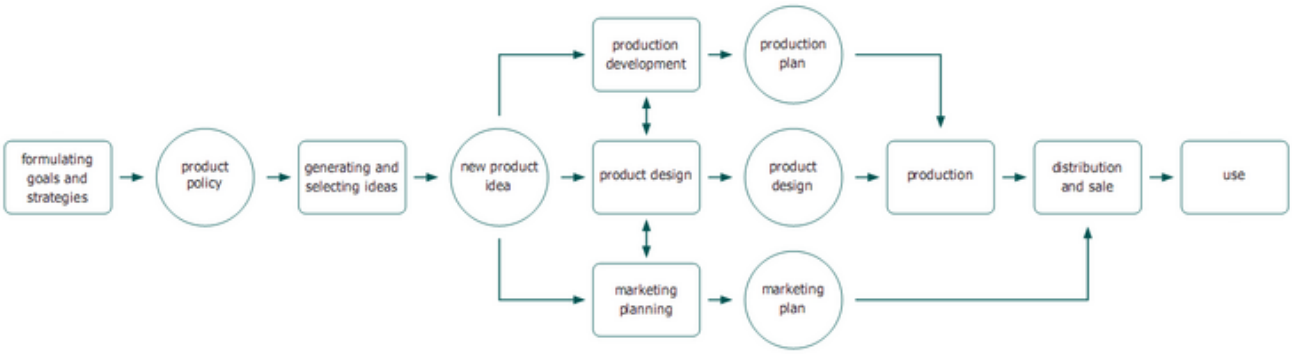
Roozenburg & Eekels, 1995



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Abstracted innovation process model

(Smulders et al 2014, Smulders, 2014 & 2015)

Based on product innovation literature (e.g. Buijs & Valkenbrug 2000; Roozenburg & Eekels 1995; Smulders 1998):

I = Initiating new product development : Front End lit.

D = Designing concepts for the product : Design lit.

E = Engineering product, process (& organization) : Engineering Lit

R = Realizing production, sales & distribution : Operations mgt lit.

- In principle for all kinds of products, services, systems, infrastructures, constructions, etcetera

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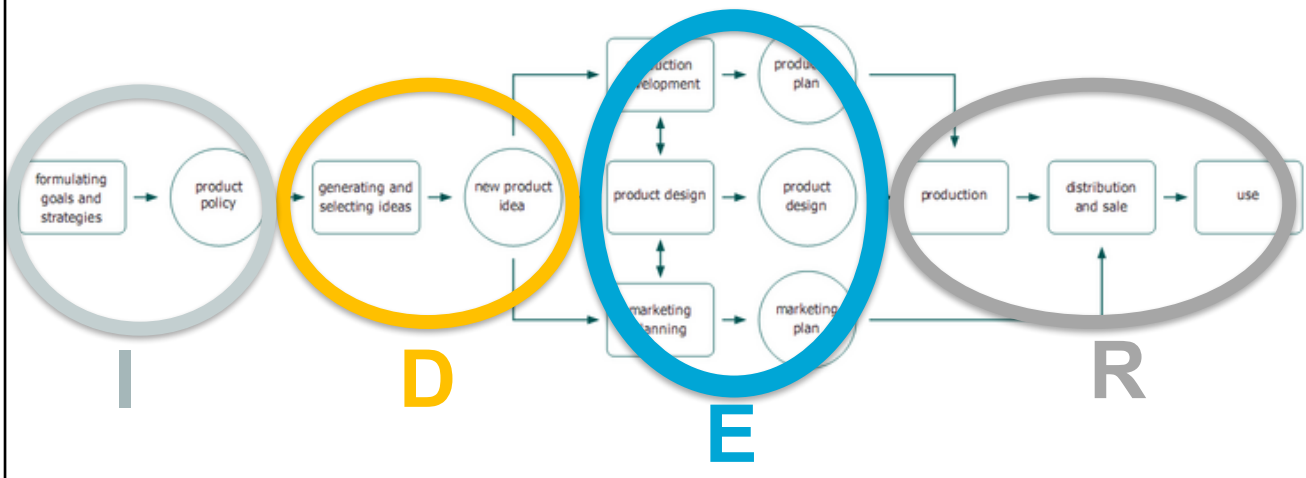
Roozenburg & Eekels, 1995



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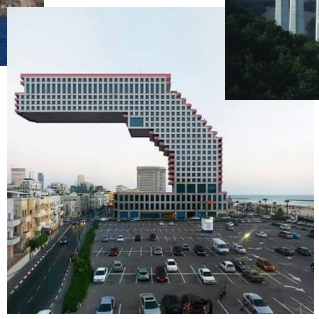
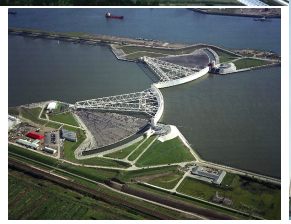
Design & Engineering …

- Living apart together?
- Symbiotic relationship?
- What constitutes these two …

Design as form …

Engineering as form …

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Design & Engineering …

- They seem to be interwoven …
- Shapes traditionally belong to design …
- Mechanics to engineering …
- Both needed for (technological) innovation …


- Differences in output …?

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Results Design & Engineering

Design results:

- A new integrated whole
- Not a finished product
- Still in conceptual state
- Assume: design => new concept/ new principle ≈ conceptual thinking

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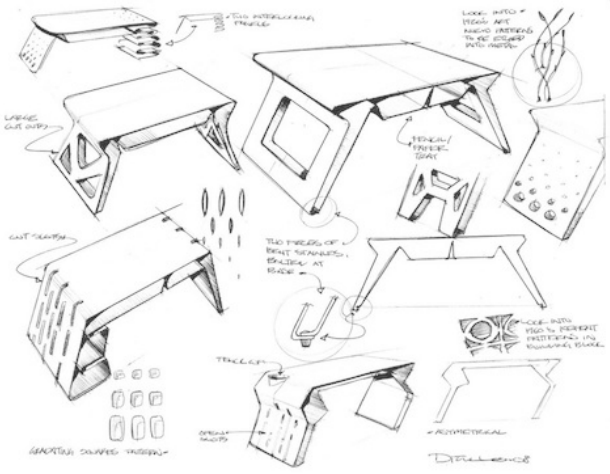
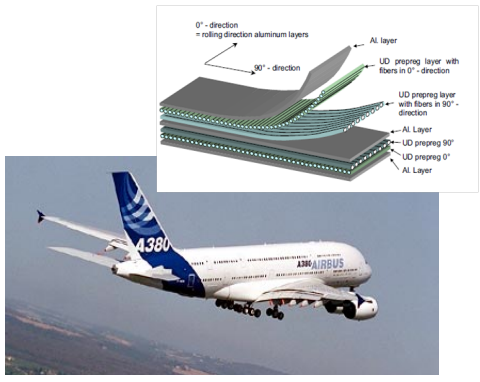
Designing is crafting the concept/principle

(Smulders: work in progress)





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Results Design & Engineering

Design results:

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- Not a finished product
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Design results are based on insights!

Results Design & Engineering

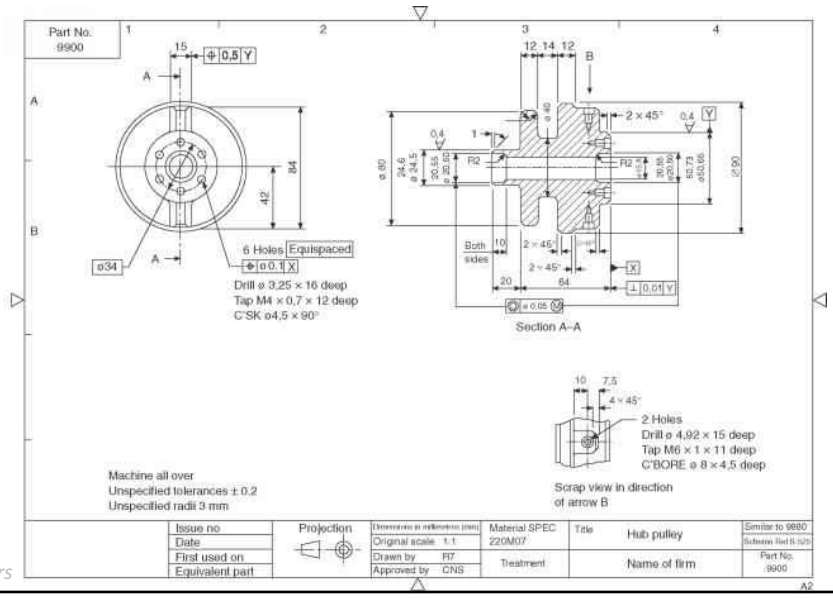
Design results:

- A new integrated whole
- Not a finished product
- Still in conceptual state
- Assume: design => new concept/ new principle ≈ conceptual thinking

Engineering results:

- Production and assembly ready
- Engineered drawings & production plans
- Potentially working and safe product
- Assume: engineering 'robustinizes' the concept

Engineering is specifying product & process



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Results Design & Engineering

Design results:

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Engineering results:

- Production and assembly ready
- Engineered drawings & production plans
- Potentially working and safe product
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Engineering results are based on knowledge!

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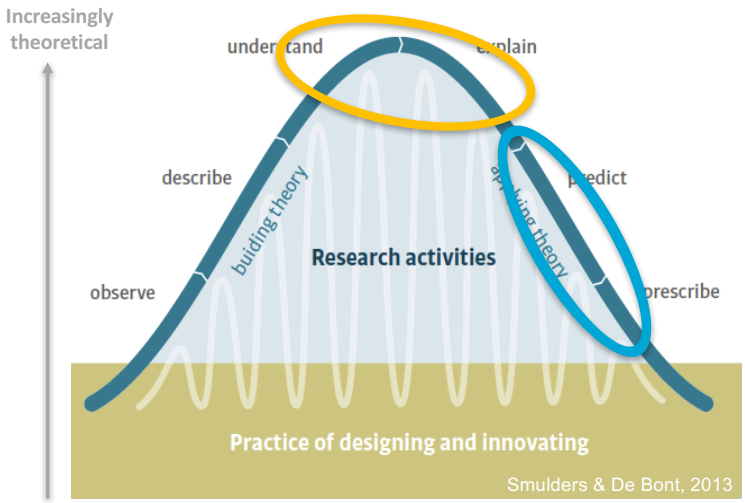
Design & Engineering sciences



Design (& innovation) sciences:

- Lots of tools & methods
- Little predictions
- No uniform theoretical base
- Relevant in practice, still weak in theory

Engineering sciences:

- Interconnected string of theories from molecules to performing constructions
- Theories are based on natural & artificial sciences
- Predictive, if this … then that
- Prescriptive handbooks

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Innovating: Perfect design & … ?

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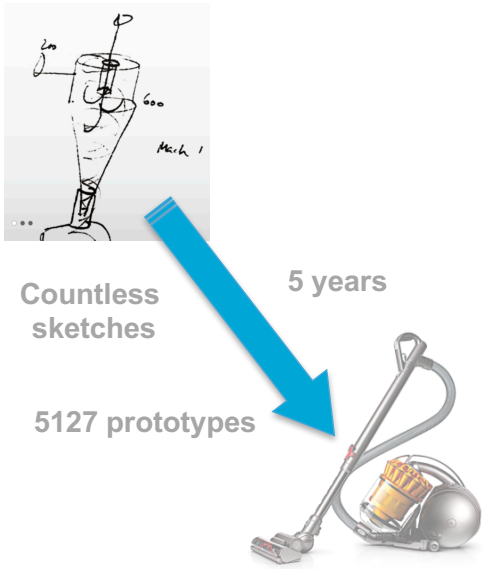
Struggle of Dyson …



Was this just design?

- What did sketches do?
- What did prototyping do?
- What did testing do?

- How can we understand this?!

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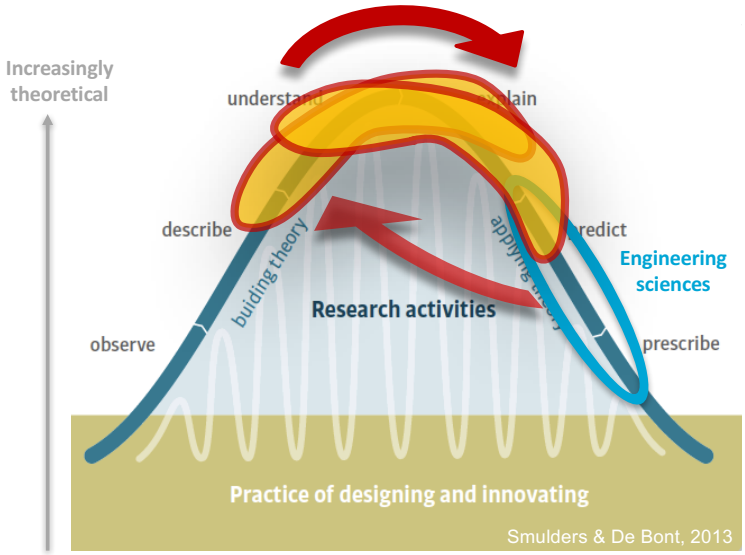
Let's explain what Dyson did …



Dyson …

- Couldn't use existing E-knowledge

He needed to …

- Identify the right concept/principle
- Create deep understanding
- Learn how to engineer this
- Develop new technology
- Use new technology for business growth.

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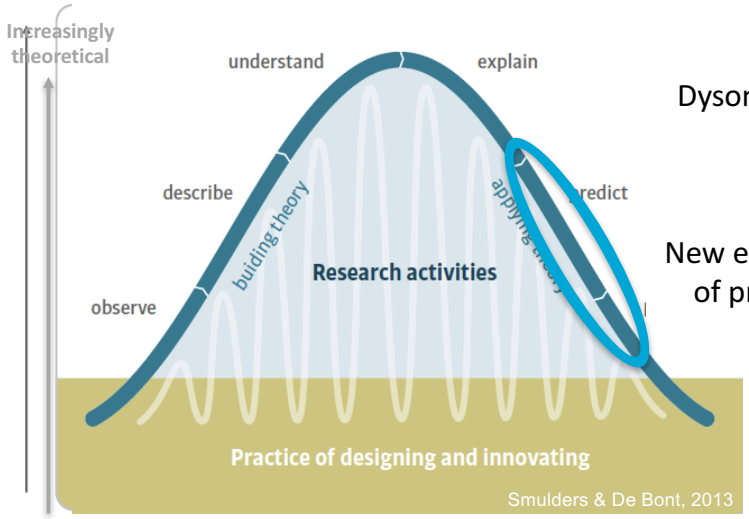
Innovating: Perfect Design & Engineering!



Dyson: Comparable process, maybe not scientific …
but for sure academic!

New engineering 'theory' to realize range of products based on same principle!

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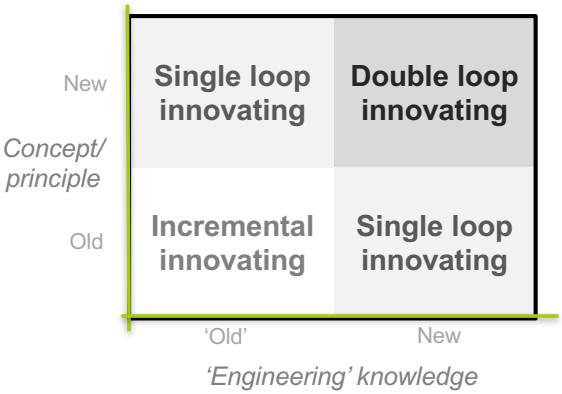
Innovating: Design & Engineering

(Smulders, work in progress)



Let's look at innovating

- There two axes
- Design delivers concept/principle
- Engineering 'robustinizes' concept
- Existing & new concepts/principles
- Existing and new E-knowledge

⇒ 'Simple' 2 x 2 matrix

⇒ Three forms of innovation

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Innovating: Design & Engineering

(Smulders, work in progress)

Let's look at innovating

- There two axes
- Design delivers concept/principle
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⇒ 'Simple' 2 x 2 matrix

⇒ Three forms of innovation

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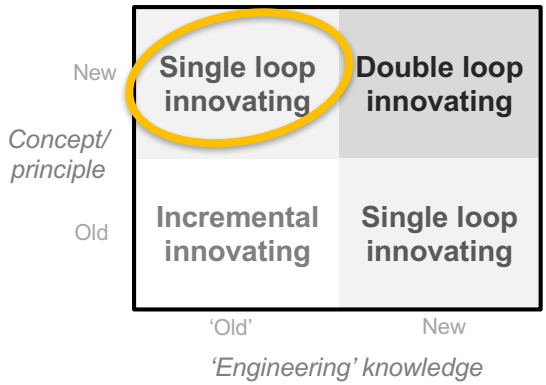
Innovating: Design & Engineering

(Smulders, work in progress)



New design concept – existing engineering

Senz: Storm proof umbrella

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Innovating: Design & Engineering

(Smulders, work in progress)

New design concept – existing engineering

'Black aluminum' airplanes

Concept/ principle \ Engineering knowledge	'Old'	New
New	Single loop innovating	Double loop innovating
Old	Incremental innovating	Single loop innovating

Composites in airplanes

- First constructions
- Existing aluminium E-knowledge

⇒ 'Black aluminum' planes

- After decades => new E-knowledge

⇒ Dreamliner

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Innovating: Design & Engineering

(Smulders, work in progress)

Old design concept – New engineering

Concept/ principle \ Engineering knowledge	'Old'	New
New	Single loop innovating	Double loop innovating
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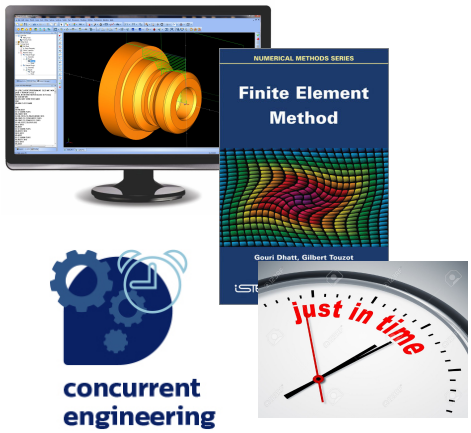

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Innovating: Design & Engineering

(Smulders, work in progress)

New design concept – New engineering

Concept/ principle \ 'Engineering' knowledge	'Old'	New
New	Single loop innovating	Double loop innovating
Old	Incremental innovating	Single loop innovating

Ampelmann offshore access

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Technological innovation …

✓ New concepts, new class of products, etc.

✓ New engineering +

⇒New technology

⇒Technological innovation = double loop innovating

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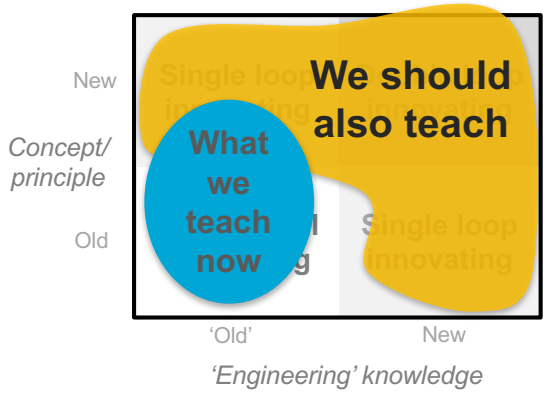
What we teach and could/should teach



- One could say: 'we teach old knowledge'
- What is meant: old **validated** engineering knowledge
- We can't teach new knowledge …
- We should teach H2 develop new **E**ngineering knowledge
- … and teach **D**esign for new concepts/principles

How to do this?

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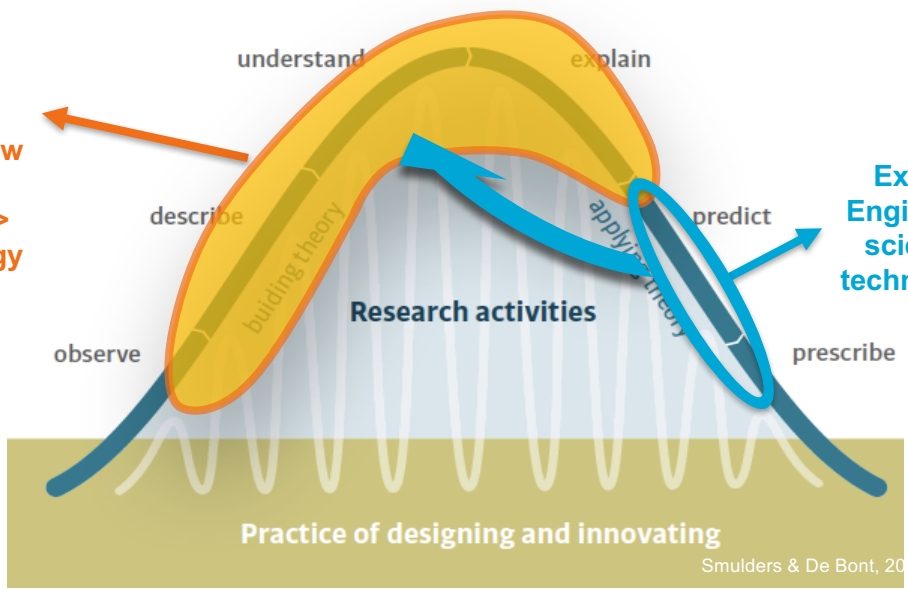
What we teach

Conceptual thinking and interacting: H2 develop new engineering knowledge => new technology



Existing Engineering sciences/ technologies

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H2 educate for 'dysons' & 'ampelmanns' …?

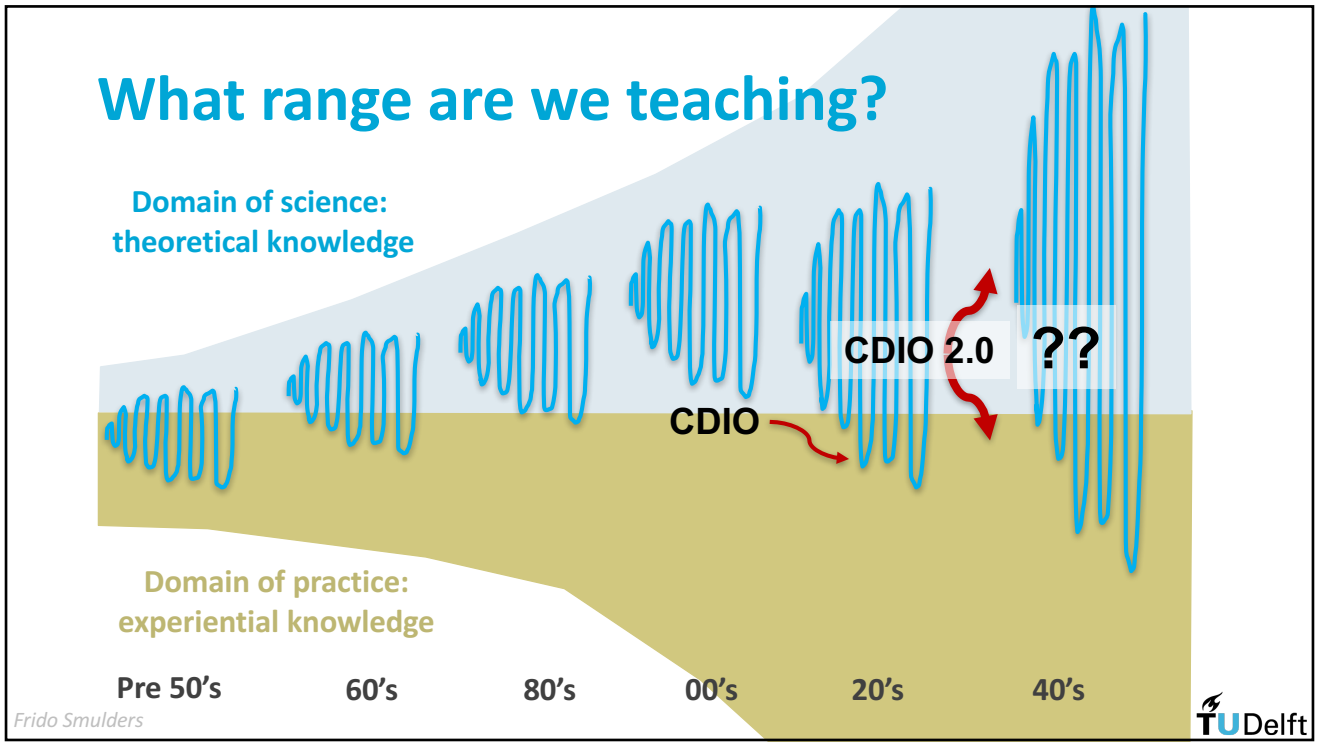
- Add understanding of thinking & acting in conceptual spaces
- Add understanding of development of E-knowledge
- Add how to develop new technologies …

⇒ Create knowledgeable technological innovators!

Anybody can say this! How …… ??

Workshop issues …

- Exponential increases in knowledge: practice **ánd** science
- What is it that we need to teach to create life-long learning engineers??
- Where to find Double loop innovation within CDIO framework?
- How to complement CDIO with development of new E-knowledge?
- How/what to teach engineering at BSc, MSc and PhD levels?


What range are we teaching?
Domain of science:
theoretical knowledge
CDIO 2.0
??
CDIO
Domain of practice:
experiential knowledge
Pre 50's
60's
80's
00's
20's
40's
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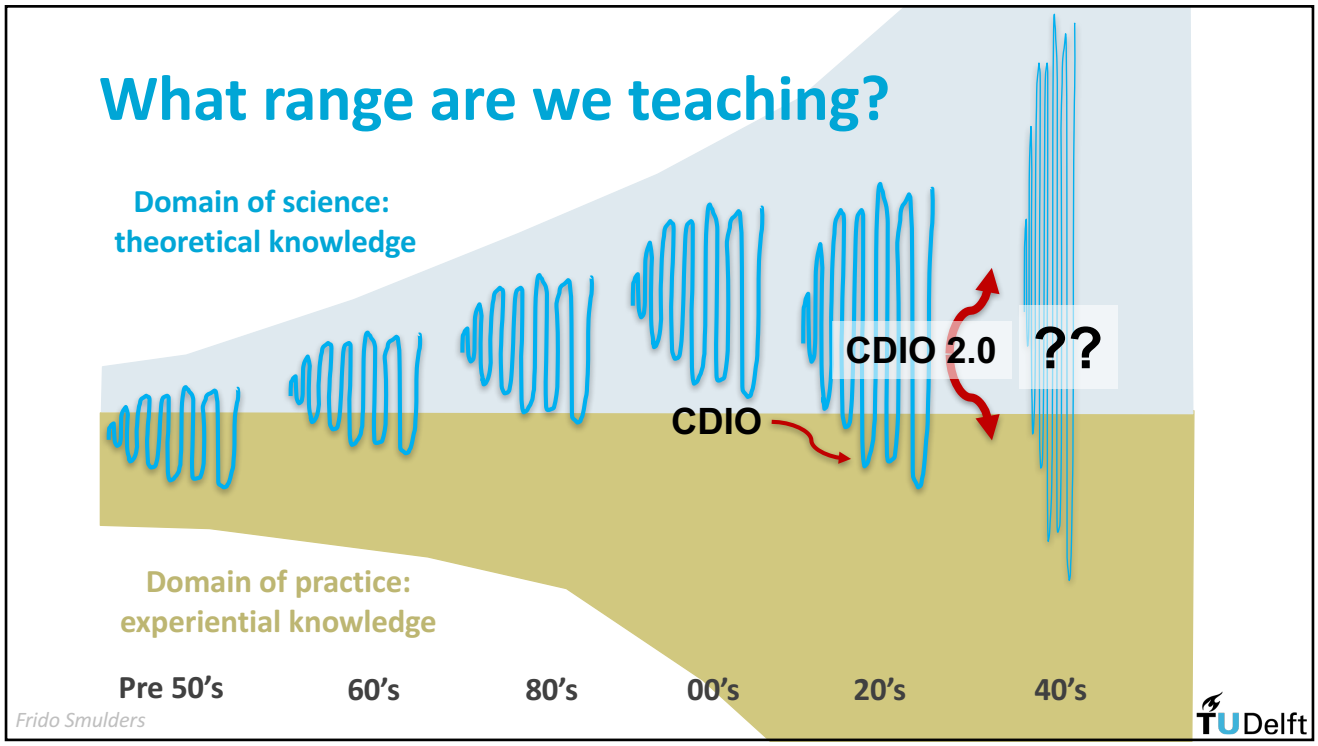
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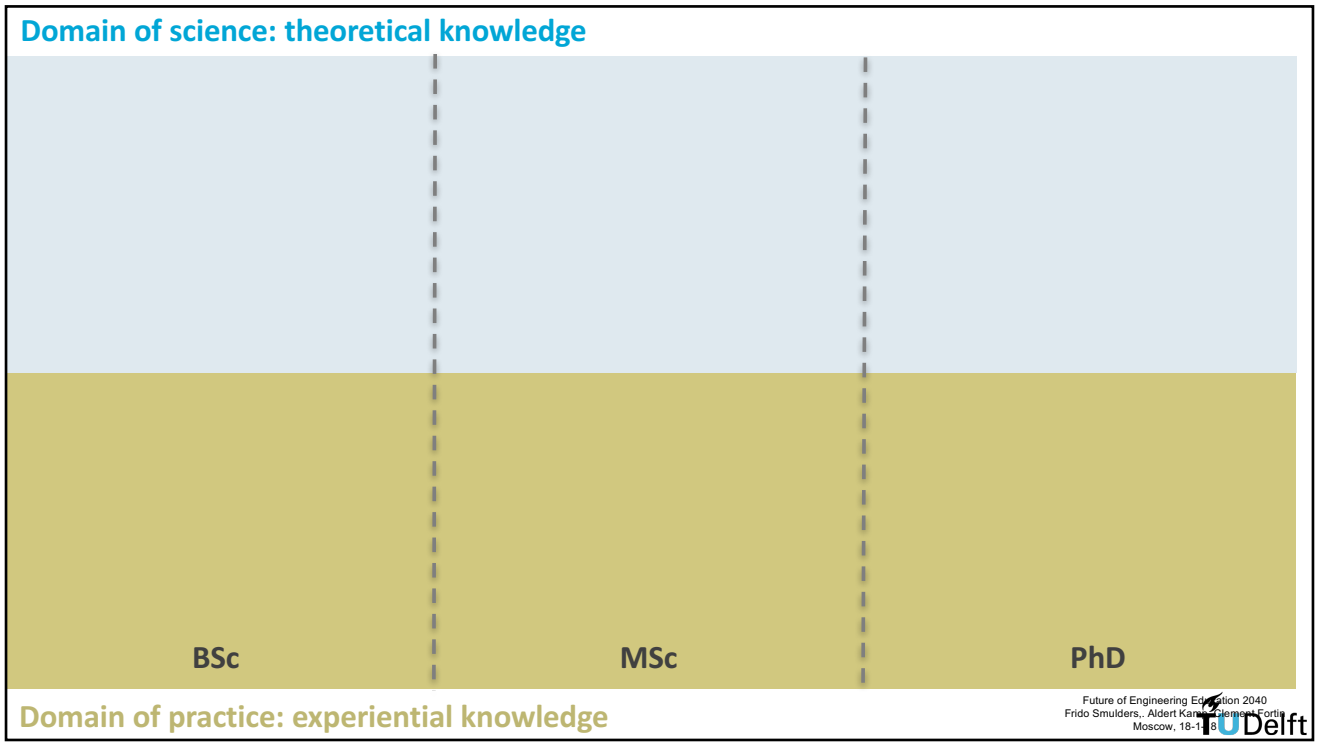
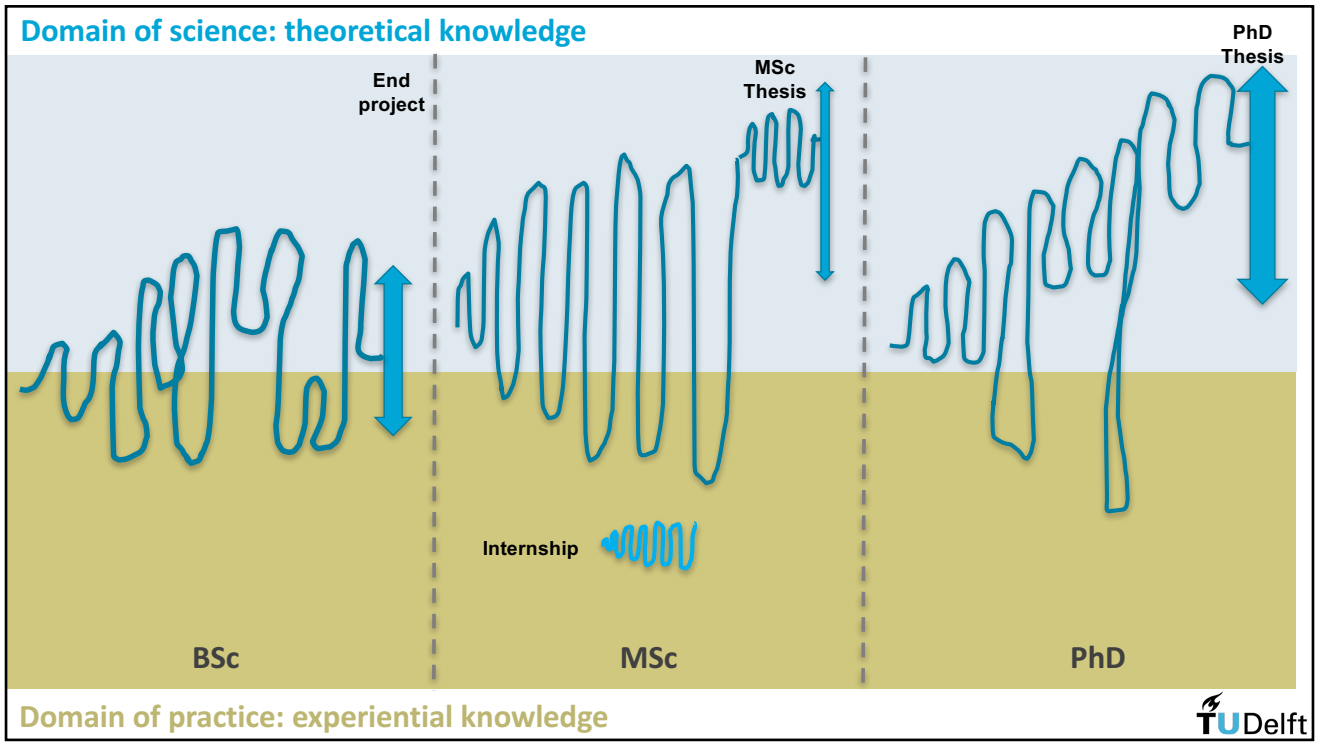

Domain of science: theoretical knowledge
BSc
MSc
PhD
Domain of practice: experiential knowledge
Future of Engineering Education 2040
Frido Smulders, Aldert Kamp, Clement Fortin
Moscow, 18-1
TU Delft


Domain of science: theoretical knowledge
End project
MSc Thesis
PhD Thesis
Internship
BSc
MSc
PhD
Domain of practice: experiential knowledge
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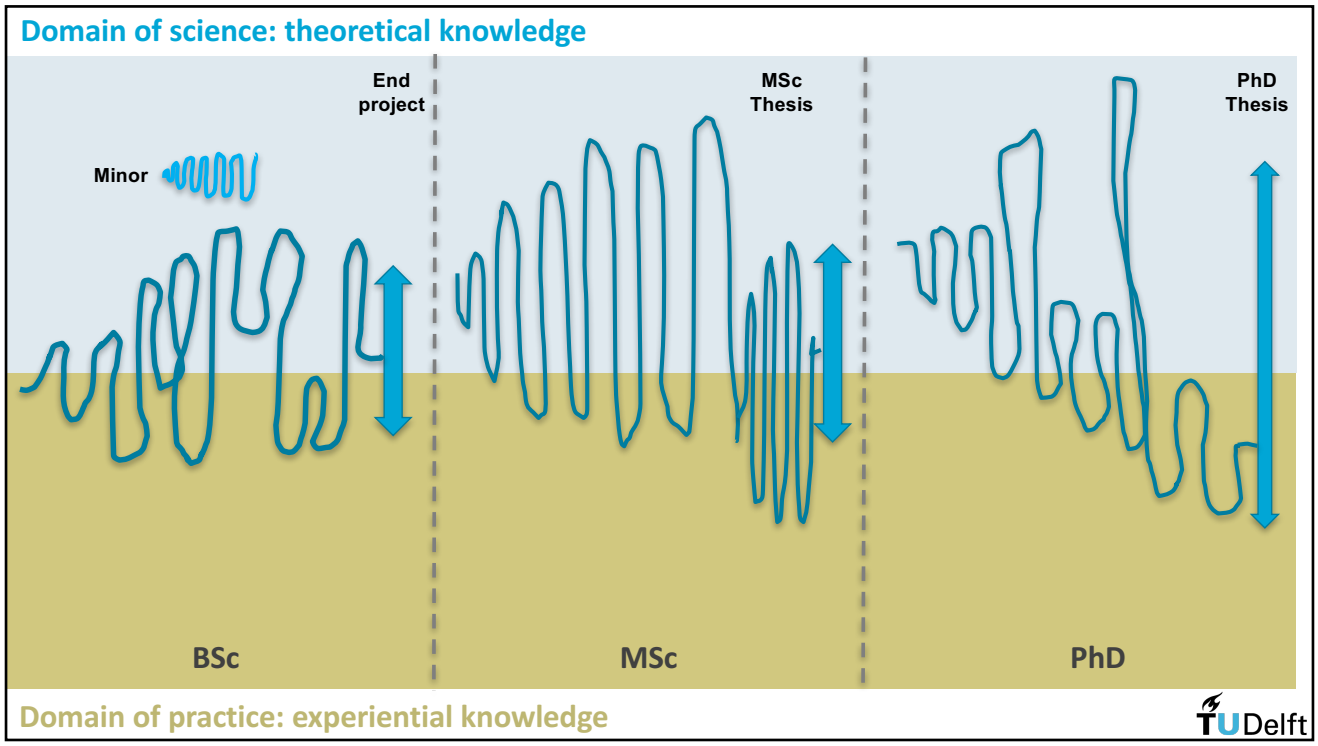
Domain of science: theoretical knowledge
End project
MSc Thesis
PhD Thesis
Minor
BSc
MSc
PhD
Domain of practice: experiential knowledge
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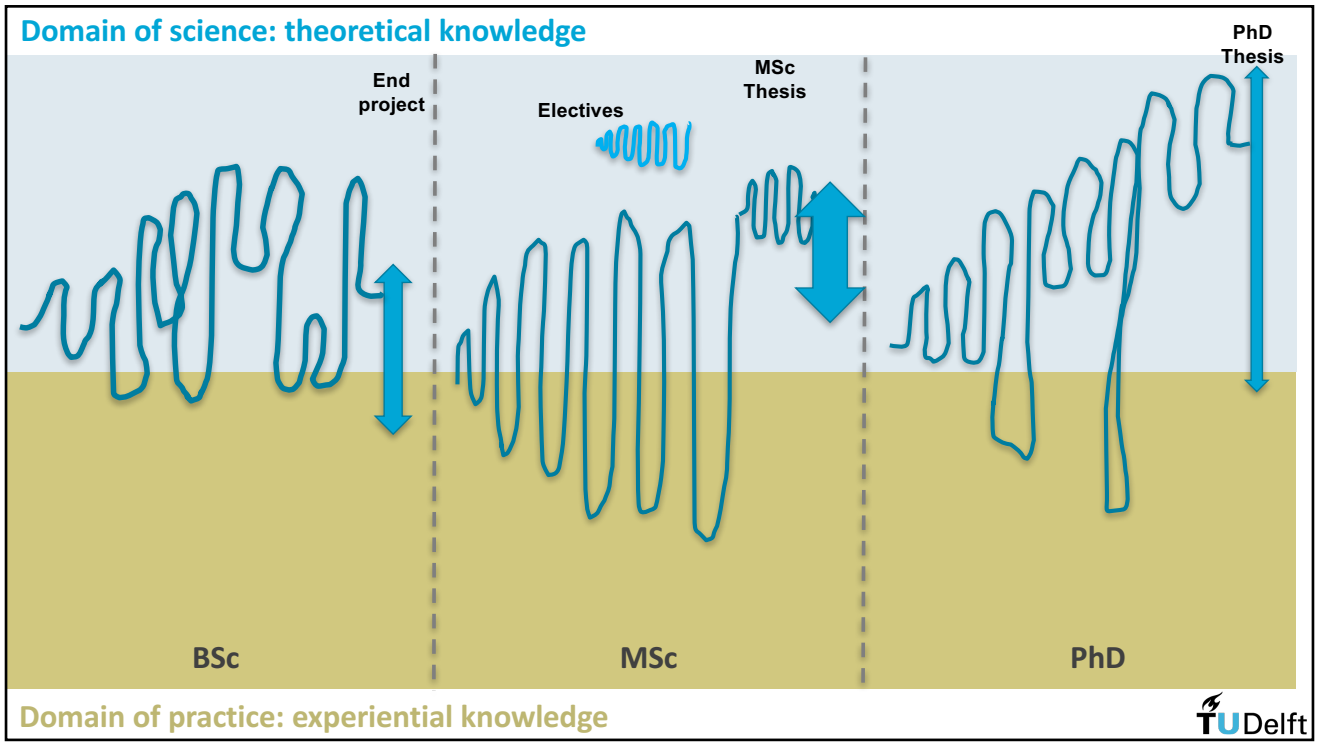
Domain of science: theoretical knowledge
End project
MSc Thesis
PhD Thesis
Electives
BSc
MSc
PhD
Domain of practice: experiential knowledge
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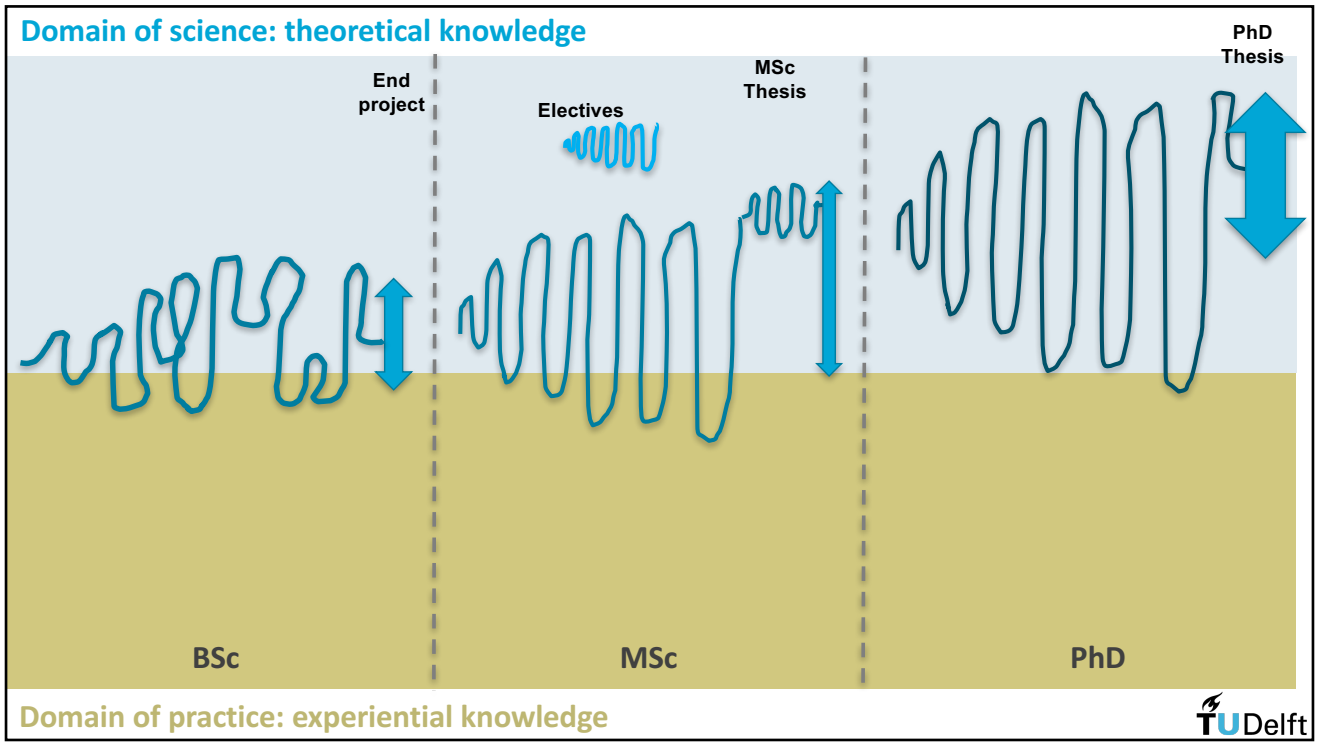
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End project
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MSc
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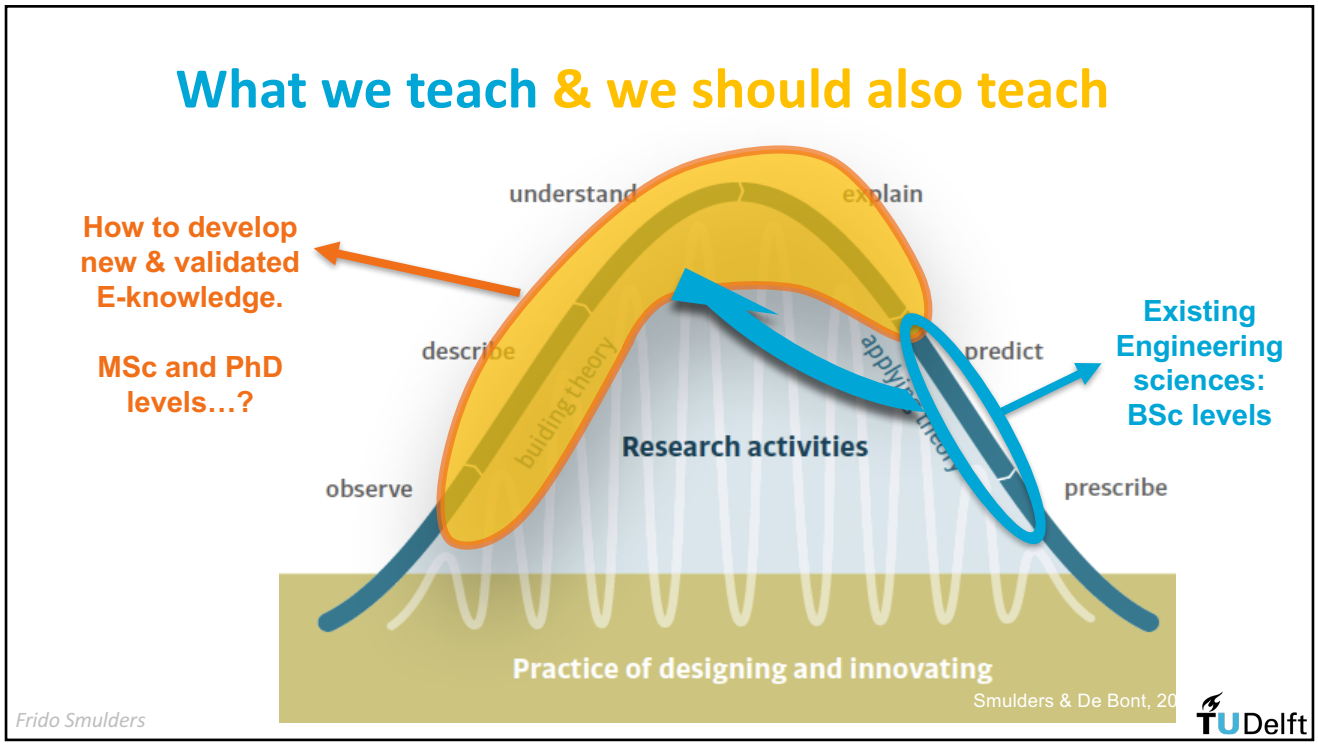
What we teach & we should also teach
How to develop new & validated E-knowledge.
MSc and PhD levels…?
understand
explain
describe
predict
building theory
Research activities
observe
prescribe
Existing Engineering sciences: BSc levels
Practice of designing and innovating
Smulders & De Bont, 20
Frido Smulders
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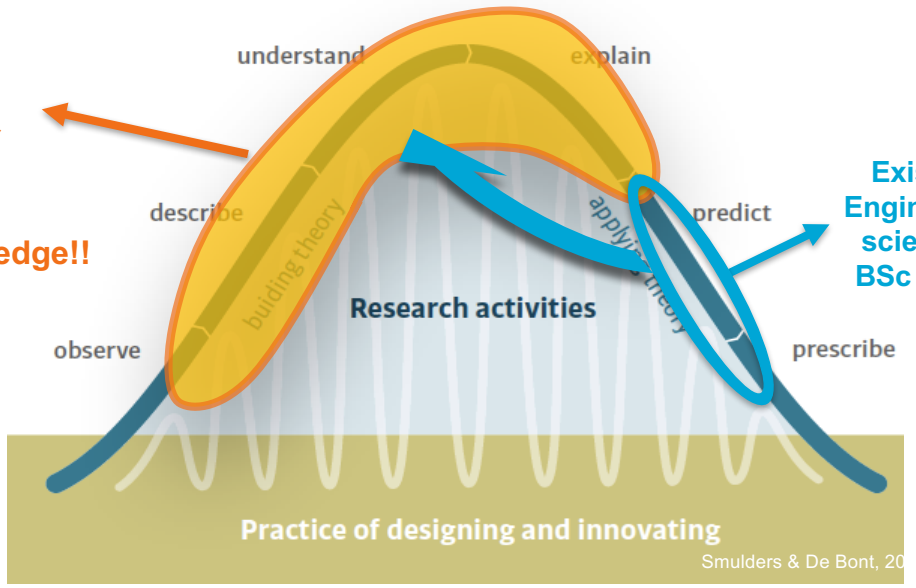
What we teach & we should also teach

Practice, Academic & scientific research:

Fledgling knowledge!!



Existing Engineering sciences: BSc levels

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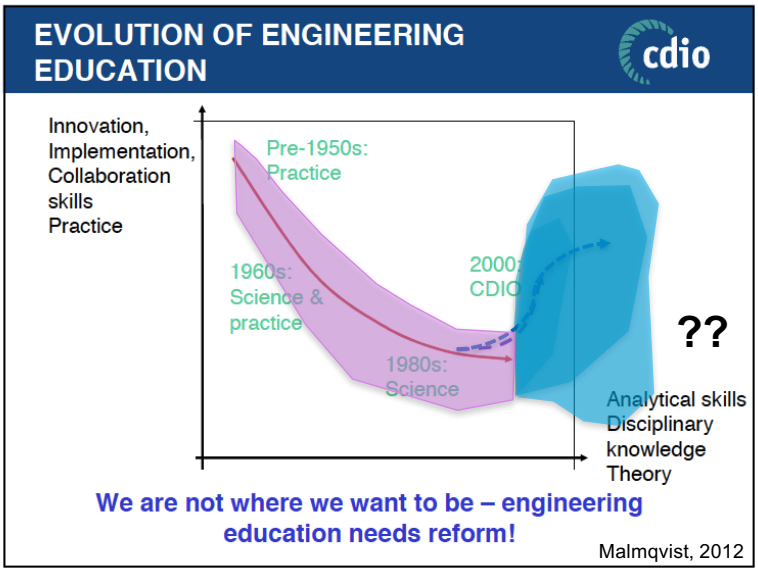
CDIO + range of teaching …



= Range of teaching

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Thank you!
Спасибо