Innovation in Engineering Education

Educating the engineer as a social responsible change agent

Anette Kolmos

UNESCO Chair in Problem Based Learning

http://www.ucpbl.net

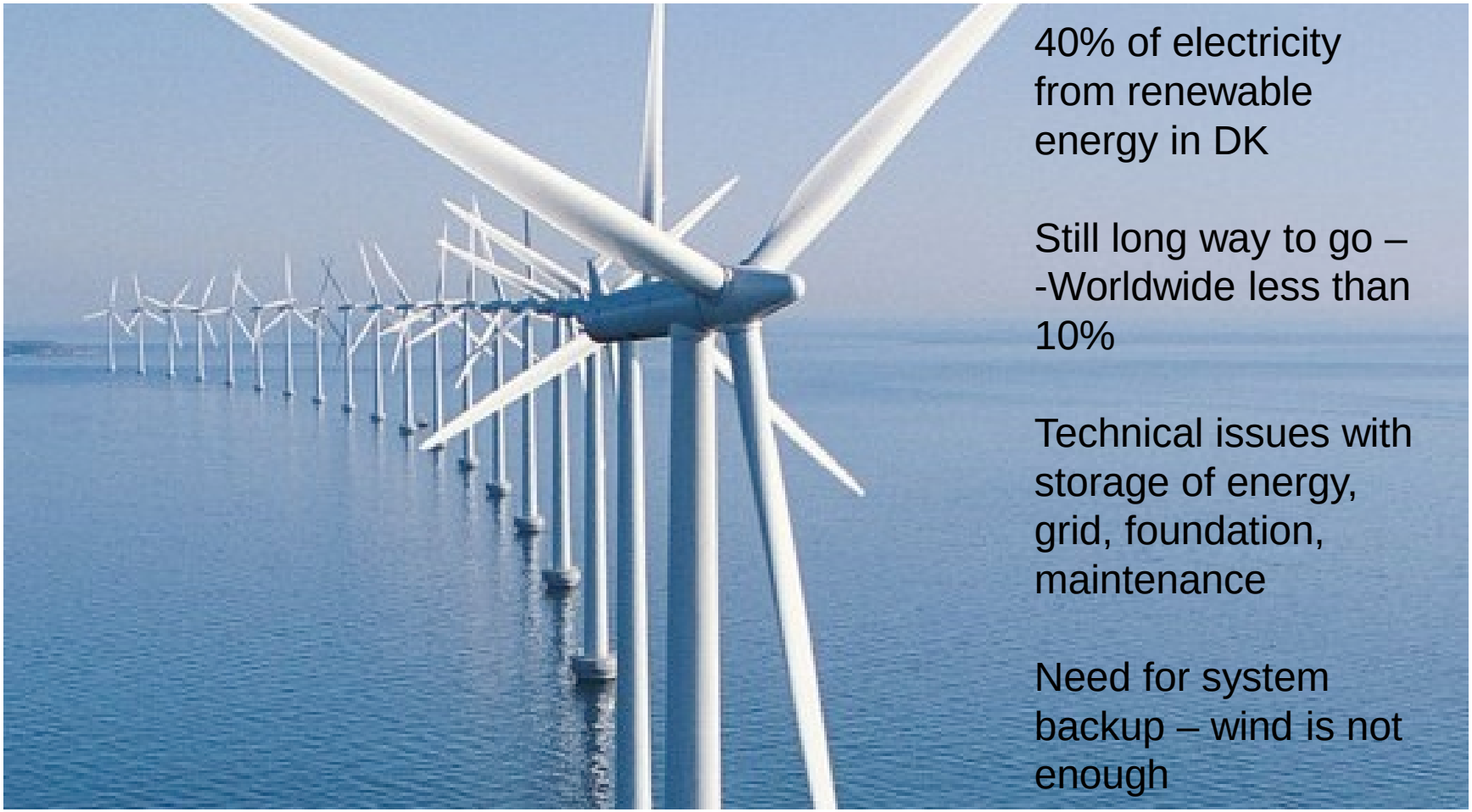
United Nations Educational, Scientific and Cultural Organization

UNESCO Chair in Problem Based Learning Aalborg University, Denmark

Educating the engineer as a social responsible change agent

- What are the problems engineers are going to solve?
- How do we integrate this into our engineering curricula?
- How can we facilitate a change in engineering education? – case of the UNESCO Chair

Change agent in and with innovation



40% of electricity from renewable energy in DK

Still long way to go – -Worldwide less than 10%

Technical issues with storage of energy, grid, foundation, maintenance

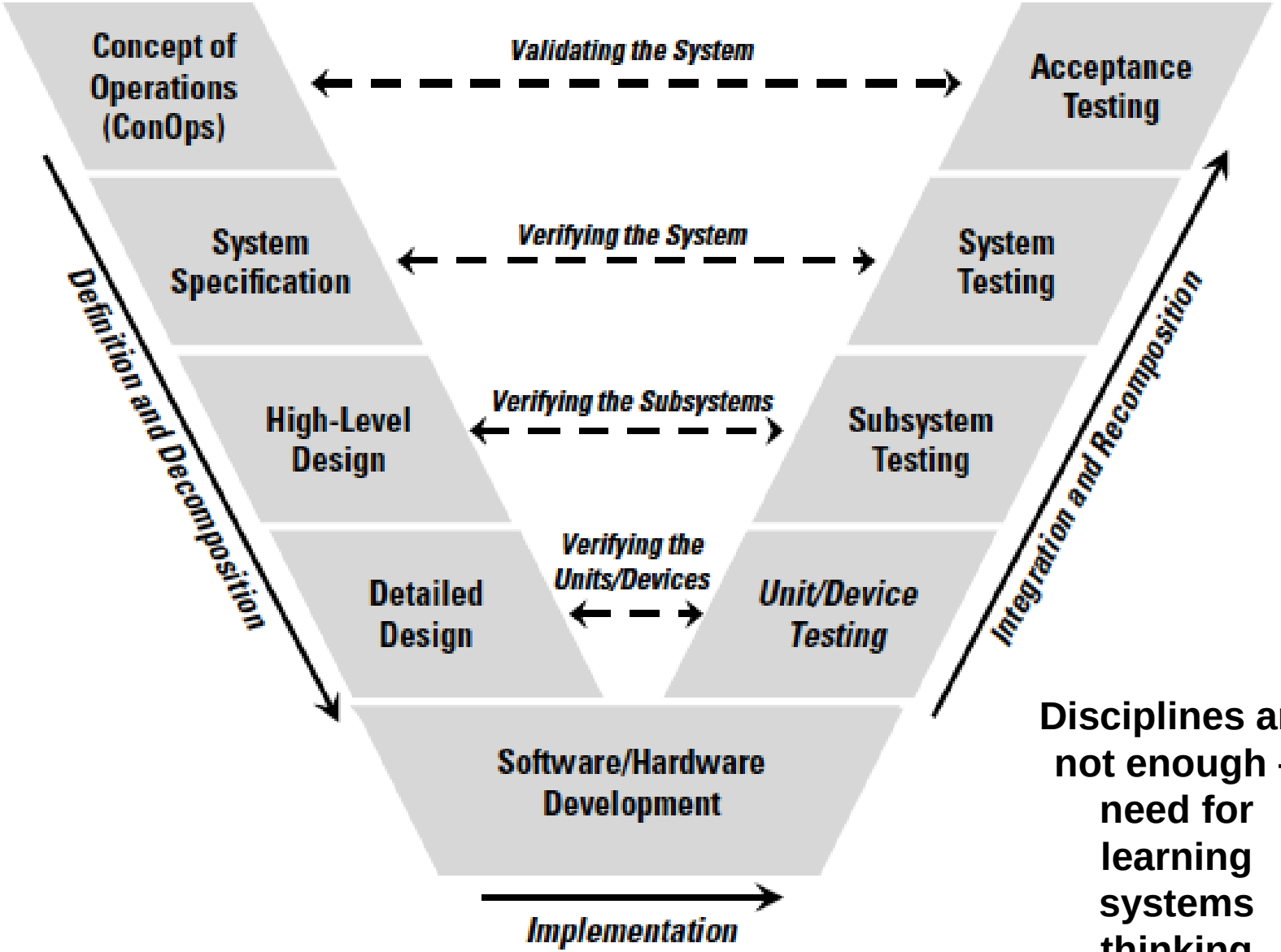
Need for system backup – wind is not enough

Work in complex systems – impact on society and people

- Water and Sanitation and Public Health
- Food
- Energy
- Transport
- Communications
- Security

http://images.businessweek.com/ss/08/10/1028_global_cities/&docid=FIrJkDDjWia23M&imgurl=http://images.businessweek.com/ss/08/10/1028_global_cities/image/intro.jpg&w=600&h=350&ei=oZQ9UqzdlaSI4ASryYGYBA&zoom=1

Requirements



Disciplines are not enough – need for learning systems thinking

From “Systems Engineering for Dummies” by Cathleen Shamieh

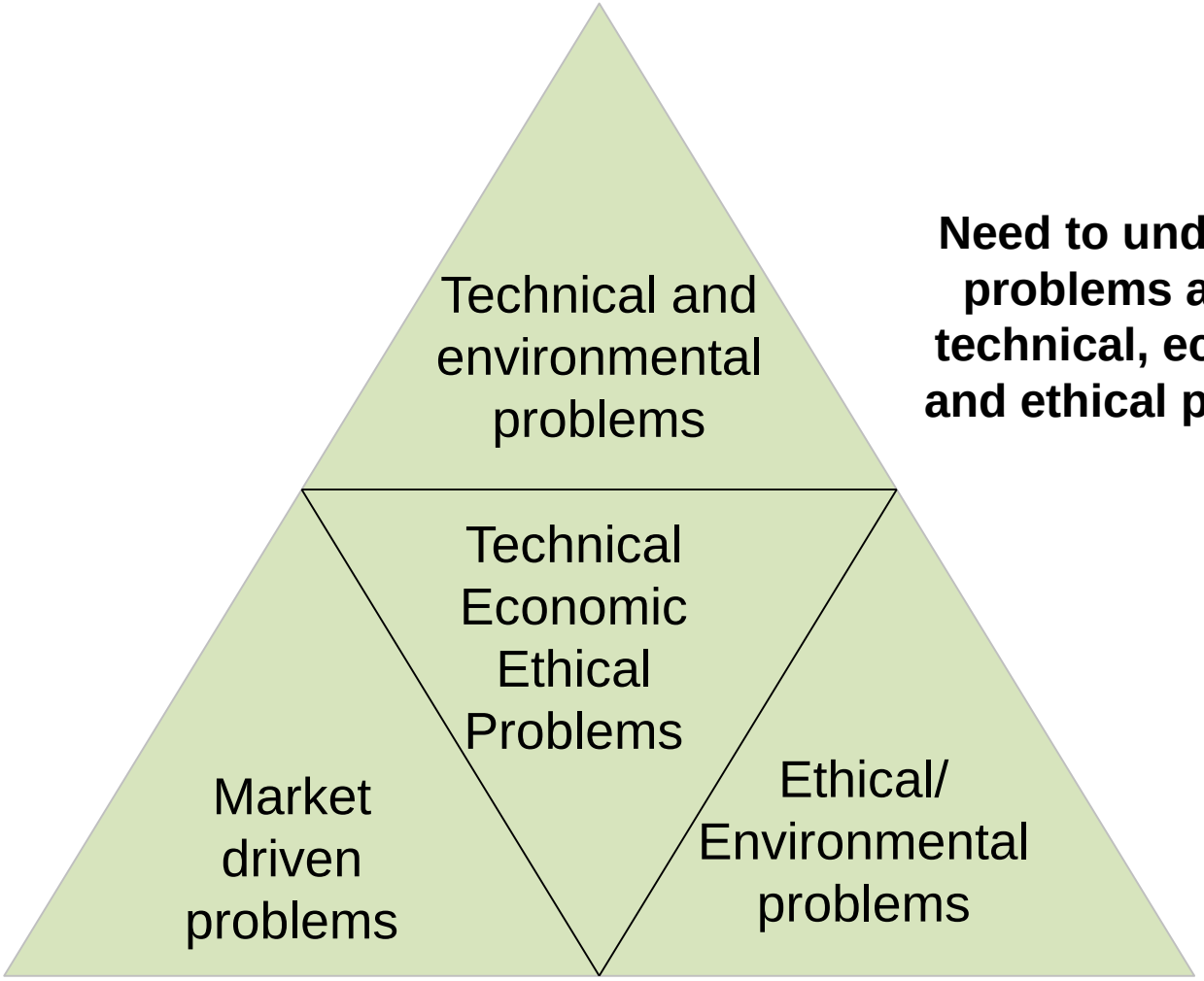
Not all the issues are solved…also look at problems….

http://southasiarev.wordpress.com/2010/01/09/sanhati-development-terrorism-in-india/

300 million Africans have no access to safe drinking water

http://moonofthesouth.com/300-million-africans-access-safe/

Acedemic/ Scientific/Technical



Need to understand problems as both technical, economic and ethical problems

Jamison, Kolmos, Holgaard: Aalborg University

Entrepreneurial

Social/Ethical

Types of competence approaches

	Academic	Entrepreneurial and economic	Social ethical
A new profession	Expert Policy advisor	Entrepreneur Project manager Global Market	Citizen Change agent Global civil society
Knowledge	Scientific (sub) disciplinary	Instrumental Cross disciplinary	Reflective Transdisciplinary Sustainability
Education and learning	Scholastic Theoretical By the book	By doing Problem solving Collaborative with companies	Situated Problem analysis Student centred Participant directed
Types of projects	Discipline projects	Company projects	Open problem projects

Innovative and creative competences

(Jamison, Kolmos and Holgaard, 2014

Say hello the person next to you

- Present your self

- Does the points make sense?

Education of the engineer as a social responsible change agent

- What are the problems engineers are going to solve?
- **How do we integrate this into our engineering curricula?**
- How can we facilitate a change in engineering education? – case of the UNESCO Chair

How do we integrate this into our engineering curricula?

Add on strategy	Linear block system	Single courses
Integration strategy	System approach CDIO, active learning and narrow problems	Institutional re-organisation Critical reflection on and in action + Collaboration with companies
Re-building strategy	System approach Problem and project based learning	"Building a new institution" Rethink values, academic identity, commitment, Collaboration with companies and society

Holgaard, 2009 with inspiration from Sterling 2002

Add on strategy: Mechanical Engineering (example)

	Year 1	Year 2	Year 3	Year 4
Semester 1	Engineering, Society and Sustainability	Renewable Energy Systems	Management of Design	Professional Project Part 1
	Engineering Design 1	Mechatronics Principles	Solid Mechanics 3	Technical elective 1
	Engineering Mathematics 1	Solid Mechanics and Materials	Dynamics and Control	Technical elective 2
	Engineering Mechanics	Mechanics of Machines 1	Mechanics 3	General elective 2
Semester 2	Manufacturing Systems	Mechanical Design 1	Mechanical Design 2	Professional Project Part 2
	Engineering Mathematics 2	Mathematics and Statistics	Mechanics of Machines 2	Technical elective 3
	Solid Mechanics and Materials 1	Thermo-Fluid Mechanics 2	Introduction to	echnical elective 4
	Thermo-Fluid Mechanics	General Elective 1	Engineering and Enterprise	General elective 3

Sustainable Design and systems

Project management and collaboration

Hadgraft, 2013, keynote at SEFI annual conference

Add on strategy:
Single course strategy for change

Semester 4	Traditional lecture class	Traditional lecture class	Traditional lecture class	Traditional lecture class
Semester 3	PBL/active learning	Traditional lecture class	PBL/active learning	Traditional lecture class
Semester 2	Traditional lecture class	Traditional lecture class	Traditional lecture class	Traditional lecture class
Semester 1	Traditional lecture class	Traditional lecture class	Traditional lecture class	PBL

Disadvantages with this strategy: uncoordinated, non stable, overloaded curriculum,

Add on strategy: Active learning in courses Reduction of contact hours

Traditional curriculum		
lectures	Students individual work	Assessment

Active learning curriculum

Lectures	Team work	Assessment

Strategies for reduction of lectures

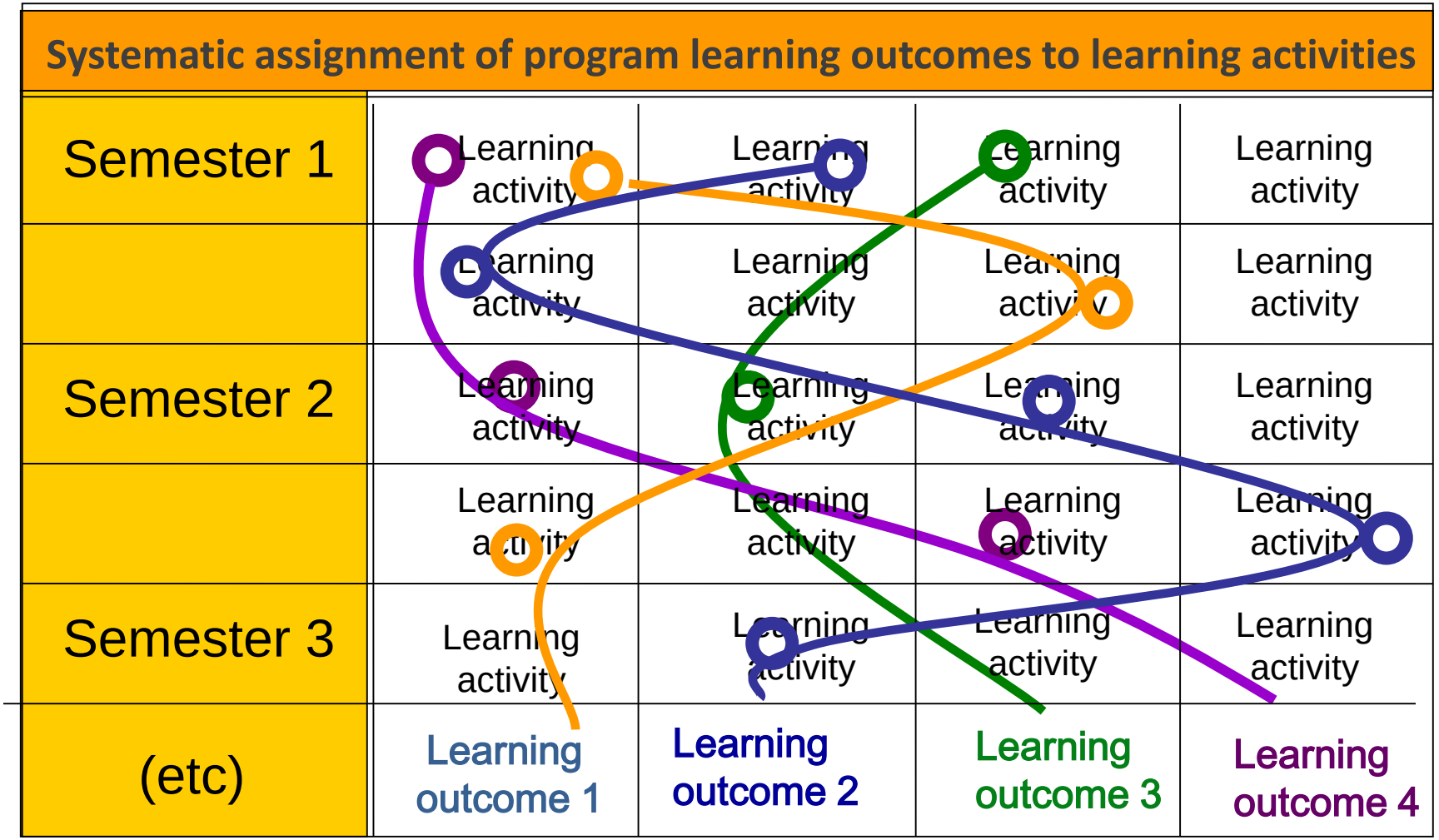
- Re-selection
- Speed mode
- Laissez faire

Kolmos, A 2002, 'Facilitating Change to a Problem-based Model' *International Journal for Academic Development*,

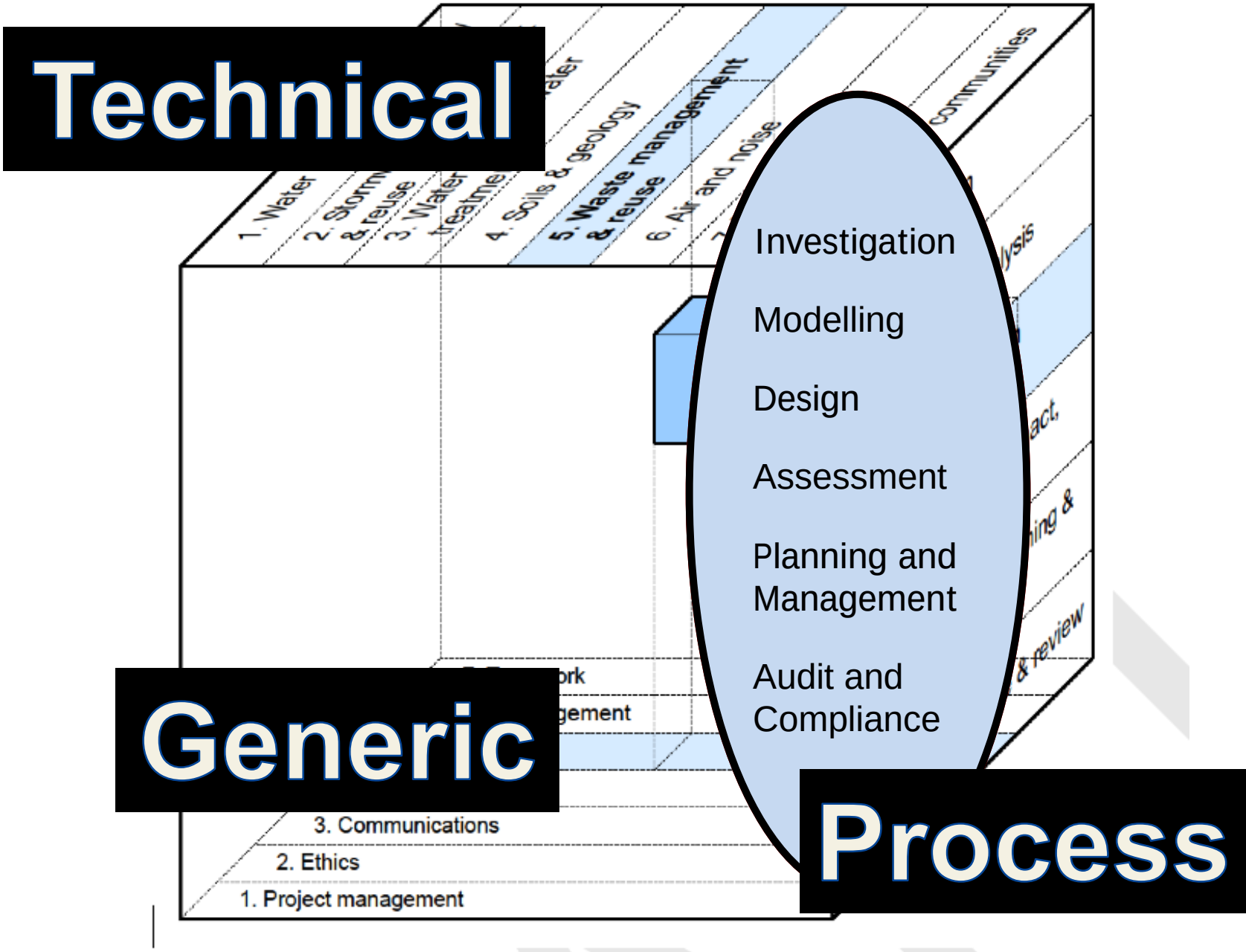
Integration strategy

- Mapping strategy of knowledge, skills and competences
- Define your discipline and the learning outcomes
- Go for bigger courses across disciplines
- Integration of company projects

Integration strategy
Mapping the courses and integrate new skills(CDIO)



Edström, 2012



Dowling, D. G. and R. G. Hadgraft (2012). What do we teach? Defining your discipline to drive curriculum renewal: an environmental engineering case study SEFI 2012. Thessaloniki, Greece, SEFI:

Integration strategy for change
Grouping and merging the disciplines

	Year 1	Year 2	Year 3	Year 4
Semester 1	Engineering, Society and Sustainability Engineering Design 1	Renewable Energy Systems Thermo-Fluid Mechanics	Management of Design Engineering and Enterprise	Professional Project Part 1 Technical elective 1
	Engineering Mathematics 1	Solid Mechanics and Materials 2	Dynamics and Control	Technical elective 2
	Engineering Mathematics 2	Mathematics and Statistics	Mechanics of Machines 2	General elective 2
Semester 2	Engineering Mechanics	Mechanical Design 1	Mechanical Design 2	Professional Project Part 2
	Solid Mechanics and Materials 1	Mechanics of Machines 1	Thermo-Fluid Mechanics 3	Technical elective 3
	Manufacturing Systems	Thermo-Fluid Mechanics 2	Solid Mechanics 3	Technical elective 4
	Mechatronics Principles	General Elective 1	Introduction to Computational Engineering (FEM)	General elective 3

A project-based curriculum …

Theme	Year 1	Year 2	Year 3	Year 4
Social, Environmental Economic	Engineering, Society, Sustainability and Self	User-Centred Engineering	Engineering Entrepreneurship	Engineering for Business
Modelling	Mathematical Modelling	Modelling Failure (including Statistics)	Computational Solid and Fluid Mechanics	Industry Project 1
Structures and Machines	Design of Structures and Machines	Design and Control of Machines	Advanced Manufacturing Systems	Industry Project 2
Thermo-Fluids	Design of Thermo-Fluid Systems	Design of Renewable Energy Systems	Energy Efficiency	Industry Project 3

From integration to re-building

Problem analysis

Re-building

+ ethical and social

Problem solving

Integration

Rebuilding strategy

- Define your discipline and the learning outcomes
- Go for bigger courses
- Mapping strategy of knowledge, skills and competences
- Integration of company and society projects
- Emphasize on problem identification, problem analysis, problem solving and underlying values.
- Participant directed learning and open projects

A project-based curriculum 2 …

Theme	Year 1	Year 2	Year 3	Year 4
Social, Environmental Economic	Engineering, Society, Sustainability and Self	User-Centred Engineering	Engineering Entrepreneurship	Engineering for Business
Modelling	Mathematical Modelling	Modelling Failure (including Statistics)	Green Building Design	Electric Vehicle Design
Structures and Machines	Design of Structures and Machines	Design and Control of Machines	Manufacturing for Sustainability	Social Responsibility and Engineering
Thermo-Fluids	Design of Thermo-Fluid Systems	Design of Renewable Energy Systems	Energy Efficiency for Industry	Industrial Design for Sustainability and ethics

Summing 2

- Now in teams of 4

- Would this be possible in your institution – to use integration or re-building strategy?

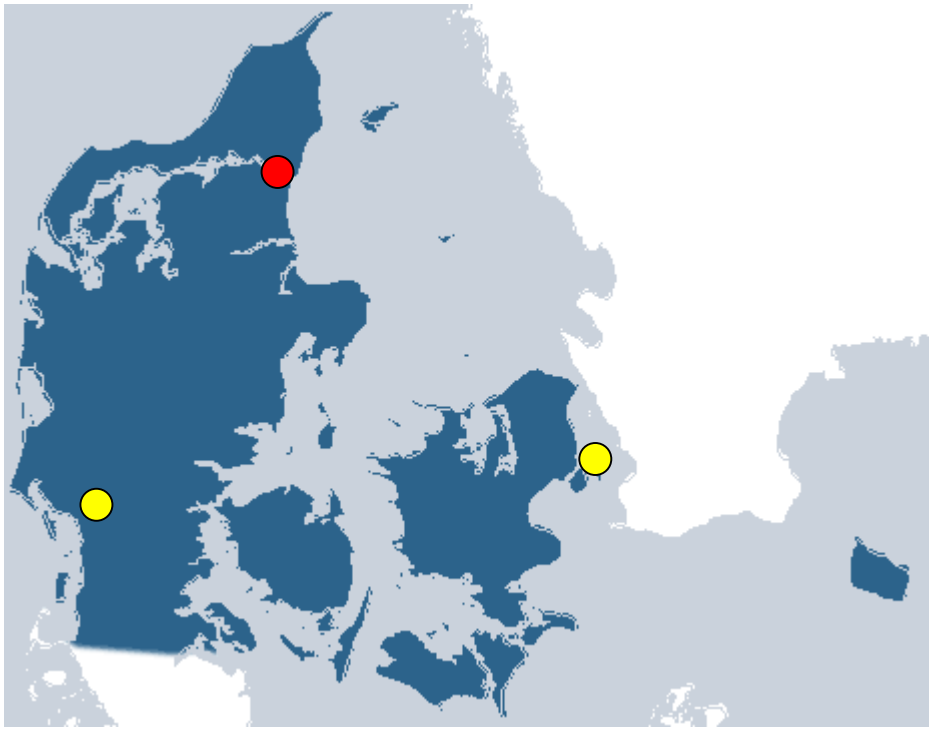
Rebuilding cases – Olin College, Boston, established in 2002

Design studio Olin College

Design studio Olin College

Another new institution: **Aalborg University, 1974**

- Founded 1974
- Faculties:
  - Humanities (2 departments)
  - Social Sciences (5 departments)
  - Engineering and Science (11 departments)
  - Medicine (1 department)
- 18 Departments
- National Building Research Institute (SBi), Cph
- > 18,500 students
- Campuses:
  - Aalborg (Main)
  - Esbjerg
  - Copenhagen



Aalborg University – 1974 and reform university

Project organized/based

- formulation of objectives and problems
- unique and complex tasks
- active searching and writing process which may lead to deeper understanding
- Teamwork
- deadlines

Aalborg model
Problem based

Problem based – open

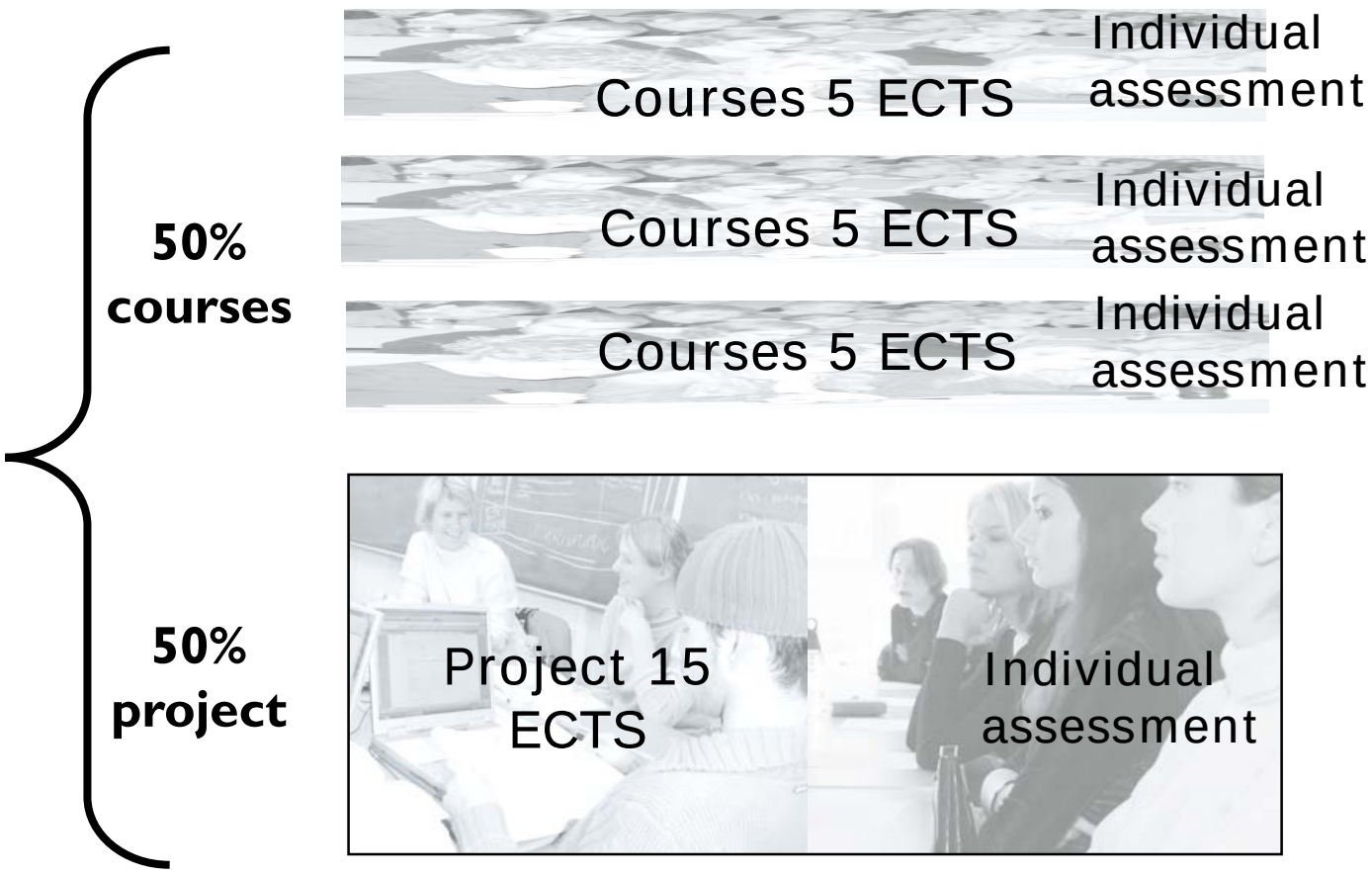
- methodical objectives
- problem based themes –

- ill defined problems
- learner directed
- interdisciplinary
- exemplarity

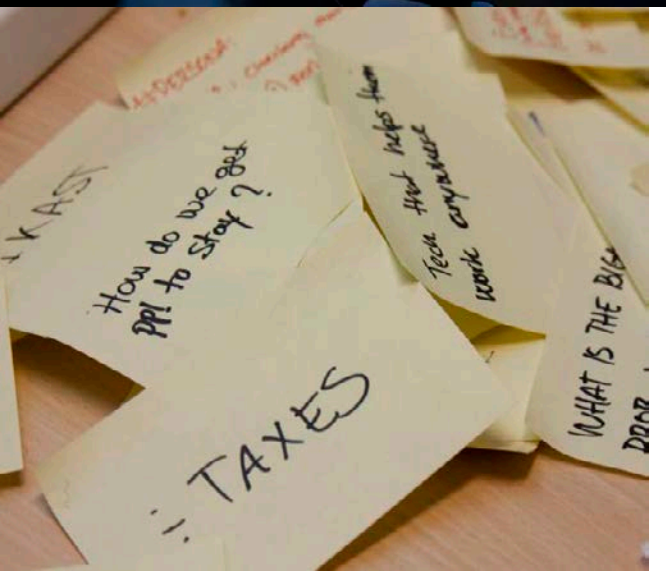
Discipline based – narrow

- subject objectives
- methodological/discipline themes
- subject understanding
- “Well defined problems”
- learner and teacher controlled
- disciplines
- exemplarity

The new Aalborg Model

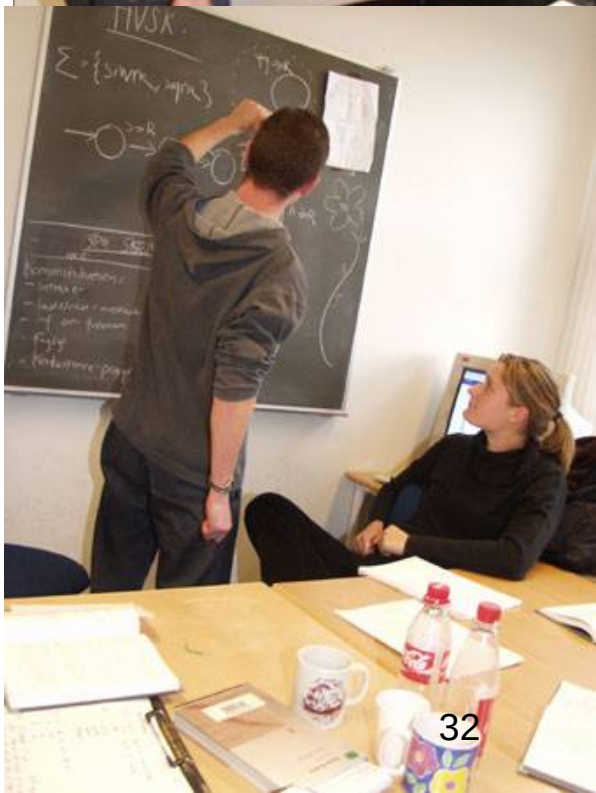


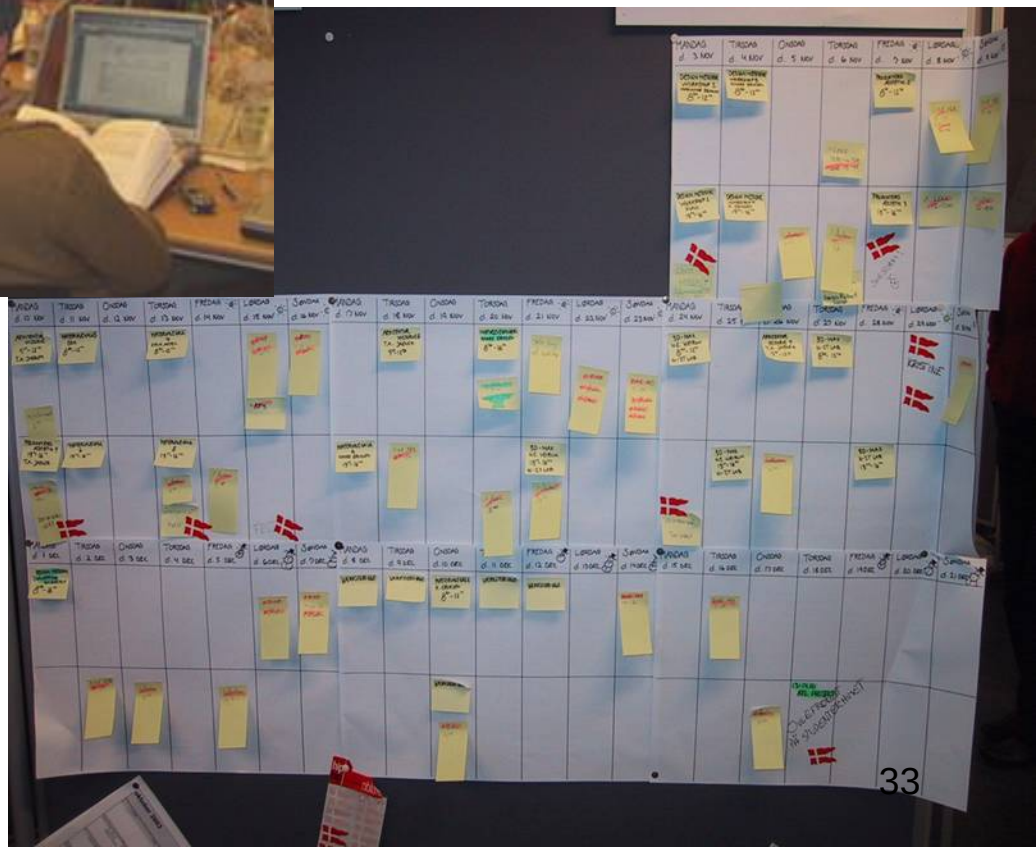
1 ECTS (European Credit Transfer System)
= 30 working hours



One project per semester

15 ECTS = 450 hours of student work



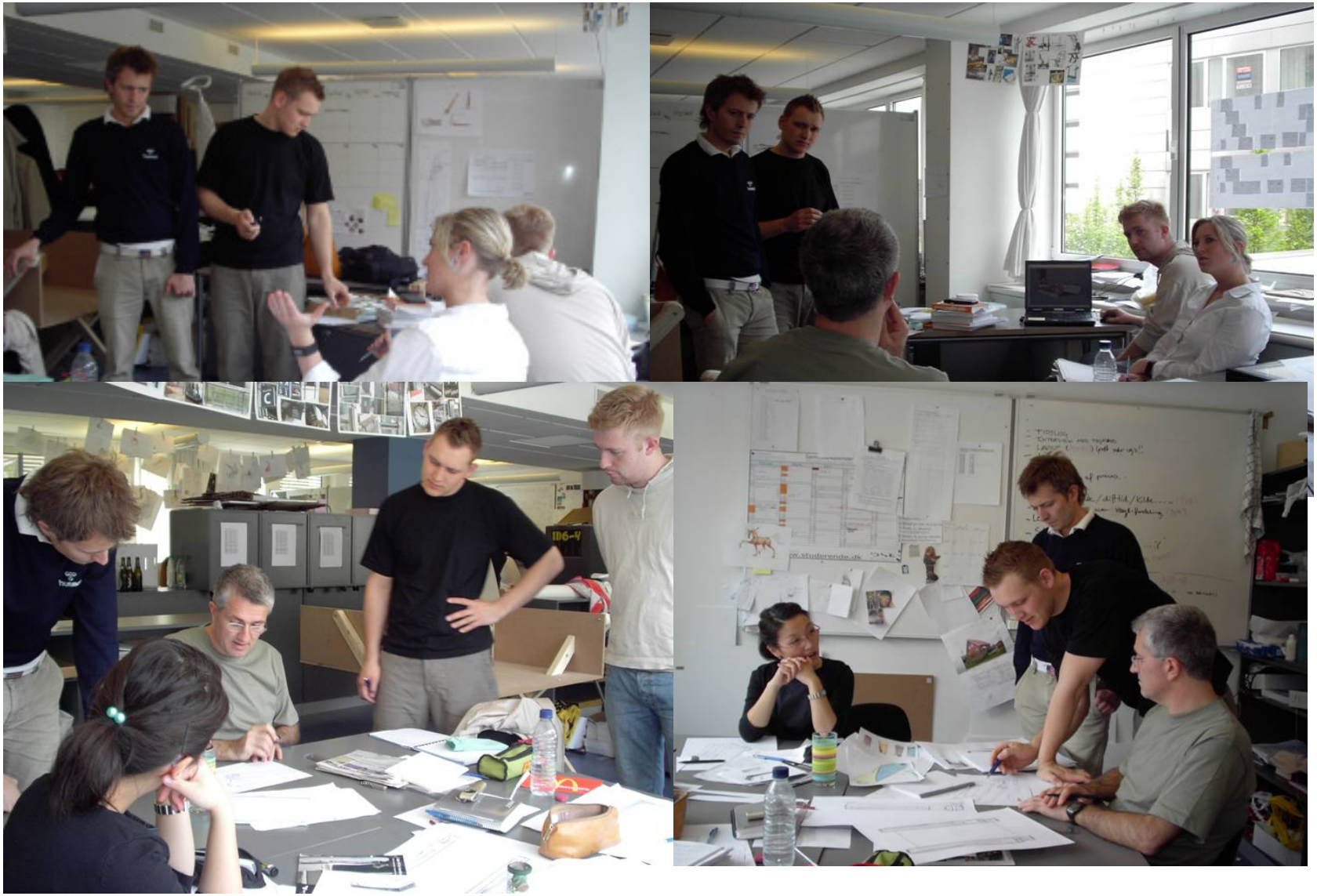


Self organised groups

Project management

Courses, lectures, seminars

Facilitation and supervision



Diversity of physical facilitation
More than 1400 rooms for teams

PBL Cases
”The impossible”

- **Project**: Understand, Map and try to improve business processes at Printca A/S (circuit boards manufacturer)

- But i don’t know anything about circuit boards – or manufacturing?

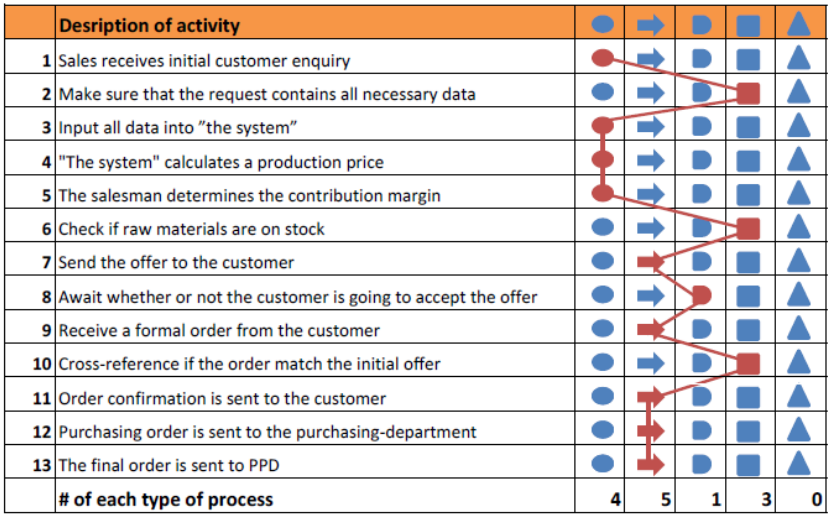
Vestergaard, 2012

PBL Cases
”The impossible”

Vestergaard, 2012

PBL project: ”The impossible”

- **Result:**
  - Understanding the importance of scope.
  - Understanding how to map a business process
  - Understanding how to make a 100 page report in collaboration with 4 others
  - Giving actual, usable suggestions to the case company
  - … still not knowing anything about circuit boards!



	Desription of activity					
1	Sales receives initial customer enquiry					
2	Make sure that the request contains all necessary data					
3	Input all data into ”the system”					
4	"The system" calculates a production price					
5	The salesman determines the contribution margin					
6	Check if raw materials are on stock					
7	Send the offer to the customer					
8	Await whether or not the customer is going to accept the offer					
9	Receive a formal order from the customer					
10	Cross-reference if the order match the initial offer					
11	Order confirmation is sent to the customer					
12	Purchasing order is sent to the purchasing-department					
13	The final order is sent to PPD					
	# of each type of process	4	5	1	3	0

Vestergaard,

PBL project: ”The impossible”

- **Semester topics:**
  - Product development
  - Marketing
  - Production planning
  - Budgeting

- **Project topic:** Create a fictional manufacturing facility somewhere in the world, that should produce all LEGO mini figures
  - **Invent new ways of using the mini figure**
  - **Market this new product**
  - **Produce this new product**
  - **Account for the financing of producing this new product**

Vestergaard, 2012

PBL- learning principles

Learning
Problem
Project organised or case based
Contextual learning
Activity based

Social
Participant directed
Team based learning

Content
Theory-practice/context
Interdisciplinary learning
Exemplary learning

PBL designs for different purposes

Subject based ⟷ **Problem based**

Cases ⟷ **Projects**

Academia ⟷ **Contextualisation**

Teacher directed ⟷ **Participant directed**

Individual learning ⟷ **Peer learning** ⟷ **Collaboration**

Disciplinary ⟷ **Interdisciplinary** ⟷ **Trans-disciplinary**

Knowledge ⟷ **Skills** ⟷ **Competences**

Text book learning ⟷ **Exemplary learning**

Theory ⟷ **Practise**

Education of the engineer as a social responsible change agent

- What are the problems engineers are going to solve?
- How do we integrate this into our engineering curricula?
- **How can we facilitate a change in engineering education? – case of the UNESCO Chair**

Work in the UNESCO Chair

- Established in 2007
- Research and research training
  - 15 PhD studerende
    - Creativity and mega projects (satellit),
    - Organisational change to PBL
    - PBL and the subject identity
    - Design of PBL curricula in Thailand, India og Malaysia
    - Intercultural learning in teams
    - PBL and sustainability – strategies for implementation
- Master education in PBL
- Consultancy

Research symposia Malaysia, 2013


st International Conference on
Mobility for Life:
Technology, Telecommunication and Problem Based Learning
5-7 March 2012
Mae Fah Luang University, Chiang Rai, Thailand

Thailand

Malaysia
Joint PhD programme with UTM

Singhad Institute, India

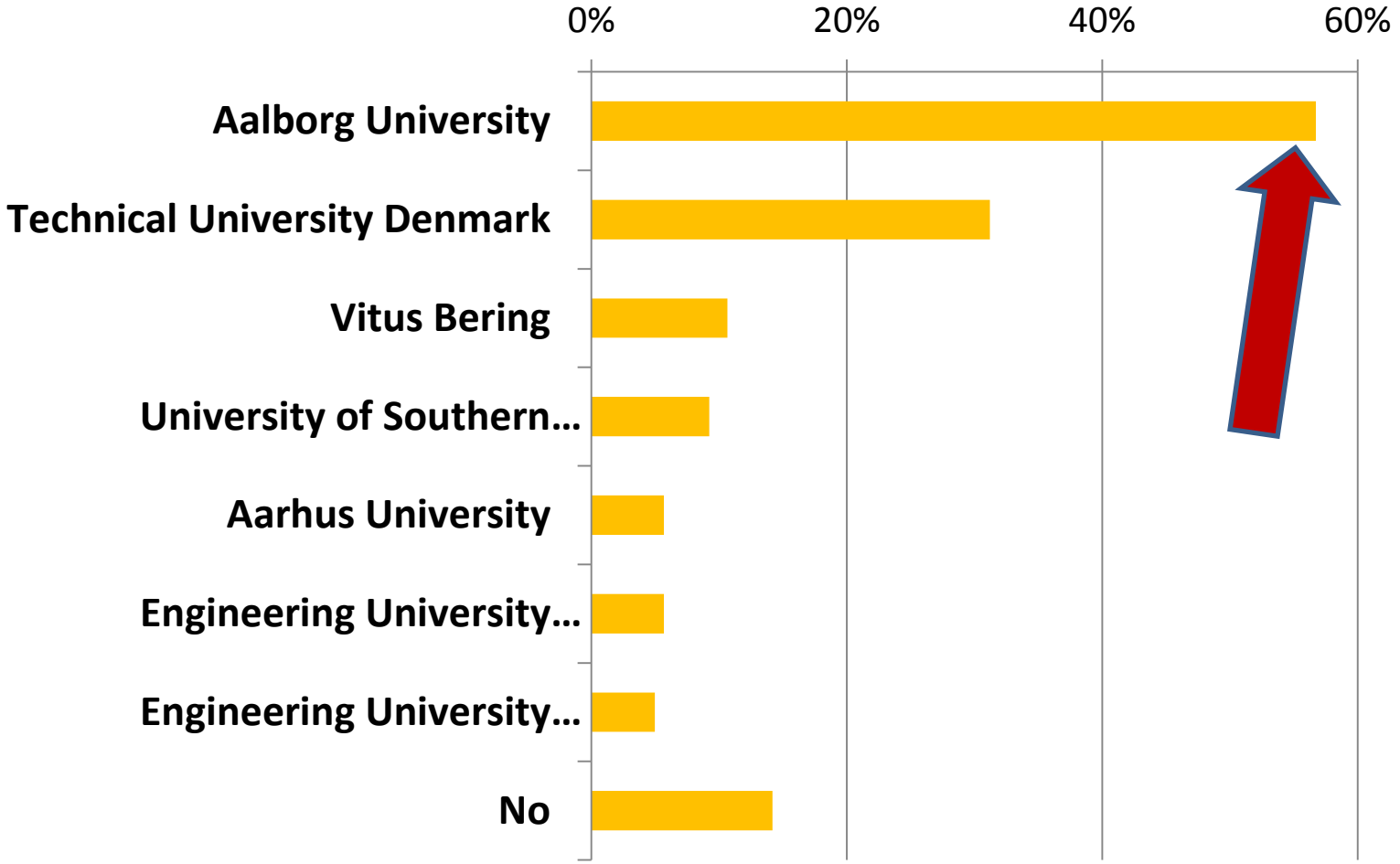
- Training
- PhD scholarships

Chile – training and master

Victoria University/Australia combined with learning in the work place

30 participants from Victoria university MPBL

Are there one or more institutions which you find particular good at developing engineering education according to the needs of society and companies? (Ingeniøren, 2008)



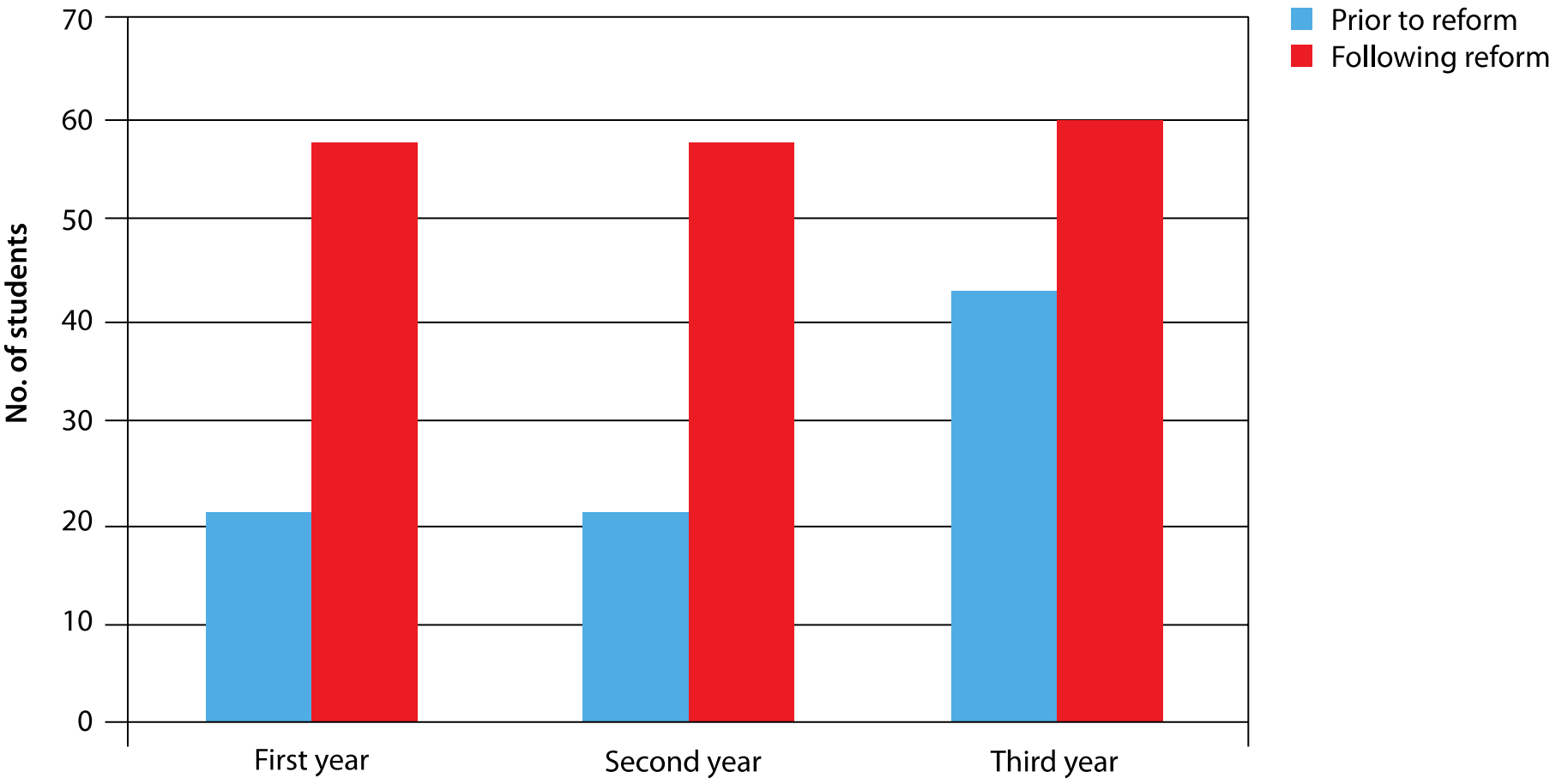


Figure 6. Percentage of students achieving the two highest attainment classifications (1st and 2:1), comparing average scores before and since reform was implemented in that year of study. Data taken from attainment score from 2002–2010.

Problem and project – PBL programmes

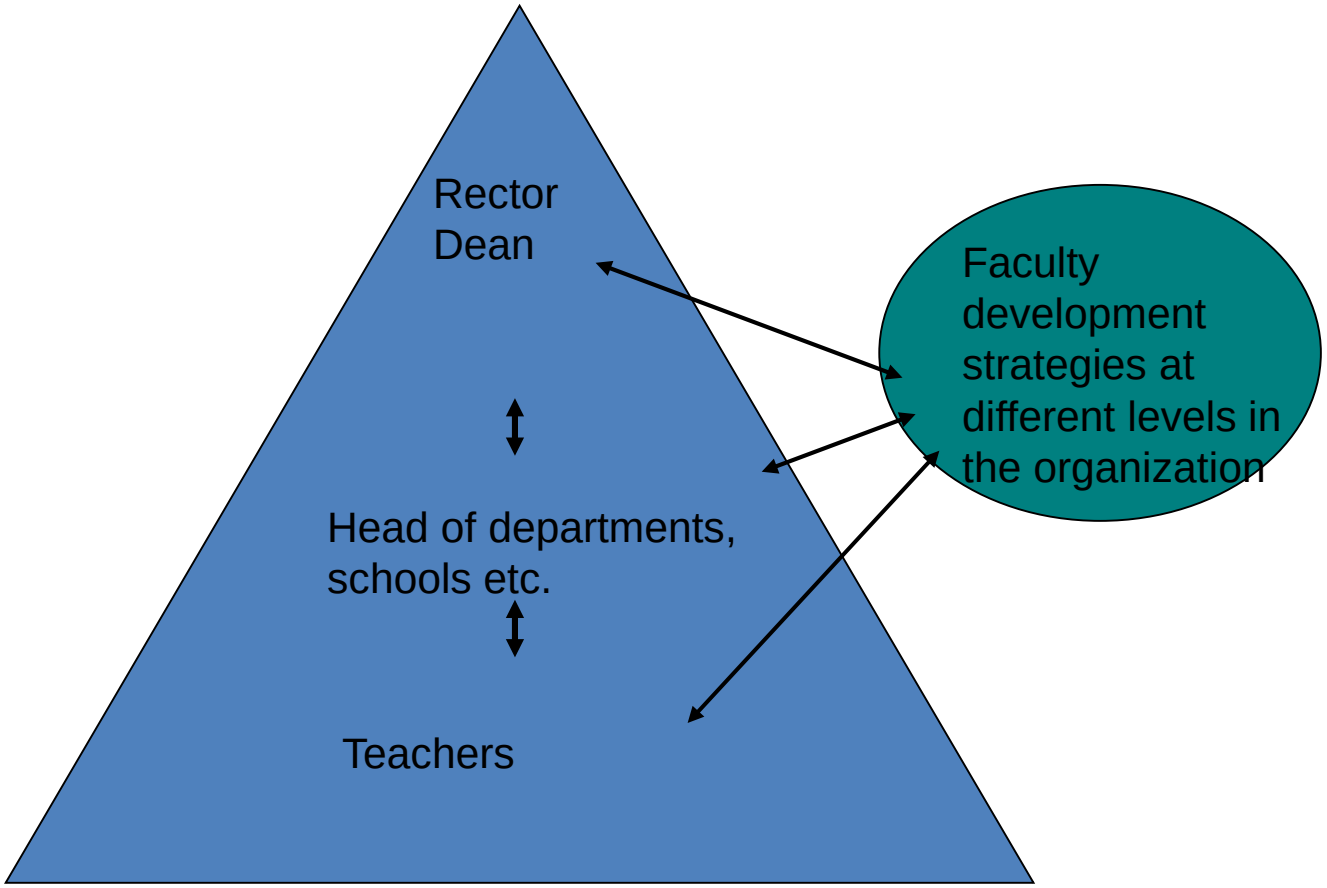
- More motivated
- Deeper learning
- Increased skills and competences
- Higher grades

- Employability increased – relevant skills process skills: collaboration, project management… etc.

- Higher retention
- Faster duration
- Higher salary after ten years from enrollment


I have never ever seen institutional change without external pressure ……..
Accreditation, bologna, retention rates/resources

Motivation and decision phase



Radical change need both bottom up and top-down decision

Vision +	Consensus +	Skills +	Incentives +	Resources +	Action Plan +	= Change
	Consensus +	Skills +	Incentives +	Resources +	Action Plan +	= Confusion
Vision +		Skills +	Incentives +	Resources +	Action Plan +	= Sabotage
Vision +	Consensus +		Incentives +	Resources +	Action Plan +	= Anxiety
Vision +	Consensus +	Skills +		Resources +	Action Plan +	= Resistance
Vision +	Consensus +	Skills +	Incentives +		Action Plan +	= Frustration
Vision +	Consensus +	Skills +	Incentives +	Resources +		= Treadmill

Knoster/Moesby

Kolmos, A 2010, 'Premises for Changing to PBL' *International Journal for the Scholarship of Teaching & Learning*, vol 4, nr. 1

Issues – challenges?

ak@plan.aau.dk

http://www.ucpbl.net