Engineering education reform with CDIO:

“Educating engineers who can engineer...”

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Kristina Edström

- Educational developer at KTH since 2001
  - Lecturer in Engineering Education Development
  - M. Sc. in Engineering (Chalmers)
- Strategic educational development at KTH, in Sweden and internationally
  - CDIO Initiative since 2001
  - SEFI Administrative Council since 2010
- Faculty development
  - So far 527 participants have taken Teaching and Learning in Higher Education (7.5 ECTS credits) at KTH
- Honours
  - KTH Education Prize 2004
  - Lifetime honorary member of the Student Union at KTH since 2009
Developed jointly by KTH, Chalmers, Linköping University and MIT, starting in 2000

Stakeholder perspectives

- Alumni
- Employers
- Students (present and future)
- Society
- Faculty (as researchers and teachers)

Engineering Education
Faculty perspective

Quality of student learning

If didn’t "get it" - passed exam

If "got it" - failed exam

Conceptual understanding

- Not just reproduction of known solutions to known problems
- Being able to explain what they do and why
- Deeper working knowledge


Work life perspective I

Disciplinary theory applied to “Problem-solving”

NECESSARY BUT NOT SUFFICIENT

Theory and judgement applied to real problems

Real problems

- are complex and ill-defined and contain tensions
- need interpretations and estimations
- cross disciplinary boundaries
- sit in contexts with societal and business aspects
- require systems view
Work life perspective II

Individual approach

Communicative and collaborative approach

- Communication and dialogue is crucial for all engineering work processes – they involve customers, suppliers, colleagues, citizens, authorities, competitors...
- Collaboration is much more than just being able to work within project teams on specific tasks – it is networking within and across organizational boundaries, in a globalized world
- Technical solutions/systems always sit in a social context

NECESSARY BUT NOT SUFFICIENT

Work life perspective (conclusion)

Education set in the context of: Engineering science

NECESSARY BUT NOT SUFFICIENT

Educate for the context of: Engineering practice

- Engineers who can engineer!
The strategy is integrated learning of knowledge and skills

Skills are context-dependent and should be learned and assessed in the technical context.

Systematic integration of disciplinary knowledge and engineering skills

<table>
<thead>
<tr>
<th>Development routes (schematic)</th>
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<tr>
<td><strong>Year 1</strong></td>
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<td><strong>Year 2</strong></td>
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<td><strong>Year 6</strong></td>
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<td><strong>Year 7</strong></td>
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Skills are enabling for engineering

Communication in engineering means being able to
► use the technical concepts comfortably,
► discuss a problem at different levels,
► determine what is relevant to the situation,
► argue for or against conceptual ideas and solutions,
► develop ideas through discussion and collaborative sketching,
► explain the technical matters for different audiences,
► show confidence in expressing yourself within the field...

Communication skills as contextualized competences are embedded in, and inseparable from, students’ application of technical knowledge.

The same kind of reasoning can be made for teamwork, ethics (etc...) as well.

This is not about "soft skills" but about students becoming engineers!

Contextualized:
What does "ability to communicate" mean for each specific professional role, subject area, and context?

[Barrie 2004]
The dual nature of engineering education

Integrated development of technical knowledge & engineering skills

...in meaningful relationship

Not a zero-sum game

- Practicing CDIO competences in the disciplinary context means that students will have opportunities to express and apply technical knowledge.

- Learning activities where skills are practiced will therefore at the same time reinforce students’ understanding of disciplinary content – they will acquire a deeper working knowledge of engineering fundamentals.

  “I can’t see that a credit of writing reports in my course is a wasted credit. Writing reports is an appropriate learning activity in my subject.”

(Claes Tisell, KTH Machine design)
<table>
<thead>
<tr>
<th>Place in curriculum</th>
<th>Faculty perception of generic graduate skills and attributes</th>
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<tbody>
<tr>
<td>Integral</td>
<td>They are integral to disciplinary knowledge, infusing and <strong>ENABLING</strong> scholarly learning and knowledge.</td>
</tr>
<tr>
<td>Application</td>
<td>They let students make use of or apply disciplinary knowledge, thus potentially changing and <strong>TRANSFORMING</strong> disciplinary knowledge through its application. Skills are closely related to, and parallel, discipline learning outcomes.</td>
</tr>
<tr>
<td>Associated</td>
<td>They are useful additional skills that <strong>COMPLEMENT</strong> or round out discipline knowledge. They are part of the university syllabus but separate and secondary to discipline knowledge.</td>
</tr>
<tr>
<td>Not part of curriculum</td>
<td>They are necessary basic <strong>PRECURSOR</strong> skills and abilities. We may need remedial teaching of such skills at university.</td>
</tr>
</tbody>
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Learning outcomes are the basis for course design

Learning outcomes

- Activities

- Assessment

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

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 [Biggs]
Integration of engineering skills into learning outcomes, activities and assessment

Learning outcomes

Activities

Assessment

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

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 [Biggs]

CDIO curriculum development - the process in a nutshell

- Set program learning outcomes in dialogue with stakeholders
- Map out responsibilities to courses – negotiate intended learning outcomes (knowledge and engineering skills)
- Integrated learning experiences – subject courses – design-implement experiences
- Course development with constructive alignment
- Faculty development
- Evaluation and continuous programme improvement
12 CDIO Standards
- a change management roadmap

Context:
- Educate for the practice of engineering [1]

Curriculum development:
- 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]

Specific curricular elements:
- Introduction to engineering [4]
- Design-implement experiences and workspaces [5, 6]

Course development:
- Integrated learning experiences [7]
- Active and experiential learning [8]

Please download from www.cdio.org

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

The CDIO Initiative

Codifying the concept

Building a community
- CDIO Initiative was founded in 2000
  - MIT, KTH, Chalmers, Linköping University
  - Support from Knut & Alice Wallenberg foundation (2001-2005)
- Worldwide annual CDIO Conference from 2005
- Today over 60 institutions are CDIO Collaborators
CDIO Collaborators

- Aalborg University, Denmark
- AFEKA Tel Aviv Academic College of Engineering, Israel
- Arizona State University, US
- Aston University, UK
- Australasian Association for Engineering Education, Australia
- Beijing Jiaotong University, China
- California State University, US
- Chalmers University of Technology, Sweden
- Chengdu University of Information Technology, China
- Chisholm Institute, Melbourne
- Daniel Webster College, US
- École Polytechnique de Montréal, Canada
- Embry-Riddle University
- Engineering College of Aarhus, Denmark
- Gdansk University of Technology, Poland
- Group T - International University College, Leuven, Belgium
- Hochschule Wismar, Germany
- Hogeschool Gent, Belgium
- Instituto Superior de Engenharia do Porto, Portugal
- Jönköping University, Sweden
- Kanazawa Technical College, Japan
- Kemi-Tornio UAS
- KTH Royal Institute of Technology, Sweden
- Lancaster University, UK
- LaspaU Academic and Professional Programs for the Americas, US
- Linköping University, Sweden
- Massachusetts Institute of Technology, US
- Metropolia AMK
- Nanyang Polytechnic, Singapore
- Pennsylvania State University, US
- Polytechnico di Milano, Italy
- Pontificia Universidad Javeriana, Colombia
- Purdue University, US
- Queen's University, Canada
- Queen's University, Belfast, UK
- Queensland University of Technology, Australia
- Qinggong College, Hebei United University, China
- RWTH Aachen, Germany
- Savonia University of Applied Science, Finland
- School of Engineering at Taylor’s University College, Malaysia
- SCE Shamoon College of Engineering, Ashdod & Beer-Sheva, Israel
- Shantou University, China
- Singapore Polytechnic, Singapore
- Taylor’s University College, Malaysia
- Technical University of Denmark, Denmark
- Telecom Bretagne, France
- Tsinghua University, China
- Tungh MK
- Umeå University, Sweden
- UNITEC Laureate International Universities, Honduras
- US Naval Academy, Annapolis, MD
- US Naval Postgraduate School, Monterey, CA
- Universidad Católica de la Santísima Concepción, Chile
- Universidad de Chile, Chile
- Universidad de Santiago de Chile, Chile
- Universitat Politècnica de Catalunya, Spain
- University of Auckland, New Zealand
- University of Bristol, UK
- University of Calgary, Canada
- University of Colorado, US
- University of Leeds, UK
- University of Leicester, UK
- University of Liverpool, UK
- University of Manitoba, Canada
- University of Notre Dame College of Engineering, US
- University of Michigan, US
- University of Pretoria, South Africa
- University of Straatkely, UK
- University of Sydney, Australia
- Vietnam National University, Vietnam

More about CDIO

- **8th International CDIO Conference**
  July 2-5, 2012, Brisbane, Australia

- **Fall Collaborator meeting**

- **Regional CDIO meeting**
  Sept 22-23, 2011, University of Gdansk, Poland

- **www.cdio.org**

  (2nd edition coming soon)
“If you want to learn about a system, try to change it”
(after Le Chatelier’s principle)

Sustainability of educational change

- After we have successfully developed a programme, we must **constantly apply force** in the system (leadership, resources) to **keep it from reverting** to its original state.
- Why is it so?
"Organizational gravity"

There is a force acting on education programs to reflect the inherent characteristics of the organization providing it. 

Edström’s Law ;-) 

Thus the lowest energy state of education (the most stable state) is to reflect the organization.

Inherent characteristics – what shapes the organisation?

HARD FACTORS (regulations and praxis)
- how the university is organized
- what is valued in recruitment, promotion and appointment processes
- how power and resources are allocated

SOFT FACTORS (culture)
- attention
- identity, status and self-image
- symbolic activities

EXTERNAL FACTORS
- funding systems
- evaluation, accreditation and ranking
- stakeholder input
- collaborations and networking
The force strategy:
- To apply force in the system (leadership, resources) to move education to a more desirable state. We must then constantly keep applying force to counteract the organizational gravity; to keep it from reverting to its lowest energy state.

The system strategy
- To adjust the inherent characteristics of the organization itself to enable a more desired lowest energy state for the education. The organization should thus be aligned with the educational experience we want to create.
Force strategy
To apply force in the system to move education into a more desirable state (and to keep it from reverting).

System strategy
To adjust the inherent characteristics of the system itself to enable a more desirable stable state for education.

Thank you!