Educating the Sustainability Engineer: Redesigning Curricula

Professor Roger Hadgraft
Deputy Dean, Learning & Teaching
CQ University, Melbourne, Australia

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21st Century Engineering is complex
Global Engineering Challenges

Our future challenges are daunting yet fascinating, to provide sustainable solutions in:

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

http://designpublic.in/blog/wp-content/uploads/2013/05/india-water-and-sanitation.jpg
Scientific/Technical

Technical problems

Technical Economic Ethical Problems

Economic problems

Ethical/Environmental problems

Entrepreneurial Social/Ethical

Jamison, Kolmos, Holgaard: Aalborg University, Denmark
Coal seam gas

- Wells typically take 2 weeks to drill
- Can produce gas for years

Unfracked well
Coal seam permeable enough to allow sufficient gas flow

Fracked well
Coal seam not permeable enough and requires fracking (hydraulic fracturing) to produce sufficient gas flow

Steps involved in fracking (hydraulic fracturing)

Step 1
Pumping fracturing fluid: typically 1 day

Step 2
Fracturing fluid flows back out of well: typically 1 - 2 days

Step 3
Sand remains and holds fractures open to stimulate gas flow

Credit: Australian Science Media Centre

How do we educate engineers for this challenging environment?
What is it that engineers actually do?
Define Your Discipline

1. “Write TASKS that a graduate would be expected to perform in your organisation”

2. CLUSTER the tasks in meaningful ways
Investigation
Modelling
Design
Assessment
Planning and Management
Audit and Compliance

Figure 2: The Environmental Engineering Capability Cube
ABET Process skills

a) **apply knowledge** of mathematics, science, and engineering

b) **design and conduct experiments**, as well as to analyze and interpret data

c) **design a system**, component, or process to meet desired needs within realistic constraints ...

e) **identify, formulate, and solve** engineering problems

h) **understand the impact** of engineering solutions in a global, economic, ...

k) **use the techniques, skills**, and modern engineering tools necessary for engineering practice.
ABET Generic skills

d) function on multidisciplinary teams
f) an understanding of professional and ethical responsibility
g) communicate effectively
i) engage in life-long learning
j) a knowledge of contemporary issues
International Reviews of Engineering Education


ASCE ‘Body of Knowledge 2’

The Engineer of 2020

Educating the Engineer of 2020

UK Henley Report

King, R. – Australia
Recommendations

Engage students by:

- Balancing **theory** and **practice**
- More **industry** involvement
- More **active** learning
- **Share** best-practice
- More **diversity**
So, how do we do engineering?
The Design Process is central:

Systems Engineering

Client need

Requirements

Alternative solutions

Social, Economic & Environmental Requirements

Model and Evaluate

Build + Test

Deliver + Test

Sustainability is key to decision making
How is this best learned?

- Need complex learning situations
- Using a sequence of project-based courses
- Supported by online skill development and assessment
Two basic processes are required.

- **Project task**
- **Skill development**

- **Divergent learning and thinking**
- **Convergent learning and thinking**
How do we change curricula?
<table>
<thead>
<tr>
<th>Current PBL sequence</th>
<th>Specialisation</th>
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<tbody>
<tr>
<td><strong>12 cp</strong></td>
<td><strong>6 cp</strong></td>
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<tr>
<td>1 Engineering Skills 1</td>
<td>Engineering Foundation Mathematics</td>
<td>Engineering Physics A</td>
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<tr>
<td>2 Engineering Skills 2</td>
<td>Engineering Mathematics</td>
<td>Engineering Physics B</td>
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<td>Engineering Mathematical Applications</td>
<td>Analysis of Structures</td>
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<td>4 Engineering Design &amp; Management Implementation</td>
<td>Materials Science and Engineering</td>
<td>Solid Mechanics</td>
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<td>5 Transportation Engineering Design</td>
<td>Hydraulics</td>
<td>Steel Structures</td>
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<td>6 Water and Environmental Design</td>
<td>Geotechnical Engineering</td>
<td>Surveying and Mapping</td>
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<td>7 Capstone Structural and Geotechnical Design</td>
<td>Engineering Project Planning</td>
<td>Concrete Structures</td>
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<td>8 Engineering Project Implementation</td>
<td>Traffic Engineering</td>
<td>Elective</td>
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The CDIO™ INITIATIVE is an innovative educational framework for producing the next generation of engineers. The framework provides students with an education stressing engineering fundamentals set in the context of Conceiving — Designing — Implementing — Operating real-world systems and products. Throughout the world, CDIO Initiative collaborators have adopted CDIO as the framework of their curricular planning and outcome-based assessment.
We’re moving from a focus on scientific knowledge to a focus on Process Skills (Design, Investigation, Modelling, ...)

Through Online supported, Project Based Learning
We know it works!

http://www.airbus-fyi.com/
In Summary

1. Students learn **sustainable practice**
2. through **complex projects**
3. supported by **online skill development**.
4. Use **professional practice** to build **process skills**.
5. Access **knowledge** as required.
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## Combining projects and skills...

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