Educating Chemical Engineers for Contemporary Challenges: The value of Context, Connection and Collaboration

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International Engineering Education Forum, Tianjin University, 11-12th December 2017

E.P. Byrne
University College Cork BE Process & Chemical Engineering

Overall Winner:

IChemE Sustainability Teaching Award 2016

“University College Cork demonstrated that they could integrate sustainability teaching principles across the curriculum, which will provide their chemical engineering students with a set of values to apply to their future careers.”

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Educating Chemical Engineers for Contemporary Challenges:
The value of Context, Connection and Collaboration

• Contemporary Challenges?
  • Considering Context?
  • Recognising Connection?
  • Seeking Collaboration?
• So what? Implications for Chemical Engineering Education?
• A Case Study
• University College Cork’s Approach

Engineering Education: Reform/Evolution to produce fit-for-purpose Engineers to address Emerging and Contemporary Challenges?

Business/Industry needs?
Accelerating change (Δt↓): Tech/IT environment?
Environmental degradation-climate change-food-water-energy nexus?
To (Serve) What Purpose? ..and How?
Complex socio-technical recursive interactions?
All would agree that the: ‘traditional’ engineering toolbox of technical skills, while absolutely required, is alone, insufficient:

- **Soft skills** (communication, teamworking, presentation)
- **Contextualisation** of engineering social practice
- **Inter- and Transdisciplinary** approaches

...are all also necessary
Environmental degradation-climate change-food-water-energy nexus?

Complex socio-technical recursive interactions?

Ecological footprint by component

Source: WWF Living Planet Report 2016

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Energy Demand and resultant CO₂ emissions

Material and Energy flows driven by Economics without Limits

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Contemporary Challenges: Considering Context

"Every day, nine out of 10 of us breathe air that exceeds WHO guidelines for air quality"

UN Environment Assembly (UNEA) Declaration, Kenya, 6 December 2017

World Air Quality Index (www.aqicn.org), Tue 5th December 2017 (20.30h GMT)
• Economy – (Industry, Employment, Globalisation)
• Technology
• Climate Change (including wind)
• Geography
• Energy (Fossil fuel burning)
• Transportation

Despite massive efforts to improve Tianjin’s pollution problem, the air quality in the city has actually gotten worse this year. In fact, recent data from the Ministry of Environmental Protection shows that Tianjin is one of the most polluted cities in China. (Not that we’re surprised)

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Contemporary Challenges: Recognising Connection
‘The history of life on earth has been a history of interactions between living things and their surroundings.’

Rachel Carson, Silent Spring

‘Our capacity for analysis sometimes leads us to an arrogant illusion: that we are so special and unique that nature isn’t connected to us.

But the fact is, we’re inextricably tied.’

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‘It cannot be emphasized enough how **everything** is **interconnected**.

..It follows that the **fragmentation** of knowledge and the **isolation** of bits of information can actually become a form of **ignorance**, unless they are **integrated** into a **broader vision of reality**.’

seek only a **technical** remedy to each environmental problem which comes up is to separate what is in reality **interconnected** and to mask the true deepest problems of the global system.’

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**Contemporary Challenges:**

**Seeking Collaboration**
‘pay more attention to *processes* (flows) than to *objects*’
Robert Ulanowicz, 2004, (Computational Biology & Chemistry, 28, 322)

[In considering/modelling ecosystems], researchers could...

‘The problems that engineers will face in the future are often unique, complex, heterogeneous, ill-defined and even wicked. Past solutions will no longer suffice. In order to solve these problems, engineering education must develop a new ‘breed’ of engineers that are innovative, cross-disciplinary, collaborative, and holistic.’

[Such engineers] ‘..just want to solve *real* problems, *not just* some technical part of problems.’

Anders Buch (2016)
(In: Jørgensen & Brodersen (Eds.), Engineering Professionalism, 147–169)
Context, Connection and Collaboration: in (Chemical) Engineering Education?

Competing Conceptions of Engineering*

1. Engineers as value neutral ‘guns for hire’ or ‘paid hands’

2. Engineers as committed to a social good thus being constrained in some ways, privileged in others to achieve this*

Kick-off Reflection PE1006 Professional Engineering Communication & Ethics (2017-18):

What social and ethical commitments should engineering have?..

Take others ideas on board to enhance overall project

- Enhance people’s lives
- Protect the environment
- Safety of others

Honesty regarding one’s work/products

- MACRO-ETHICAL (Societal good)
- Be aware of consequences of one’s actions
- Do not infringe on rights

Do not plagiarise

- MICRO-ETHICAL (Individual morals)
- Enhance communication between nations/communities, etc.

Pride in one’s work

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Melbourne Comminiqué, 2001:

[20 global chemical engineering institutions]

“We acknowledge both our professional responsibilities and the need to work with others as we strive to meet the challenges facing the world in the Twenty-First Century.”

Agreed at the 6th World Congress of Chemical Engineering Melbourne 2001
3.2.3 China

1. a knowledge of humanities and an understanding of social, professional and ethical responsibility;

5. an ability to innovate; an attitude and awareness of innovation; an ability to synthesize theories and techniques to design a system and process within the economic, environmental, legal, safety, health and ethical constraints;

7. a knowledge of policies, laws and regulations on the production, design, research and development, environment protection and sustainable development related to the profession and industry; a recognition of the impact of engineering to the external world and society;

8. an ability to manage, communicate and function in teams;

10. an global vision; an ability to communicate, compete and cooperate in the multicultural context.
• Chemical Engineering: emanated end 19th Century from need to understand both:
  • the processes & chemistry around fractionation of oil
  • the design and development of safe industrial-scale processes to carry this out.

• Chemical engineers are justly proud of their achievements in helping fuel the industrial and social revolution through the 20th Century with respect to oil, but also food, drugs, chemicals, etc. concurrent with a rapidly growing global population.

• One such product that chemical engineers are proud of is an oil derived product with a huge range of uses: Plastic

What is Chemical Engineering?
Our modern society relies on the work of Chemical Engineers – they help manage resources, protect the environment and control health and safety procedures, while developing the processes that make the products we desire or depend on......

Chemical Engineering is all about changing raw materials into useful products you use everyday in a safe and cost effective way. For example petrol, plastics and synthetic fibres such as polyester and nylon, all come from oil.
• **Environmentally** though, plastics are deeply problematic: Most end up being dumped in landfills or incinerated

• All plastics have some residual contaminants, no recycled plastics are suitable as food grade product

• **Poor degradability** means they have become an environmental scourge, on the natural land and seascapes, where they accumulate as a hazardous material to wildlife and can enter the food chain.

“Consumers around the world buy a million plastic bottles a minute. Plastic production is set to double in the next 20 years and quadruple by 2050. Around the world, more than 8m tonnes of plastic leaks into the oceans, and a recent study found that billions of people globally are drinking water contaminated by plastic.”

(Graham Ruddick, The Guardian, 15 October 2017)
UN commits to stop ocean plastic waste

By Roger Harrabin
BBC environment analyst, Nairobi

5 December 2017

Nations have agreed that the world needs to completely stop plastic waste from entering the oceans.

The UN resolution, which is set to be sealed tomorrow, has no timetable and is not legally binding.

But ministers at an environment summit in Kenya believe it will set the course for much tougher policies and send a clear signal to business.

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Points to ponder:

• Do chemical engineers bear a moral and ethical responsibility for the ‘unintended’ consequences plastics bring?

• Do we have a responsibility to take a broader view e.g. develop and promote alternative materials to oil based plastics? e.g. biodegradable plastics produced from polymerized lactic acid bacteria?

(Dedicating dedicated to the future)
"Dedicated modules and elective streams alone are not in themselves sufficient to demonstrate how sustainability should be the context through which 21st Century chemical engineering must be practiced. To do this programmes must inherently and consistently demonstrate the need for sustainable practice."

Byrne & Fitzpatrick* (2009)


"A sustainability context and ethos pervades the UCC programme through dedicated ‘primary’ modules concerning sustainability, scaffolded by a series of ‘secondary’ modules at each stage (one to four) of the programme."

<table>
<thead>
<tr>
<th>‘Primary’ Sustainability Modules</th>
<th>‘Secondary’ Sustainability Modules</th>
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<tbody>
<tr>
<td>PE1006 Professional Engineering Communication &amp; Ethics</td>
<td>PE1003 Intro. to Process &amp; Chemical Engineering</td>
</tr>
<tr>
<td>PE3011 Sustainability in Process Engineering</td>
<td>PE2005 Introduction to Biochemical Engineering</td>
</tr>
<tr>
<td>PE3008 Safety &amp; Environmental Protection I</td>
<td>PE2011 Plant Design and Commissioning</td>
</tr>
<tr>
<td>PE4004 Safety &amp; Environmental Protection II</td>
<td>PE3001 Applied Thermodynamics and Fluid Mechanics</td>
</tr>
<tr>
<td>PE4006 Design Project</td>
<td>PE4001 Advanced Process Design</td>
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Wicked Problem Group Assignment

Wicked Problems: Complex messy societal problems where people often cannot agree on what the problem is (framing) and which do not lend themselves to solving through simple deterministic interventions.

Task: Research. Frame problem according to different perspectives (techno-optimistic, local/community, global(ised), techo-critical, integrative, etc.) Identify problematic issues/potential unintended consequences with each framing.

Year 1: PE1006 Professional Engineering Communication & Ethics

Module Objective:
To improve students’ skills in communicating and presenting complex technical information both to technical audiences and to the public at large.

News
Process II triumph again! This time at Climathon

Winners 2017 UCC Climathon:
Competition to devise low-carbon transport and mobility schemes for UCC

Year 2: PE2004 Communication in Engineering

News
‘Energy Futures’ Innovation Challenge 2017:
Team of 3 Process & Chem. Eng. + 1 Finance student

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PE3011/SC3029 Assignment: Reflection on Sustainability

A collaborative exercise undertaken by students of:
• PE3011 Sustainability in Process Engineering
• SC3029 Sociology of the Environment

Transdisciplinary Group Assignment

Task: Consider and present on any aspect of ‘sustainability’. Can include contrasting perspectives, framings or angles, and disciplinary norms. Also, how it has potential to change the way we do things, how it might be achieved, potential consequences, difficulties or problematic issues, etc.

Sustainability in a more solar powered society

Consumerism

Concepts of Progress

The Socio-Environmental Impacts of Plastic

Sustainability And

Entropy and

The Green Belt
Sustainability

Movement

Quality vs Quantity

Globalisation

Sustainability and Behaviour Patterns

Sustainable Food Production

Consumerism and Energy

Unsustainability on a global scale

‘Embedding Sustainability’ into the final year capstone Design Project

Do the design first

Then perform sustainability assessment at the end

This philosophy seems to be somewhat ‘upside down’: Sustainable assessment should NOT just be a “bolt-on” activity, but should be incorporated throughout the design process in a way that recursively influences design decisions and the final outcome.
Revised approach to placing sustainability as context of design project requires:

a) Considering sustainability throughout a (semi open ended) design process
   -Thus feed into design decisions from start, including framing

b) Environmental aspects
   -Employ scientific/engineering tools and methods which can have a real impact and can directly influence the design (e.g. LCA, EIS, material and energy balances)

c) Socio-economic aspects
   - More difficult and possibly outside scope (e.g. societal structural issues).
   It could be argued that the key sustainability ‘game-changers’ lie in the broader socio-economic domain; aim is to challenge to consider broader sustainability education and at least identify key problematic issues. Ideas?

Framing Considerations:
Might students propose reframing a design project which requires the production of plastics or VCM, a PVC precursor, to one which would produce inherently ‘more sustainable’ non-oil based plastics, such as a biodegradable plastics? This too could have longer-term positive economic (sustainability) implications for a plastics business.
Moreover,

- In siting and designing the plant, might students consider broader issues such as low carbon/healthy transportation options: safe/easy walking and cycling access and/or frequent and efficient public transport routes.

Consider aspects such as:

- local community involvement?
- family friendly working shifts and practices?
- on-site natural amenities (wetlands, groves, walkways, etc.)?
- on-site renewable energy production?

Also, what are possible economic, policy or socio-technical barriers to such initiatives?

*Group Head of Sustainability and Innovation at Balfour Beatty

"The approach taken in Cork has demonstrated that it is possible to sensitize young engineers to the dimensions of modern day challenges that lie beyond the technical realm. In my view at least, Cork’s students are being prepared for a world that is increasingly connected and increasingly collaborative; for a fulfilling and successful public and private life."


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