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## **Educating Chemical Engineers** for Contemporary Challenges:

The value of Context, Connection and **Collaboration** 

### **Edmond Byrne**

Head & Professor of Process & Chemical Engineering University College Cork, Ireland



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

E.P. Byrne



👪 UCC



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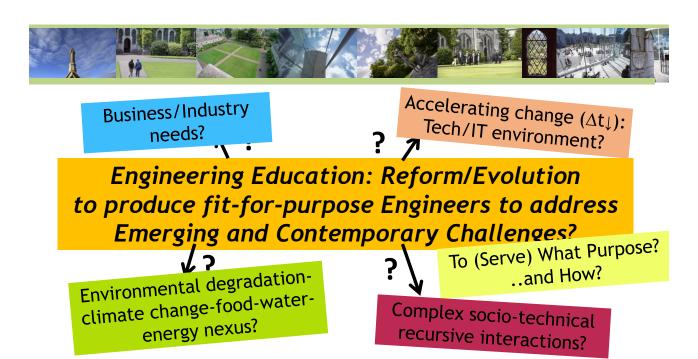
# Educating Chemical Engineers for Contemporary Challenges: The value of Context, Connection and Collaboration

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

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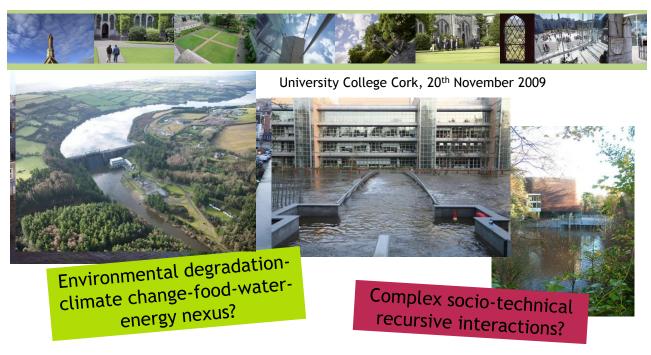
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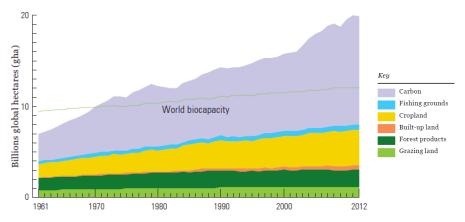
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### **Ecological footprint by component**



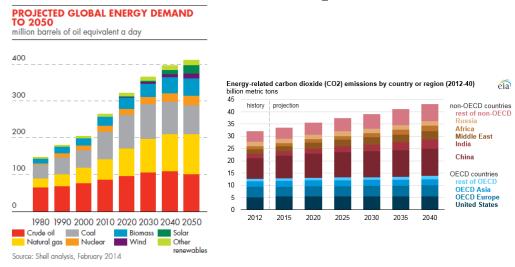
Source: WWF Living Planet Report 2016

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### Energy Demand and resultant CO<sub>2</sub> emissions



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### Material and Energy flows driven by Economics without Limits



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# Contemporary Challenges: Considering Context

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World Air Quality Index (www.aqicn.org), Tue 5th December 2017 (20.30h GMT)

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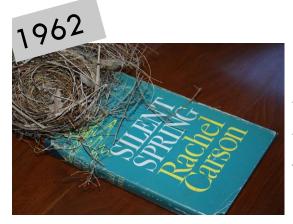




# Contemporary Challenges: Recognising Connection







'The history of life on earth has been a history or **interactions** between living things and their surroundings.'

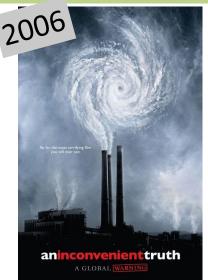
Rachel Carson, Silent Spring

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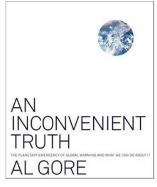






'Our capacity for analysis sometimes leads us to an arrogant illusion: that we are so special and unique that nature isn't **connected** to us.

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

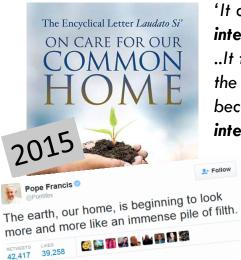


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'It cannot be emphasized enough how **everything** is **interconnected**.

...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 **technica**l remedy to each ronmental problem which comes up is to **separate** t is in reality **interconnected** and to mask the true deepest problems of the global system.'

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# Contemporary Challenges: Seeking

**Collaboration** 

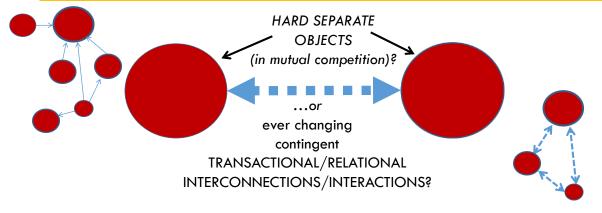
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[In considering/modelling ecosystems], researchers could..

### 'pay more attention to processes (flows) than to objects'

Robert Ulanowicz, 2004, (Computational Biology & Chemistry, 28, 322)



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'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 <u>real problems</u>, <u>not just</u> some technical part of problems.'

Anders Buch (2016)

(In: Jørgensen & Brodersen (Eds.), Engineering Professionalism, 147–169)

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# Context, Connection and Collaboration: in (Chemical) Engineering Education?

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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\*

\*Deborah Johnson, 'The Social/Professional Responsibility of Engineers' (1989)

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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

MACRO-ETHICAL (Societal good)

Enhance people's lives

Protect the environment Safety of others

Honesty regarding one's work/products

Do not plagiarise

Pride in one's work

Do not infringe on rights

Enhance communication between nations/communities, etc.

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**FTHICAL** 

(Individual morals)

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### **MELBOURNE COMMINIQUÉ, 2001:**

[20 global chemical engineering institutions]

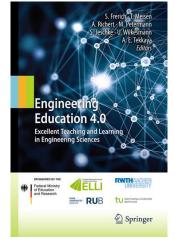
"We acknowledge both our professional responsibilities and the need to work with others as we strive to meet the challenges facing the world in the Twenty-First Century."

AGREED AT THE 6<sup>th</sup> WORLD CONGRESS OF CHEMICAL ENGINEERING MELBOURNE 2001

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The Globally Competent Engineer – What Different Stakeholders Say About Educating Engineers for a Globalized World May et al. (pp. 895-910, 2016) 3.2.3 China

- a knowledge of humanities and an understanding of social, professional and ethical responsibility:
- 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;
- 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;
- an ability to manage, communicate and function in teams;

external world and society;
8. an ability to manage, communicate and function in teams:

 an global vision; an ability to communicate, compete and cooperate in the multicultural context.

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### **Contemporary Challenges Case Study:**



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- 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 20<sup>th</sup> 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

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- 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.

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UN Ocean Conference: Plastics Dumped In Oceans Could Outweigh Fish by 2050, Secretary-General Says

By Pam Wright - June 06 2017 02:45 PM EDT - weather.com



"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)

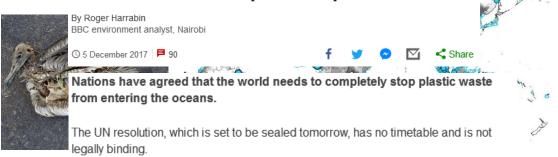
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### Science & Environment

### UN commits to stop ocean plastic waste



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 plastic 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?

See: Byrne, E. (2011) Educating the chemical engineer of the future, The Chemical Engineer, 833, 27-29. (Nov. 2010)

http://www.ucc.ie/en/processeng/staff/academic/ebyrne/publications/thechemicalengineerarticlen
10educatingchemengofthefuture/TCENov2010Educatingthechemicalengineerofthefuture.doc

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sustainability needs o quickly become the context for 21st century themical engineering aducation, argues admond Byrne

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will flourish on Earth forever". Based on trend expressed through any of the metrics that abound regarding ecological, environmental, social and even economic measures, one would be hard pressed to angue that the current societal construct is sustainable by

understanding of material and energy
balances and the second law of
themselvamines, can appreciate how any
economic societal construct that does not
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critical, will not create sustainability. Inseet the existing paradigm of ever increasing consumption of everything (material, energy, e.g. must be replaced by one which recognises the earth's (physical resource) limits (see Figure 1). As we increasingly presignist these limits, the call for such change becoming ever more urgent in the context our complex ecological, social and recommen

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## **Contemporary Challenges:**



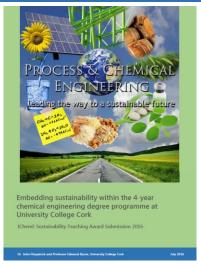
# University College Cork Approach

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### UCC BE Process & Chemical Engineering: "IChemE Sustainability Teaching Award 2016"



"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)

\*Byrne E.P. and Fitzpatrick, J.J. (2009) Chemical engineering in an unsustainable world: Obligations and opportunities. *Education for Chemical Engineers*, 4, 51-67.

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"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."

'Primary' Sustainability Modules	'Secondary' Sustainability Modules
PE1006 Professional Engineering Communication & Ethics	PE1003 Intro. to Process & Chemical Engineering
	PE2005 Introduction to Biochemical Engineering PE2011 Plant Design and Commissioning
PE3011 Sustainability in Process Engineering PE3008 Safety & Environmental Protection I	PE3001 Applied Thermodynamics and Fluid Mechanics
PE4004 Safety & Environmental Protection II PE4006 Design Project	PE4001 Advanced Process Design

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### Year 1: PE1006 Professional Engineering Communication & Ethics

### **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.









Electrical Power Transmission - Ireland

Sea Levels and

Flood Protection





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### Year 2: PE2004 Communication in Engineering

### **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 Climaton: Competition to devise lowcarbon transport and mobility schemes for UCC

News

Process II are 1st runners up in the ESB Inter-Colleges Challenge - WOW!



**'Energy Futures' Innovation Challenge 2017:** Team of 3 Process & Chem. Eng. + 1 Finance student

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Year 3: PE3011 Sustainability in Process Engineering

#### 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 The Green Belt Movement

Entropy and Sustainability

Quality vs Quantity

Globalisation

Sustainability through Community Projects

Sustainability and Behaviour Patterns

Consumerism and Energy

**Sustainable Food Production** 

Unsustainability on a global scale

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Year 4: PE4006 Design Project

### 'Embedding Sustainability' into the final year capstone Design Project

Traditional 'end of pipe' approach

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.

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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?

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Sustainability needs to quickly become the context for 21st century chemical engineering education, argues Edmond Byrne

### 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...

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embedded approach involves the traditional chemical engineering capstone design project, typically a group design of an industrial process to produce some given (chemical/pharmaceutical/ food) product. As part of the design the group typically considers possible alternative processes to produce the product and then chooses and design a suitable process having analysed and compared the available processes subject to a number of constraints, including economic, environmental, safety, availability, and so on. A commonly quoted example is the production of the vinyl chlorine monomer (VCM), the precursor to the poly vinyl chloride (PVC) polymer. Here, as part of the design exercise, students may be required to investigate two options; one with an ethylene raw material, the other using novel unit operations may be considered which lead to a reduction in volatile organic compound (VOC) emissions in one process compared with the other. The system can then be extended to production and a lifecycle analysis can be undertaken. While these are interesting and in many ways innovative approaches,



system with another less unsustainable system. A more appropriate question from a standpoint whereby sustainability is context might not be simply: "What is the best way to produce vinyl chloride? but instead: "Design a process to produce a material with the properties of PVC." This turns the design question on its head and opens up many potentially innovative possibilities whi empowering the students' learning. It provokes follow-on questions among the design team, such as: "Are there other than MVC/PVC that can take their place, that are sustainable, or at least, less unsustainable?" Could for example, lactic acid, and the resultant biodegradable plastic polymeric lactic acid (PLA) take the place of PVC for many applications? Or "In general, how feasible is it to produce plastics from renewable materials as opposed to oil?" "What are the technical and economic barriers preventing for example, the production of biodegradable polymeric materials to me the required specifications?"

E.P. Dyllie



### 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:

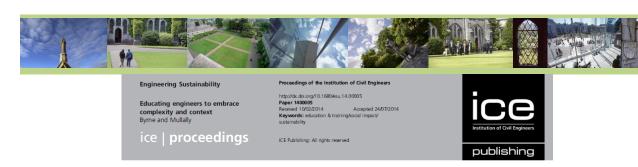
- local community involvement?
- family friendly working shifts and practices?
- on-site natural amenities (wetlands, groves, walkways, etc.)?
- on-site renewable energy production?

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

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# Educating engineers to embrace complexity and context

Edmond P. Byrne MSc, MA, PhD Senior Lecturer, School of Engineering, University College Cork, Ireland Gerard Mullally MA, PhD Lecturer, Department of Sociology, University College Cork, Ireland

"The approach taken in Cork has demonstrated that it is possible to sensitise 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."

Chris Whitehead\*, Editorial, ICE Proceedings- Engineering Sustainability, Nov 2014.
\*Group Head of Sustainability and Innovation at Balfour Beatty

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University College Cork, Ireland



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