ENGINEERING: A CHALLENGING AND CHALLENGED PROFESSION

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Science is organized knowledge.
Wisdom is organized life.

Immanuel Kant
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Wisdom is organized life.

Immanuel Kant

Scientists investigate that which already is; Engineers create that which has never been.

Albert Einstein
Overview

1. Overall context in which address is framed
2. Some external viewpoints
3. Three areas of challenge:
   I. Technical
   II. Societal
   III. Educational
4. Conclusions
1. OVERALL CONTEXT IN WHICH THIS ADDRESS IS FRAMED
THE EXISTENTIAL PLEASURES OF ENGINEERING
SECOND EDITION

“ENCHANTING” — The New Yorker

SAMUEL C. FLORMAN
Florman’s position is that “professionals have an obligation to lead, but they also have a duty to serve.”

And “having been served, society then has no right to blame the professionals for its own shortsightedness.”

Samuel C Florman, born 1925 in New York City. Civil Engineer and author.
50 years ago, ICEI President (1965)
Richard Cross in his Presidential Address

‘The story of the progress of civilisation is in effect the story of the development of engineering and of the organised national efforts of a dedicated profession’.

How is this progress viewed?
Progress? One extreme - Prof Pangloss

Tout est pour le mieux dans le meilleur des mondes possibles:
“all is for the best" in the "best of all possible worlds”.

Candide: Novella first published in 1759 by Voltaire. A satire that aimed to counter Leibnizian optimism.
And at the other extreme ... things couldn’t be much worse

I don't consider myself a pessimist. I think of a pessimist as someone who is waiting for it to rain. And I feel soaked to the skin.

(Leonard Cohen)
So, depending on your viewpoint

*It is the best of times, it is the worst of times, it is the age of wisdom, it is the age of foolishness, it is the epoch of belief, it is the epoch of incredulity ....*

*With apologies to Charles Dickens (*A Tale of Two Cities*)*
Zeitgeist? A perfect storm of concerns

It is probably a conceit to imagine that we live at a special time ... but it is hard to resist the thought that in fact we do, especially as we are now entering the Anthropocene\textsuperscript{1} epoch

\textsuperscript{1} a proposed term for the present geological epoch during which humanity has begun to have a significant impact on the environment
2. SOME SELECTED OBSERVATIONS WITH RELEVANCE TO ENGINEERING
Japanese Prime Minister Shinzo Abe lays out his goals for the G7 summit on 7-8 June 2015 in Schloss Elmau.

1. Climate change.

2. **Quality infrastructure.** To sustain high quality growth that can enhance well-being now and in the future, then developing countries will need high quality infrastructure in place.

3. Health and medicine.
The reason we should reflect on this encyclical is that it addresses the complex question of our stewardship of Earth, our home for the foreseeable future.
In referring specifically to diversity the encyclical letter states

“We must be grateful for the praiseworthy efforts being made by scientists and engineers dedicated to finding solutions to man-made problems. But a sober look at our world shows that the degree of human intervention, often in the service of business interests and consumerism, is actually making our earth less rich and beautiful, ever more limited and grey, even as technological advances and consumer goods continue to abound limitlessly”. 
The question of Technology: creativity and power is discussed

“We are the beneficiaries of two centuries of enormous waves of change: steam engines, railways, the telegraph, electricity, automobiles, aeroplanes, chemical industries, modern medicine, information technology and, more recently, the digital revolution, robotics, biotechnologies and nano-technologies”.
... and it continues

... “technology has remedied countless evils which used to harm and limit human beings. How can we not feel gratitude and appreciation for this progress, especially in the fields of medicine, engineering and communications? How could we not acknowledge the work of many scientists and engineers who have provided alternatives to make development sustainable?”
But!!!

“... never has humanity had such power over itself, yet nothing ensures that it will be used wisely, particularly when we consider how it is currently being used”.

The phrase ‘Tragedy of the commons’ - attributed to William Forster Lloyd and later used by Garrett Hardin.
The True Grand Challenge for Engineering: Self-Knowledge

3. AREAS OF CHALLENGE
Three related sets of challenges

I. Technical
II. Societal
III. Educational

*These challenges are inextricably interconnected*
I. TECHNICAL CHALLENGES

As David Balmforth President of the ICE reminded us in his lecture last January, Engineering has in the past made very significant and beneficial contributions to the well-being of people. Think of the great water and sewage schemes in cities.

Current examples of looking to the future (based on current situations) include Engineers Ireland’s *Review of Infrastructure in Ireland.*
I. TECHNICAL CHALLENGES
14 Grand Challenges for Engineering

The USA National Academy of Engineering (NAE) Committee on Engineering's Grand Challenges identified 14 grand challenges and opportunities for engineering during the world's next few generations. It pointed to engineering or scientific research and innovation that look promising for addressing each challenge as well as suggested currently unmet research needs.

1. Make solar energy economical
2. Provide energy from fusion
3. Provide access to clean water
4. Reverse-engineer the brain
5. Advance personalized learning
6. Develop carbon sequestration methods
7. Engineer the tools of scientific discovery
8. Restore and improve urban infrastructure
9. Advance health informatics
10. Prevent nuclear terror
11. Engineer better medicines
12. Enhance virtual reality
13. Manage the nitrogen cycle
14. Secure cyberspace
14 Grand Challenges for Engineering

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In general, a lack of adequate economic support for Renewables development is an obstacle ... With some negativity being expressed from within our own engineering community!!
14 Grand Challenges for Engineering

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The Science is easy ... it is the Engineering that is hard!!
14 Grand Challenges for Engineering

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14 Grand Challenges for Engineering

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6. Develop carbon sequestration

A new report by Citigroup - "Energy Darwinism" - says an ambitious COP 21 implies that a third of global oil reserves, half the gas and 80pc of coal reserves cannot be burned, unless carbon capture and storage (CCS) comes to the rescue.

A report by the Stranded Assets Research Network at Oxford University warned that continuing to burn coal with CCS would lead to the capture of 125 gigatonnes of CO2 by 2050, blocking up the disused wells that may one day be needed for emergency storage of negative emissions. Better to switch to renewables, and never burn the stuff in the first place.

Lucky Britain to win 21st century jackpot from carbon capture

Telegraph.co.uk
Global Grand Challenges Summit
Beijing 15-16 September 2015

The Chinese Academy of Engineering (CAE), the U.S. National Academy of Engineering (NAE), and the Royal Academy of Engineering (RAE) are leading the way in advancing solutions to humanity’s grand challenges.

[Images of Global Grand Challenges Summit posters]

GGCS 2015
Recent SFI funding

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Ireland can contribute
II. SOCIETAL CHALLENGES
“IT IS A NARROW MIND WHICH CANNOT LOOK AT A SUBJECT FROM VARIOUS POINTS OF VIEW.”
— GEORGE ELIOT, MIDDLEMARCH

There is a fundamental imbalance between the views of society and the perspectives of both the funders and providers of solutions.

Groups in society largely address single topics in limited timeframes. Funders and solution providers on the other hand need to take long-term and more holistic views.

And our democratic system (in reacting to public opinion) is prone to short-termism and choosing heavily comprised solutions.
The need for informed consent

Baroness Onora O’Neill (philosopher) considers that informed consent is the key legal instrument of bioethics ... this is a sound principle that extends to other domains and activities such as engineering, but it is not without its problems.

In general the public need to (a) be properly informed ... (b) by those that can be trusted.

We “need to free professionals and the public service to serve the public...to work towards more intelligent forms of accountability...[and] to rethink a media culture in which spreading suspicion has become a routine activity”.
In addressing Societal Needs the interaction between Engineering and Society is poorly moderated by a climate of misunderstanding — on both sides — and sometimes even a wilful misunderstanding. “Unknown knowns”!!

There is also the C P Snow “Two Cultures” factor at play.

A model of what constitutes Engineering

Hence the need for dialogue based on trust and respect
CAETS - independent international organization of engineering and technological sciences academies

1. Prepared to advise governments and international organizations on technical and policy issues related to its areas of expertise;
2. Contribute to the strengthening of engineering and technological activities to promote sustainable economic growth and social welfare throughout the world;
3. **Foster a balanced understanding of the applications of engineering and technology by the public**;
4. Provide an international forum for discussion and communication of engineering and technological issues of common concern;
5. Foster cooperative international engineering and technological efforts through meaningful contacts for development of programs of bilateral and multilateral interest;
6. Encourage improvement of engineering education and practice internationally; and
7. Foster establishment of additional engineering academies in countries where none exist.

*The European Council of Academies of Applied Sciences, Technologies and Engineering*
The EU has identified the challenge of having a well informed Society with the publication of a recent report (2015).
The challenge is one of both informing society and maintaining trust.
TO ILLUSTRATE THE DIFFICULTIES IN ADDRESSING THIS CHALLENGE

CONSIDER THE TOPICAL QUESTION OF ENERGY PRODUCTION
Backbone of production: plenty more left! Use it?

Fossil fuels
Fracking
Fission (nuclear)
Wind
Wave
Deep mine coal gasification
Solar
Hydro ....
Has brought economic advantage to US, but is controversial

Fossil fuels
Fracking
Fission (nuclear)
Wind
Wave
Deep mine coal gasification
Solar
Hydro ....
France: 75% of Electricity from Nuclear
Ireland: 0%?

- Fossil fuels
- Fracking
- Fission (nuclear)
- Wind
- Wave
- Deep mine coal gasification
- Solar
- Hydro ....
Intrusion on Nature: Network implications

Fossil fuels
Fracking
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Hydro ....

James Harpur, “Nature is key to heritage and we must defend it” (Irish Times, 14 Sept. 2015)
Wave power systems can attract predatory fish, damaging ecosystems

Fossil fuels
Fracking
Fission (nuclear)
Wind
Wave
Deep mine coal gasification
Solar
Hydro ....
Secret report reveals toxic legacy of coal gasification trials (Australia)

Fossil fuels
Fracking
Fission (nuclear)
Wind
Wave
Deep mine coal gasification
Solar
Hydro ....
Unsightly in urban settings:
Huge potential using low cost/low grade silicon

Fossil fuels
Fracking
Fission (nuclear)
Wind
Wave
Deep mine coal gasification
Solar
Hydro ....
Dams have mixed histories

Fossil fuels
Fracking
Fission (nuclear)
Wind
Wave
Deep mine coal gasification
Solar
Hydro ....
Andre Bryans has noted that “the installation of Tidal Energy Devices will result in the earth moon distance increasing at a rate of approximately 1 cm per year per 1 TW year extracted”.

One can envisage the eventual formation of the Conserve Lunar Orbit Society of European Technophobes!
Some points to ponder....

• Each of the energy sources mentioned are not without significant undesirable attributes
• Very strong and very different lobby groups exist opposing the utilisation of each source
• The lobby groups, to a large extent, operate in isolation and are independent of each other
• Politicians because of the need to maintain a voting base, and because the lobbying is invariably local, find it almost impossible to challenge any lobbying
• And it has to be admitted, that each of us unencumbered with more general or holistic considerations, either would support or have sympathy with each lobby group.
But we have a dilemma....

• Unless we are prepared to re-think how we wish to live our lives, we will continue to need energy ... utilising one or more sources that in isolation we would prefer not to deploy

• To return to Samuel Florman: “professionals have an obligation to lead, but they also have a duty to serve”.

   To get the right balance between leading and serving is certainly difficult and it requires a climate of sustained dialogue and trust.

As Professionals are we addressing this challenge?
But it is even more difficult!!

- Energy is difficult enough as a topic but the more general challenge really centres on infrastructure. The challenge is all the greater when climate change adaption is to be addressed.

- In a recent book Prof Henry Petroski, amongst other aspects, explains the associated political nature of the problem.
III. ENGINEERING EDUCATION CHALLENGES
The ongoing tension!

“... there aren’t enough high skilled industry-ready graduates coming out of Irish colleges”

“... we can’t redesign our university courses to cover a new trend that has just appeared ...”

Two quotations from The Sunday Business Post, 1st Feb. 2014
Employability can be defined as:

‘a set of achievements – skills, understandings and personal attributes – that make graduates more likely to gain employment and be successful in their chosen occupations, which benefits themselves, the workforce, the community and the economy’

Professor Mantz Yorke (2004) 'Employability in Higher Education: what it is - what it is not', Higher Education Academy/ESECT

The USEM model (Knight and Yorke, 2004) outlines employability as four broad and inter-related components:

- Understanding
- Skilful practices (including deployment of skills)
- Efficacy beliefs (including students views of themselves)
- Meta-cognition (including self-awareness and a capacity to reflect on learning)

http://www.employability.ed.ac.uk/What/
Amongst other aspects - an appreciation of the uncertainty, ambiguity and limits of knowledge
EUR-ACE accreditation criteria for engineering programmes

The Programme Outcomes of accredited engineering degree programmes have the following dimensions:

- Knowledge and Understanding;
- Engineering Analysis;
- Engineering Design;
- Investigations;
- Engineering Practice;
- Transferable Skills.
Programme areas to ‘deliver’ on the ‘promise’ offered

Engineers Ireland, for example, has determined that the study of six Programme Areas is necessary if graduates are to achieve the required Programme Learning Outcomes.

- Mathematics & Science
- Technology
- Software & Inf. systems
- Innovation
- Engineering practice

PLUS

Social and Business Context
ASEE : Ongoing project
(Special Interest Group - International Engineering Development)
Attributes of a Global Engineer

- Engineering Science Fundamentals
- Engineering
- Context in which Engineering is practiced
- Communication
- Teamwork
- Leadership
- Flexibility
- Curiosity and Desire to Learn - For Life (Show initiative, Inquire & Learn)
- Ethical Standards and Professionalism

The Attributes of a Global Engineer Project: Updates, Inputs, Faculty Development Considerations.
ASEE : Ongoing project (SIG Int. Eng. Dev.)
Attributes of a Global Engineer

Engineering Science Fundamentals
- Mathematics (including statistics)
- Physical and Life Sciences
- Political and Socio-economic Sciences
- Information Technology - Digital Competency

Engineering
- Understanding of Design and Product Processes
- Understanding of Product Life Cycle Development
- Effective Teamwork/Common Goals
- Possess a Multi-Disciplinary, Systems Perspective
- Maintain Focus with Multiple Project Assignments

The Attributes of a Global Engineer Project: Updates, Inputs, Faculty Development Considerations.
ASEE: Attributes of a Global Engineer

Context in which Engineering is practiced
- Economics/Finances of Projects
- Basic Supplier Management Principles
- Customer and Societal Emotions and Needs
- Cultures, Languages, and Business Norms
- Societal, Economic, and Environmental Impacts of Engineering Decisions
- An International/Global Perspective

Communication
- Written (Memos, reports, email, letters, etc.)
- Verbal (Technical & non-technical presentations)
- Foreign Language (Technically fluent in at least two languages)
- Graphic (Design drawings, charts & graphs, presentation and basic brochure design)
- Digital Competency
- Listening
- Competent at Internet Collaboration and Communication Tools (Web-based meeting tools, team rooms, teleconferencing; file sharing, E-mail)
ASEE : Attributes of a Global Engineer

Teamwork
- Active and Effective Participation in Team Efforts
- A Willingness to Respect the Opinions of Others and Support Team Decisions

Leadership
- An Acceptable Personal Image and a Positive Personal Attitude
- Treating People with Fairness, Trust, and Respect
- Respect for Diversity
- Courtesy and Respect
- An Eagerness to Help Others

Flexibility
- Self-Confidence to Adapt to Rapid/Continuous/Major Change
- Thinking Both Critically and Creatively - Independently and Cooperatively
ASEE: Attributes of a Global Engineer

Curiosity and Desire to Learn - For Life (Show initiative, Inquire & Learn)
- Seeking Advice and Forming Daily Questions to Discover New Insights.
- Commitment to Quality, Timeliness, and Continuous Improvement
- Understanding Basic Project and Risk Management and Continuous Improvement Concepts (like LEAN+)

Ethical Standards and Professionalism
- Operate in Accordance With Acceptable Business, Societal, and Professional Norms
- Maintain the Highest Level of Integrity, Ethical Behaviour, and Professional Competence
- Understand and Applies Good Personal Judgment
How emotion and culture **not** content, curriculum & pedagogy are the crucial elements of change.

David Goldberg was the Jerry S. Dobrovolny Distinguished Professor in Entrepreneurial Engineering at the University of Illinois at Urbana-Champaign

http://www.amazon.com/Whole-New-Engineer-David-Goldberg/dp/0986080004
'Challenges for Engineering Education in the 21st Century'

Professor Andrew Deeks (UCD President)
*UCD EGA Annual Spring Lecture 2015*

*Michael Brooks ... we need agile thinkers rather than just more science, technology, engineering and maths graduates. New Scientist, Feb 2014*
Over the past decade, high-profile employers across the world have emphasised the need for today’s young professionals to possess not just deep disciplinary knowledge but a keen ability to operate effectively across disciplinary, social and cultural boundaries.
The ideal Engineer

The ideal engineer is a composite ... He is not a scientist, he is not a mathematician, he is not a sociologist or a writer;

but he may use the knowledge and techniques of any or all of these disciplines in solving engineering problems.

N. W. Dougherty, 1955
Big question:
Can all the ‘boxes’ be ticked?
Emer O’Toole: 
Irish students’ crisis of confidence poses a problem

“In scientific disciplines a shy student body might not matter too much, but in the arts and humanities it’s of huge importance. The most crucial skill we foster is independent thought and an ability to analyse the world in structured and productive ways. The arts and humanities teach people to question orthodoxies: to research, critique, challenge, solve problems.”

This attitude needs to be challenged: engineers and scientists most certainly need to ‘question orthodoxies: to research, critique, challenge, solve problems’.

Radar plots of different types of graduate

A range of ‘footprints’ should be permitted
4. CONCLUSIONS
Conclusions

1. As a profession we should engage in identifying, agreeing and reviewing today’s global challenges for engineering and then follow up accordingly.

2. We need to be part of and encourage a change of culture in society by which to oppose is replaced by one of collectively choosing the best from a set of options.

3. No one educational programme can be expected to provide the learning environment in which its graduates excel in all or most attributes linked to the ideal engineer.

4. What is required is greater diversity. Diversity should be valued both in respect of individuals and educational programmes and Accreditation Bodies should consider relaxing their criteria to allow for greater diversity in constructing engineering programmes.

5. The soft skills (emotional intelligence, critical thinking ...) are in fact hard or difficult to inculcate and need to be developed throughout the formation of the engineer (pre-university, undergraduate, postgraduate and in employment): a lifelong challenge!
To mirror the opening quotation

Where is the life we have lost in living?
Where is the wisdom we have lost in knowledge?
Where is the knowledge we have lost in information?

_T S Eliot_ The Rock (1934)
Thank You