A **New** Kind of **Engineer**: Incorporating Complexity, Uncertainty and Ethics as Bases for EESD

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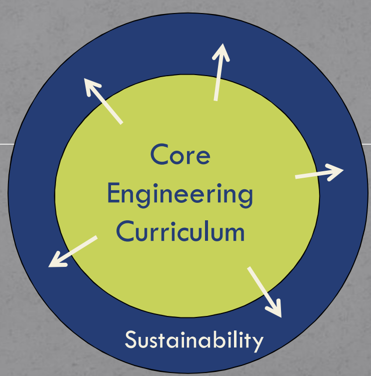
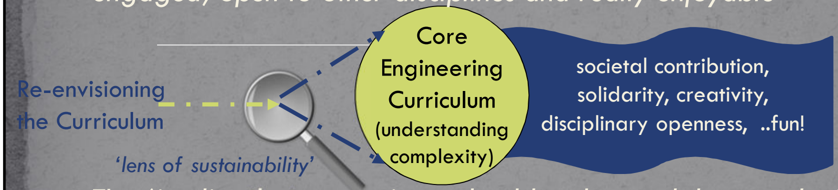
After more than a decade of EESD, a view has emerged around the need for engineering programmes to go *beyond* incorporating SD/sustainability as mere '*add on*' material to already overcrowded expanding curricula.



Mulder *et al*, 2012:

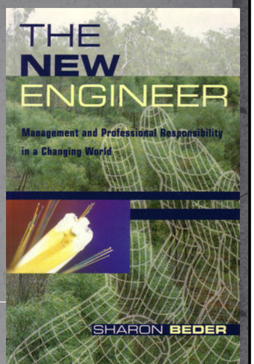
'Instead of adding SD to an unsustainable curriculum, we should rebuild curricula' so that SD is *'the leading principle for curricula'*

- whereby *'engineering universities [would] renew their culture emphasizing commitment to contribute to society, solidarity, openness and creativity'*
- thus *'making engineering education creative, effective, societally engaged, open to other disciplines and really enjoyable'*



- This *'implies that an engineer should understand the complexities of the societal setting in which he/she is developing solutions, and the complexities of making short term improvements that fit into a long term SD path.'*

The 'New Engineer' (Sharon Beder, 1999);



- recognises the *'deep sociotechnical complexities that are often at the heart of [engineering] "Grand Challenges."'* while making *'explicit the social and ethical responsibilities of engineers'* (Herkert & Banks, 2012).
- leaves hubristic illusions of control aside and embraces context, complexity, inherent uncertainty and risk (Bucciarelli, 2008).
- *While valuing science and technology, they acknowledge that technocentric approaches alone* are incapable of achieving progress towards sustainable outcomes among inter-related complex social, techno-economic and ecological systems (Conlon, 2008).

Professional Engineering Communication and Ethics (PE1006)

- Role of engineering in society
- Wicked problems
- Philosophy of engineering
- Professional engineering ethics and ethos
- Micro and macro ethical frameworks
- Complex problems; risk and uncertainty
- The new engineer and post-normal science

Goals/'learning outcomes':

- Relate professional engineering practice to the ethics and ethos of the profession and the role of engineering in society.
- Understand the nature of complex wicked problems and apply appropriate strategies for resolving such problems.

Professional Engineering Communication and Ethics (PE1006)

The student learning experience and success in meeting the goals of the module during 2012-2013 were assessed via:

1. A post-module reflective survey.
2. Module feedback administered by the university's Quality Promotion Unit.
3. Students' wicked problem assignment material.

1. Post-module Reflective Survey

58% response rate (73/125)

Students shown pairs of statements and asked to reflect on which they most closely agreed with:

1st statement: aligns with the dominant societal (reductionist) paradigm which has characterised modern engineering (Riley, 2008; ~~Herkert & Banks, 2012).~~

2nd statement: aligns more closely with a 'paradigm of complexity' (Morin, 2008) which permeates module.

Students also asked if they'd changed their view as a result of taking the module. (53/73 answered this part)

Because Engineers like to gather the facts from which the truth can be logically determined, they are best positioned to solve many problems.	6 (0% change (0/5))
The 'truth' cannot be achieved through facts and logic alone; in fact, there are many possible legitimate truths within given frameworks – e.g. different disciplines hold different perspectives and hence different truths.	67 (25% change (12/48))
Engineering is largely (or exclusively) a value free endeavour.	6 (0% change (0/2))
Values are inherent in all engineering practice.	67 (16% change (8/51))
Improving efficiency is the key feature of good engineering – continually increasing both technological efficiency and human productivity towards system optimisation.	27 (5% change (1/20))
While efficiency is important for engineering, a sole focus on improving efficiency represents poor engineering practice, as it reduces system resilience and redundancy while increasing tight coupling and risk	46 (61% change (20/33))
Basic scientific research is required as a precursor to technological innovation.* (*e.g. as practised by engineers)	20 (0% change (0/16))
Technological innovation* is often largely experiential and pragmatic and emanates from ideas and creativity. Basic scientific knowledge, while potentially useful to this process is not necessarily a prerequisite.	53 (32% change (12/37))

Engineers should be considered value neutral 'guns for hire' or 'paid hands'.	8 (17% change (1/6))
Engineers should be committed to social good, thus bestowing privilege in some ways, while also conferring a level of responsibility for their work and its consequences.	65 (21% change (10/47))

Risk can be represented by objectively quantifying the likelihood of an incident occurring.	21 (13% change (2/16))
Risk is a social phenomenon and is culturally constructed; the likelihood of an incident occurring is inherently subjective and thus in turn influences both the approach taken towards a risk and the risk level.	51 (56% change (20/36))

When the general public oppose engineering projects, it is often due to scientific or technical ignorance. It is therefore a key role of the engineer as experts to better inform the public; we need to improve our communications.	22 (13% chnge (2/16))
When the general public oppose engineering projects, it is often not due to inherent scientific or technical ignorance, but because the project conflicts with inherent values, for example around ideas of wellbeing, community, acceptable risk. This requires a broader more participatory conception of engineering (the 'new' engineer).	50 (25% chnge (9/36))

Results of part 1:

- Strong consistent support for the concept of the new engineer and 'social and ethical responsibilities of engineers.'
- The module appears to have accentuated this; significant numbers (retrospectively) claimed to have altered viewpoints.

Pertinent points:

- Surveys anonymous. Hence students not compelled to claim new/different ways of thinking to impress lecturer.
- However, unavoidable reality of the power dynamic (lecturer seen as source of 'definitive knowledge') and tendency for social fitting in/groupthink may influenced feedback.
- Students comfortably 'flip-flop' between different antagonistic paradigms as presented by lecturers, particularly since the largely separate modular structure of the curriculum neither promotes nor requires an integrative approach to learning.

Part II: Gauging students conceptions

1. What is the single most relevant thing you have learned?

- *"Values are essential in the lives of engineers. Choices that engineers make cannot be based on scientific knowledge alone but also based on social, ethical and economic values."*
- *"Engineering isn't just about thinking in a linear, mathematical way about problems. It must take social (and other) aspects into consideration."*
- *"I have learned to look at problems in many different ways i.e. there are very few problems with one specific solution. Each solution has problems within."*
- *"How risk can be thought of as a social phenomenon and how a perceived risk can affect people's actions."*

Students see relevance of the concepts covered to engineering practice and roles.

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2. What is the role of the engineer?

- *"Help solve problems in society by innovative solutions, while taking into consideration society and likely reactions to such a solution."*
- *"To utilise the resources available to man for the betterment of mankind."*
- *"To provide a clear and logical solution to a posed problem."*
- *"Apply technical knowledge to solve social problems. While engineers work largely in a technical; context there is also a social responsibility."*

Mixed response as students struggle to incorporate 'new engineer' into their conception of the role of the engineer; either mirrors the traditional self-perception of the engineer, or is some muddled version of 'old' and 'new'.
e.g. Cartesian notions regarding relationship with nature, or envisaging 'solving' social problems with technological tools.

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2. University gathered Module Feedback

Surveyed electronically by UCC's Quality Promotion Unit (QPU)
48% response rate (60/125)

	Excellent	Above average	Average	Below average
The stimulation to my thinking provided by this lecturer is:	21 (35%)	23 (39%)	11 (18%)	5 (8%)

Responses on 'stimulation to my thinking' align with relatively high proportion of students who claimed to have changed their perspectives by taking the module.

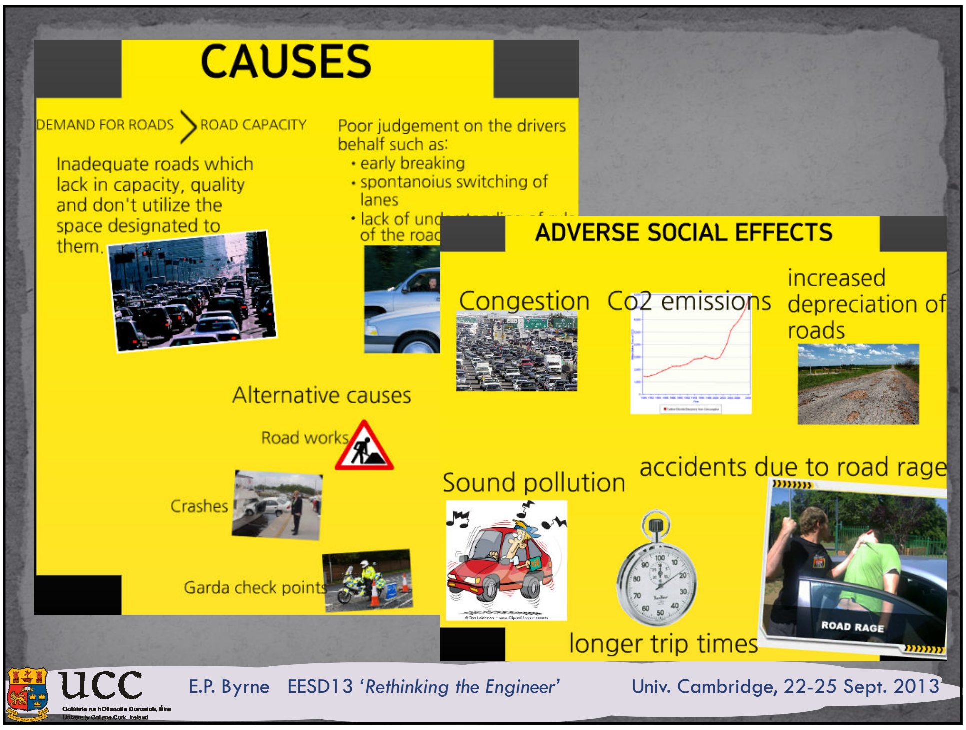
3. 'Wicked Problem' Assignment

Group assignment: students demonstrate ability to practically incorporate aspects covered in module.

In practice, proved challenging; students struggled to integrate 'new engineer' concepts into real life wicked problems.

Presentations generally displayed lack of coherence; groups ultimately proposed traditional reductionist 'solutions' to respective wicked problems, typically involving ever greater improvements in efficiency.

Study Case: Traffic


CAUSES
DEMAND FOR ROADS > ROAD CAPACITY
Inadequate roads which lack in capacity, quality and don't utilize the space designated to them.
Poor judgement on the drivers behalf such as:
• early breaking
• spontanoius switching of lanes
• lack of und
of the road
Alternative causes
Road works
Crashes
Garda check points
ADVERSE SOCIAL EFFECTS
Congestion
Co2 emissions
increased depreciation of roads
Sound pollution
accidents due to road rage
ROAD RAGE
longer trip times
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SOLUTIONS !
Improve quality of existing roads
INDIANA TOLL ROAD
Promote the use of public transport
Construct flyovers and bypass towns
Be
NEW ROADS
Produce larger and safer roads than before
Assess previous roads' various functional issues and make improvements
Straighter roads provide a less stressful commute than twisty, disorderly road systems
Improve positioning of stop signs, traffic lights and other road signs.
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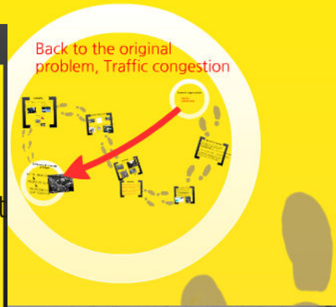
A true Wicked problem

DRAWBACKS TO SOLUTIONS

- Construction of roads is only a short term solution and doesnt look at the bigger picture
- Construction times may be inconvienent to commuters
- New roads may result in a habitat fragmentation
- Construction of bigger roads may lead to more traffic in the future on those roads, and so we are back to square one!



Reflections:

- While students claim to accept 'new engineer' ethos, in practice they struggle to implement and 'join the dots'.
  Perhaps unsurprising: its easier to revert to deeply held constructs of reality when faced with new challenges.
  Moreover, even if values are intellectually accepted, there may be other stronger conflicting values or structural barriers to change (WWF, 2010). Behavioral change is typically non-linear, taking a (fractal-like) 'zigzag course' (Hernes, 2012).

To help meet learning goals, future students will be asked to..

- Critique an earlier wicked problem presentation (e.g. traffic) & reflect on broader social complexities *(e.g. (sub)urban planning; pedestrian, cyclist & public transport status; health & well-being; obesity; environmental impacts; energy & fuel consumption.)*

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Conclusion

- A new kind of engineer is required if engineering is to be fit-for-purpose to address 21st century sustainability related challenges.
- Such an engineer challenges current reductionist thinking and requires a broader view of the role and social responsibilities of the profession.
- A key intervention point in the precipitation of a broader fit-for-purpose profession is through formative professional education.
- While challenges to change are substantial, as evidenced by the experience of this first year module, EESD (values and learning) can play a positive transformative role.

No One Can Save Us

Mojoko + Eric Foenander. Singapore Art Museum (Feb 2012)