Non-Discipline Specific Sustainability Knowledge & Competences in the Chemical Engineering Programme at UCC

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Abstract

This paper is presented within the broader theme of considering what non-engineering-discipline specific sustainability / sustainability development (SD) knowledge and competences should be included in engineering education, in particular for four year undergraduate or four to five year integrated master's programmes. Over the last 20 years, sustainability / SD has grown in importance, and consequently many engineering programmes have endeavoured to integrate it within their programmes. The UCC chemical engineering is one of these programmes. The inclusion of sustainability / SD content inherently contains engineering discipline specific content, but also includes content that is non-discipline specific and could potentially be undertaken by any engineering student. This paper looks at the University College Cork (UCC) Process and Chemical Engineering programme, and outlines the content that is considered as non-discipline specific. This includes the following which are briefly outlined in more detail within the paper:

- Basic concepts in sustainability and SD: What is it all about? The importance of framing.
- The environmental dimension, ecological systems thinking and importance of ecological limits.
- The role of environmental legislation.
- Humanity's grand challenges; the food-energy-water nexus and climate change.
- The game-changer: The socio-economic dimension (including ecological economics); its essential role in transitioning to and maintaining a sustainable society; its impact on engineering and to what extent engineering can have influence on the socio-economic dimension.
- Holistic thinking; inherent interconnectedness, life cycle thinking and assessment.
- Energy, its importance and its commonality to all engineering disciplines, and beyond..
- Acquiring soft skills of critical thinking, communication, working with others, embracing uncertainty and complexity.
- Transdisciplinarity, emergent knowledge, and the need to be able to work with others outside our disciplinary "silo".
- Values, ethics and the normative nature of sustainability choices and narratives.
- Worldviews, paradigms, and links with consumptive growth (material, energy, information).
- Transformational change; going beyond the quantitative and reductionist and the role of narrative, imagination, myth and metaphor in precipitating authentic societal and cultural change.

Keywords: non-discipline specific; sustainability knowledge & competences; UCC Process and Chemical Engineering programme

1 Introduction

Sustainability and Sustainable Development (SD) have become increasingly more and more important over the past 30 years, particularly because of human-induced climate change, but also because of concerns about the sustainability of modern agriculture, fresh water supply for irrigation and loss of biodiversity. These have the worrying potential to threaten the future prosperity of humanity (and other species) and even the survival of many. The current dominant business-as-usual socio-economic paradigm appears unsustainable, and some fear it could lead to the collapse of the global economy and human well-being. Engineering is a technical discipline that has great scope for contributing to human well-being, and its ability "to make a difference to the world" is a major reason why students choose it as a career (Alpay et al., 2008). However, it could be argued that engineering and technology in themselves are not enough, and within the current dominant socio-economic paradigm, engineering and technology are only moving humanity faster along an unsustainable path, possibly towards collapse (Byrne & Fitzpatrick, 2009, Fitzpatrick, 2017). Yes, they may be producing benefits to humanity, but this may be only in the short-term, being ultimately unsustainable and detrimental to humanity in the longer-term. Consequently, we now need engineers who are aware of sustainability and the potential sustainability crisis. They can no longer be just "guns-for-hire" serving the current socio-economic paradigm.

Considering this context, we need to graduate engineers that are suitably equipped to contribute to the transition from our current unsustainable path to a sustainable vision. Ultimately, engineers require more than just technical / discipline specific competences. Yes, technical and discipline specific competences will always be essential and core to an engineer's contribution to society. However, contemporary and future engineers require more, in particular non-discipline specific sustainability knowledge, mind-set and competences that enable them to make effective contributions to the transition to a sustainable society. This will encourage them to take a sustainability informed perspective into consideration when choosing career options post-graduation. They may have opportunities to integrate their sustainability informed education into their contribution to the decision making processes within their respective organisations as they progress through their careers. Some may become change-leaders, like the late Ray Anderson, an engineer and industrialist who was a pioneer in trying to incorporate sustainability into his business (Anderson, 2009).

This paper outlines the non-discipline specific sustainability knowledge & competences that are taught on the chemical engineering degree programme in University College Cork (UCC), along with rationale for including this content. It is hoped that this paper could contribute to a broader discussion on what non-discipline specific sustainability topics may be of value and importance to the education of engineers.

2 Non-discipline specific sustainability related content in UCC chemical engineering

This section briefly outlines the non-discipline specific content related to sustainability knowledge and competences and its rationale in the UCC Process and Chemical Engineering degree programme. This content is mainly undertaken in two bespoke modules in Sustainability and Environmental Protection which complements discipline specific (chemical engineering) content dealing with cleaner technology, waste treatment and disposal, life cycle analysis and environmental management.

2.1 Basic concepts in sustainability and SD

Firstly, students need an awareness and basic understanding of sustainability and SD. Thus it is important that students receive a basic grounding in these concepts. The word sustainability implies the ability to sustain. It therefore needs to be stated what it is that actually needs to be sustained when using the word "sustainability". Framing too is important, not just of sustainability related issues and wicked problems, but of the concept of sustainability itself. For example, in the context of this paper, we envision sustainability as essentially relating to human flourishing: the "sustainability of human flourishing", as stated by Ehrenfeld (2013). One way of defining this is that "sustainability" is all about large numbers of people (globally) being able to "flourish" over a "prolonged" period of time. Ehrenfeld argues that this vision of sustainability (as-flourishing) implies a positive, emergent, qualitative state, while "sustainable development" implies a negative, cutting back, quantitative, reductive approach which focuses on techno-efficiency, but cannot deliver on human flourishing. In practice however, the terms sustainability and sustainable development are often used interchangeably in practice. One way used to reconcile the two terms is that sustainability is seen as the goal, vision or where we want to go to, while sustainable development is envisioned as the "road" taken to achieve this goal. These and various other concepts and models of sustainability are explored and discussed.

2.2 The environmental dimension and ecological limits

It could be argued that environmental sustainability provides a foundation to sustainability more broadly considered, in the sense that humans need the environment to provide the natural resources and to deal with their wastes to facilitate human living and flourishing. For engineers, environmental sustainability is thus very important because engineers are involved with the use of raw materials extracted from nature and with the generation of wastes and emissions discharged into nature. It is very important therefore that engineers learn to view these activities from a sustainability perspective. It is important too that students are exposed to the negative impacts that humanity is having on the natural environment, while understanding the science of how that environment works, including interconnected ecosystems. Such "ecological systems thinking" is developed via a bespoke module on "Ecology for Engineers", taken in second year.

It is useful to highlight the fact that nature manifests the concept of sustainability, as it has flourished over a prolonged period of time, and to explore some of the key features of how nature operates sustainably, including natural recycling of materials and use of solar energy. Environmental unsustainability can be viewed in terms of 1) unsustainable extraction of natural resources and 2) unsustainable discharges of emissions / wastes that "hurt" the environment (Figure 1). Consequently, there are ecological limits associated with resource extraction and discharge of wastes / emissions e.g. if a natural resource is extracted at a rate (mass flowrate) greater than it can replenish itself (ecological limit), then it is being extracted unsustainably and its capital stock will face depletion. Likewise, emissions are environmentally unsustainable if they are discharged are rates larger than that which nature can process them.

Figure 1: A schematic of environmental unsustainability.

2.3 Environmental legislation

Engineers need to be aware of and appreciate the role of legislation as a strong tool for reducing environmental impact by industrial firms and other organisations. Legislation is a particularly important environmental tool in a market economy, because organisations operating in a market economy need strong environmental legislation to reduce their environmental impact because their primary goal is to maximise profit. In Europe, EU directives are the major driver of environmental legislation and students are exposed to some key environmental directives and how they are implemented in an Irish context.

2.4 Humanity's grand sustainability challenges

It is important that students have an awareness and appreciation of the grand sustainability challenges facing humanity, and to instil in them a realisation that the negative impacts from not addressing these challenges may materialise during their lifetime, and thus could majorly impact on their lives sometime in the future. Some of the major sustainability challenges that are presented include

- Supply of the basic needs for living, in particular the food, energy, water (FEW) nexus
- Climate change and how it interacts and exacerbates the challenges associated with the FEW nexus.

Initially, students are exposed to the concept that humanity has moved into a space where it is living beyond ecological limits, as described by ecological footprinting and by the "Limits to Growth" study (Meadows et al., 2005). Humanity cannot indefinitely live beyond these limits and contraction will occur sometime in the future. This will either be through a "managed decline" to sustainable levels of activity, or "collapse" to the same levels, caused by the unmitigated work of "nature" or its impact on "the market".

The potential unsustainability of modern agriculture, its' ability to sustainably supply food and its impact on fresh water supply is a grand sustainability challenge which is presented to the students, with help of a book by Brown (2012). Brown uses the term the "food equation". On one side there is demand for food, and on the other side is the supply of food from agriculture that must satisfy the demand. There are pressures on agriculture from both sides of the food equation, as outlined in the Table 1, and these are presented and explained to the students.

Table 1: Pressures on agriculture

Demand side	**Supply side**
Increasing human population	Increasing soil erosion
Increasing affluence	Increasing water shortages
Biofuels	Increasing global temperature
	Plateauing of grain yields

Climate change and its interaction with energy are possibly the most urgent and pressing sustainability challenges, and the students have already some awareness of these. However, it is still important to spend time on these topics and explore them in detail. Global energy supply is still dominated by fossil fuels and the environmental unsustainability is explored with the students from both natural resource and carbon emission ecological limits, with the latter and its consequences for climate change being much more worrying and moving rapidly towards crisis levels. Technological approaches are considered for moving to a sustainable global energy future. However, it is suggested and explored with the students that the real "game-changers" lie in the socio-economic domain, and that these have a major impact on the development and implementation of cleaner technology approaches.

2.5 Ecological economics and the socio-economic dimension

It could be argued that the economic and social levers for change are the "game-changers" in moving to a sustainable paradigm, and have a major influence on the technical levers. Consequently, the prevailing socio-economic paradigm needs to be modified to provide a framework which facilitates and incentivises engineers to deliver technological improvements to people's well-being that are long-term, that is, they are sustainable, as schematically illustrated in Figure 2. Ecological economics can help engage students in the importance of the socio-economic dimension of sustainability, and how the socio-economic can influence engineering & the transition to the sustainability of human flourishing.

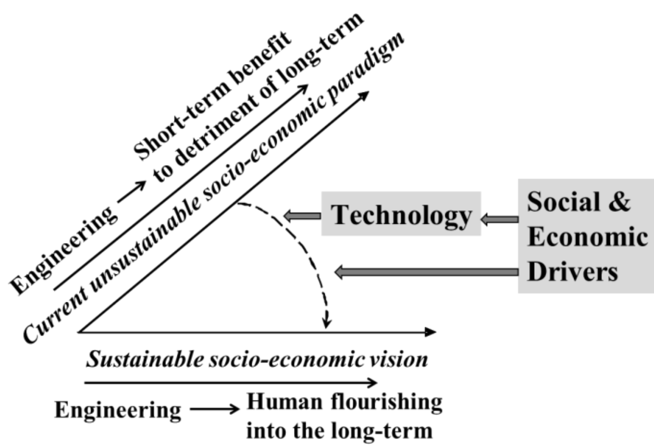

Figure 2: Moving to sustainable socio-economic paradigm that facilitates engineering to deliver technologies that enhance human flourishing in the long-term.

Its' focus and premise is on an economic system that facilitates the sustainability of human flourishing within planetary limits. There are two broad elements to a sustainable economy, as illustrated in Figure 3 and outlined by Dietz & O'Neill (2013), that can facilitate the sustainability of human flourishing, namely: Environmental and Social, and these are explored in detail with the students.

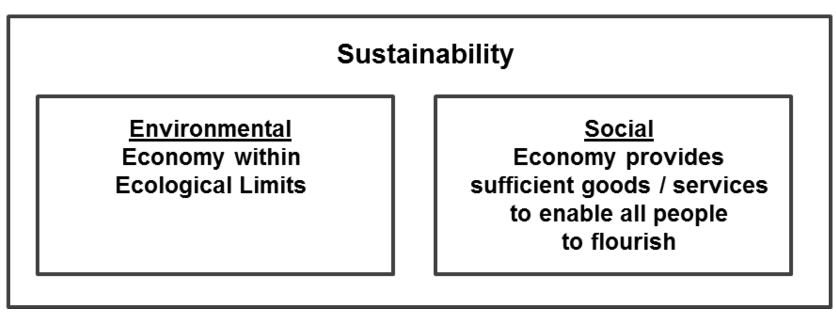

Figure 3: Two required contextual lens of an economics which facilitates sustainability as human flourishing.

2.6 Holistic thinking

This is all about trying to encourage students to think more holistically. Firstly, there is a need to develop "sustainability informed engineers" as the very *context* through which they envision their profession and practice (Byrne and Mullally, 2014), rather than "business as usual engineers". They should have a deep knowledge and consciousness of sustainability and the sustainability challenges facing humanity, and be somehow willing to engage with these throughout their careers. Furthermore, life cycle thinking (and assessment) is an important aspect of holistic thinking that engineers should be aware of.

2.7 Energy

Energy is common to all engineering disciplines, and is a major sustainability challenge. Consequently, all engineering students should receive a good education in issues around energy and sustainability, including dissipative energy (entropy) produced as per the second law, and its proportionate link with ecological degradation (Wessels, 2006). In the UCC chemical engineering programme, energy is dealt with from a global perspective and also from the perspective of a processing plant.

2.8 Transferable skills

There are a number of continuous assessments in the sustainability & environmental protection modules that assist in development of transferable skills, such as knowledge acquisition, critical thinking skills e.g. dealing with complexity / uncertainty, communication, team work, willingness to consider other sides of debates, and working with other disciplines (Fitzpatrick et al., 2020). These soft skills are particularly important for engineers working in a world where sustainable informed thinking provides the context for their work.

2.9 Transdisciplinarity

In addressing contemporary and emerging "grand challenges" associated with sustainability and the FEW nexus, disciplinary knowledge alone is insufficient. Engineers and scientists will need to work with and draw on knowledge and expertise from a range of other disciplines and from local experiential and community knowledge if we are to make authentic progress. Too often in our institutions however, we engage in the production of siloized disciplinary experts, before expecting our graduates to go out into the real world and work with others. The UCC programme brings together third year chemical engineers with sociology and government students taking an environmental sociology module to engage in a group assignment to consider some aspect of sustainability (Byrne & Mullally, 2016). This exercise adopts a transdisciplinary ethos, recognizing that through a transdisciplinary engagement we can collaboratively in a "greater than the sum of the parts" derive new insights and emergent knowledge and thus go places which any single discipline could not go. Moreover, second year students taking a communications module engage with finance students as part of an innovation energy transformation project and competition, with institutional, national and international rounds.

2.10 Values and ethics

The normative nature of sustainability means that choices and priorities are chosen based on values and value sets. This is highlighted throughout the programme so that graduate engineers recognize the normative or value laden nature of decisions that they are involved in, rather than seeing socio-technical problems and proposed solutions in a rational "value free" decontextualized setting. While chemical engineers require attention to individual level micro-ethical concerns around personally doing the right thing (including whistle blowing, etc.), there is also the macro-ethical domain, where sustainability issues reside, such as the societal and professional body inherent values which govern approaches and practice (Conlan, 2010). While these are often overlooked in our programmes, we seek to address such macro-ethical issues in the context of global and sustainability perspectives (Byrne, 2012, 2014).

2.11 Worldviews and paradigms

The sustainability and environmental modules go beyond the technical by seeking to understand why it is we act as we do and indeed why we find it so hard to change. This leads to an exploration of the history of science and technology and an exploration of the dominant socio-economic neo-Cartesian paradigm which has characterized modernity as well as other paradigms and worldviews, including emerging integrative ones, which seek to integrate useful aspects of other preceding ones (Byrne, 2017).

2.12 Transformational change

Finally, in the context of seeking transformational change towards sustainable societies, students are invited to explore the role and value of agents of human change which reside outside the domain of engineering (and in the humanities) and which expressedly go beyond the merely quantitative, rational and reductive. These include the role of narrative, imagination, myth and metaphor in precipitating authentic societal and cultural change. They are thus encouraged to reflect on how these may impact or enhance engineering practice.

3 Conclusions

Engineers cannot just be technological "guns for hire" who reside in "tech silos". Engineering graduates hoping to contribute to a world transitioning to a sustainable society need to be equipped with a variety of non-discipline specific sustainability knowledge & competences. Engineering education has an important "foundation" role to play in the formation of sustainability informed engineers, who acquire an in-depth awareness of humanity's grand sustainability challenges and the importance of the socio-economic dimension of sustainability that compliments their technical capabilities. Some of these engineers, equipped with this awareness, may be able to couple this with their own innate talents that favours a move towards a sustainable direction within their own work organisations, and/or within broader society. Furthermore, it will enable them to work more effectively with those in other disciplines.

The inclusion of non-discipline specific sustainability knowledge & competences represents a real and explicit attempt to provide a useful intervention at a key point in the educational formation of undergraduate engineers, one which, in time may produce a valuable positive impact. It is hoped that by providing engineers with some basic tools, in particular the ability to think critically around sustainability issues and narratives that they may, over the course of their future careers and lives, engage in a positive manner with the issues at hand, resulting in greater societal good as well as enhanced personal and professional satisfaction.

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