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Strategic competences for concrete action towards sustainability: An oxymoron? Engineering education for a sustainable future

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ABSTRACT

In the current discourses on sustainable development, one can discern two main intellectual cultures: an analytic one focusing on measuring problems and prioritizing measures, (Life Cycle Analysis (LCA), Mass Flow Analysis (MFA), etc.) and; a policy/management one, focusing on long term change, change incentives, and stakeholder management (Transitions/niches, Environmental economy, Cleaner production).

These cultures do not often interact and interactions are often negative. However, both cultures are required to work towards sustainability solutions: problems should be thoroughly identified and quantified, options for large change should be guideposts for action, and incentives should be created, stakeholders should be enabled to participate and their values and interests should be included in the change process. The paper deals especially with engineering education. Successful technological change processes should be supported by engineers who have acquired strategic competences. An important barrier towards training academics with these competences is the strong disciplinarism of higher education. Raising engineering students in strong disciplinary paradigms is probably responsible for their diminishing public engagement over the course of their studies. Strategic competences are crucial to keep students engaged and train them to implement long term sustainable solutions.

Contents

1. Introduction

In 1959, C.P. Snow lamented the great divide between 'science' and 'the arts': *'intellectuals often proudly proclaim that science isn't their thing, almost as a badge of honour to indicate their cultural bent'* while '*scientists being blind to the fact that live is not just about optimisation but also about the values behind that: we have to develop compromises between various, partly contradictory and overlapping, partly qualitative and emotional, demands'*. Snow argued that practitioners in both areas should build bridges, to further the progress of human knowledge and to benefit society [1,2].

Although Snow's analysis triggered lots of reactions, especially regarding its message to create more understanding for science

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among literary intellectuals that dominated the British elite, it hardly affected the phenomenon it described: Today we can observe a gap between the 'sciences' and 'the arts' that, in the industrialized world, has probably widened instead of having been bridged [3,4].

A powerful explanation for this gap was soon after provided by Thomas Kuhn. In his ground breaking "The structure of scientific revolutions" he introduced the concept of 'paradigm': the set of concepts, practices and heuristics that defines a scientific discipline [5]. Paradigms define what is of interest to a discipline, what counts as proven knowledge, and what the legitimate questions for further research are. Paradigms can be divided in categories according to the rationality that is applied:

- Scientific paradigms apply a rationality that aims at establishing truth, i.e. at creating expressions that match reality [Cf. e.g. [6]].
- Technological paradigms apply a rationality that aims at obtaining useful results, i.e. in obtaining results that fulfil practical demands [7].
- The arts apply a paradigm of beauty, i.e. it aims at results that are original, provocative, tantalizing.[1]
- Law applies a paradigm of justice, i.e. it aims at creating an institutional structure that produces 'just' decisions to resolve conflict [Cf. [8]].

A main part of Kuhn's history of science legacy establishes the point that in a scientific revolution, a paradigm changes. However, contrary to the self-image of scientists, this is not a cognitive process based on the introduction of new concepts and/or the discovery of new facts. A paradigm change often raises controversy as contestants are unable to grasp each other's arguments as the arguments refer to incompatible frameworks. A paradigm change is a social process in which generally young scientists, attracted to the new paradigm, take over power from the establishment.

The aim of this paper is to show that the challenges of the future requires changing the discipline based higher education system of industrialized countries. Future experts should learn to think and act change. This paper will focus on engineering as engineers are the experts that design and operate the main metabolic systems of the industrial society. Similar changes could be described for educating managers, lawyers, civil servants, etc.

Educating a new type of engineer requires a paradigm shift in engineering. The future requires an engineer that combines the usual scientific strengths of engineering with strength in managing change and innovation in order to deliver systems level innovation. Innovation is still promoted as if the world is still an almost barren place to be filled with new ingenious products and systems. However, modern innovation is taking place in a context of various other capital intensive systems [Cf. [9]], and in a far more participative society than the 19th century society that created the engineering profession [Cf. e.g. [10]]. Technological change requires thoughtful planning and dialogue, not just to introduce the innovation that was conceived in the laboratory, but to conceive the technologies that might survive the innovation process and deliver the changes that are required for sustainable development.

The paper will first examine how two paradigms regarding environmental issues entered the academy and will argue in favour of an understanding of both paradigms in order to be able to create change. Afterwards, the paper goes into the insufficient educational responses to the sustainability crisis. It develops an argument to restructure engineering education in order to make contributing to sustainable development the leading principle of engineering education.

[1] The Golden Ratio has been suggested as an explanation of beauty in arts, and as a tool to achieve it. However, the aim of arts is not to represent any formula.

2. Two paradigms in developing solutions towards the environmental crises

The first wave of environmental awareness developed in the 19th century. In 1848, Thoreau's classic work Walden was published that contained a message of respect for nature. It was a reaction to the tremendous damages that the rapidly developing mines, industries and infrastructures, as well as the growing population, inflicted on natural systems [11]. Nature had to be protected and hence the impacts of human activities upon natural systems were targeted by conservationists. Environmental sciences gradually started as ecology and toxicology to study nature's balance and the impacts of various man-made disturbances.

Meanwhile, environmental engineering started in the cities of the industrialised world. It was not related to any thoughts about nature but to a pressing need for public hygiene. Sewage- and drinking water systems were created as a counter measure to infectious diseases and poisoning. Tall chimneys and the first environmental regulation aimed at protecting the health of citizens [12].

2.1. Analysis of metabolic systems

In a second wave of environmental awareness, the focus of attention shifted from the decline of nature and natural systems, to industrial production as the cause of environmental degradation [13] and the limited resources available for the rapidly expanding industrial society [14]. Especially after the Brundtland report made clear that global poverty reduction and improvement of the metabolic efficiency of production and consumption were two sides of the same medal, the metabolism of human society received far more attention. Thereby the focus of the environmental problem definition shifted not only from emissions to metabolic processes, but also to global equity and issues of socio-economic development [11]. A new scientific research paradigm aimed at analysing complete sequences of metabolic processes of human society in order to assess the combined impacts of providing a product, a service or a material, and to identify the causes of these impacts. It utilised quantitative analysis, and aimed at analysing (global) flows and stocks of resources. Each unit consumed could therefore be connected to flows of resources, emissions and wastes. The combined environmental impacts of any consumption of products or services could therefore be established, although some environmental impacts (like wildlife disturbance), and some causal factors (like risks) were hard to quantify. Methods based on this paradigm are Life Cycle Analysis [15] and Mass Flow Analysis [16].

2.2. Analysis and management of change

Ever since the Enlightenment, science has been regarded as an important cultural activity that could help people understand reality. However, in the course of the 20th century, science more and more became a source of technological innovation. Hence it was a source of national strength and economic success [17]. Especially in the 1980s, historians and sociologists of science and technology started claiming that new technologies did not emerge by 'discovery' of the 'facts of nature' but as a result of economic [18] and social forces and their dynamics [19]. Technology is not prescribed by (perhaps still unknown) facts of nature; its' developers aim at serving specific goals. Hence, actors can develop strategies to try to influence, or even manage, processes of

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