INCORPORATION OF SUSTAINABILITY INTO CHEMICAL ENGINEERING CURRICULA

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Abstract

The role of engineers and designers at all scales, molecular, products, processes, and systems, is going to be central and essential in determining what tomorrow will look like. A chemical engineer, as the designer of products and processes also has a central role in designing chemical processes that have a central importance in the society. How can we incorporate sustainability principles into Chemical Engineering curriculum? There have been a lot of efforts from the Chemical Engineering (ChemEng) Academia. In this paper we our vision and ideas for the reinforcement of the Chemical Engineering degree analysing opportunities in the main subjects for incorporating sustainability principles, from freshman engineers to last year and master students.

Introduction

The world is living a change and a great number of different agents: scientists, politics, artists, people try to demonstrate it. Each individual and group of individuals has its own responsibility and percentage of participation in this change. Certainly, the change was always there, but the difference between previous ages and the present time is the acceleration of this change. Several visionaries, such as Thomas Friedman state that the world is currently under a strong acceleration motivated by the communications (1). Figure 1 shows the evolution of Gross Domestic Product using Purchase Power Parity (GDP PPP) in the time-line. Until year 1000 A.C. there was a constant capital value, human being tried to satisfy basic needs. From 1000 A.C. till ca. 19^{th} century there was the first acceleration, motivated by the starting of commerce, navigation, etc. During the 19^{th}-20^{th} century the second acceleration took place, mainly driven by the Industrial Revolution, machines, chemical products and petroleum. Furthermore, from the 1970's the World has experienced the third acceleration driven by communications and computers among other factors. This acceleration has a similar ratio of increase than the second acceleration to the first, but it is being going on very fast.

Chemical Engineers have our part of collaboration in the improvement of society. The growth and sustainability of the world requires a clear understanding of what can every agent do. Considering Chemical Engineering we do not have any dude that from the University we need to promote sustainability from the very beginning of the studies. The first paradigm (unit operations) and the second paradigm (transport phenomena) must be there, because they indicate what to do for design but, probably, a third paradigm needs to be included in the toolkit. 'Sustainability criteria' is a good candidate to become this third paradigm. Innovation and creativity to design using the well-known tools for ChemEng aimed at promoting sustainability.

Unfortunately, terms as “efficiency” and “traditional” are quite common within the “engineering world“, so several times efforts done in the direction of including sustainability criteria within Chemical Engineering curriculum are considered “philosophy” rather than Engineering and excluded from the programmes. As Hesketh *et al.* indicate professors need to recognize that green engineering should be taught at all engineering undergraduates and that green engineering is not different to current subjects (2).

Nevertheless, we believe that is our commitment to help the students in differencing between what is doing the things as correct as possible from the beginning (design) and clean the stuff afterwards (treatment, disposing, etc.). It is a long way but hopefully the starting is now on.

Different universities and colleagues have shared their valuable experiences in this important task (3). Next, we present our contribution to the modification of Chemical Engineering curriculum including some new subjects or modify the current subjects including “tips” of sustainability. In particular we focus our attention in the curriculum suggested by the European Federation of Chemical Engineering.

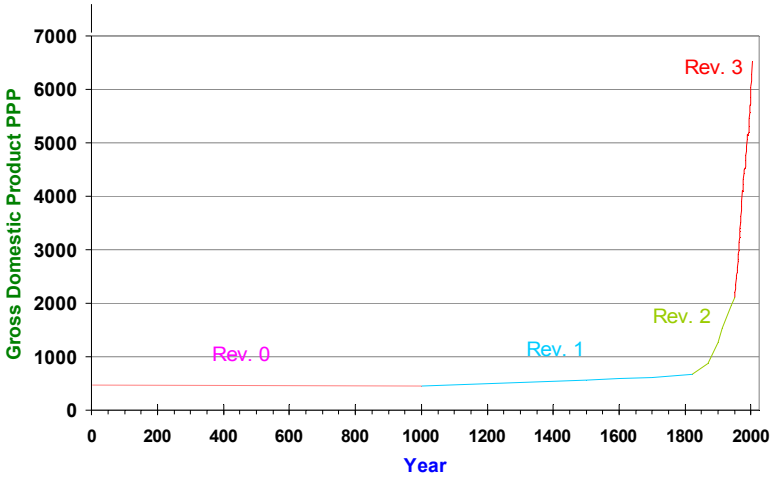

Figure 1. Evolution of Gross Domestic Product

Proposed modification of the curriculum for Chemical Engineering Degree

The following suggestions are the possibilities of modification of the current subjects and creation of new subjects within the ChemEng degree at the University of Valladolid (Spain). After several considerations we decided to concentrate in our degree with the objective to be prepared in case of a real possibility of modification in the near future, due to Bolonia treatment in Europe.

The word “sustainability” is being used too much nowadays, several times incorrectly. Being sustainable sells but, it is different to say that you are sustainable than to be truly sustainable. Many times, sustainable is only related to environment, not considering the societal and economic considerations (4).

Freshman students need to have a clear definition because in this way the will define clear objectives to promote sustainability. Once, they have a clear idea of sustainability they need criteria and tools for design, this will be acquired during the core years, second to fourth. Finally, last year students require a perspective and good case studies of green engineering design.

Experimental subjects have not been included in this manuscript.

First Year – Freshman engineers

Objective: Basis of Sustainability

Subject 1: Introduction to Chemical Engineering

- Definition of sustainability. The triple base line
- Definition of Chemical Engineering and Green Engineering
- Requirement of multidisciplinary
- What is and what is not Green Engineering?
- Mass and energy balances – Examples of sustainable solutions

Subjects 2 and 3: Organic Chemistry and Inorganic Chemistry

- Green Chemistry Principles
- Green Solvents
- Inherently Safer Design: (2) Substitution: use of non-hazardous compounds.

Second Year

Objective: Green Engineering Design Criteria

Subject 1: Introduction to Thermodynamics

- Enthalpy and entropy. The quality of the energy, Exergy.
- Efficiency of thermal machines and energy saving.

Subject 2: Fluid flow

- Criteria for sustainable pipe selection
- Inherently Safer Design: (4) Modify storage arrangements

Subject 3: Analytical chemistry

- Green solvent selection for analysis
- Green analytical techniques

Third Year

Objective: Green Engineering Tools for design (I)

Subject 1: Heat transfer

- Optimization of heat insulation
- Heat exchanger selection for material, heat and equipment optimization.
- Inherently Safer Design: (5) Energy limitation

Subject 2: Applied Thermodynamics

- Supercritical Fluid State. CO_2 as a solvent and thermo fluid.

Subject 3: Materials in ChemEng

- Definition of eco-efficiency
- Optimum design for eco-efficiency
- Biomaterials. Biopolymers.

Subject 4: Fundamentals of Kinetics

- Inherently Safer Design: (3) Alternative Reaction Routes
- Green Chemistry: Catalyst for efficiency
- Heterogeneous *vs* homogeneous catalysis. Heavy and precious metals.

New 1: Renewable mass and energy sources

Fourth Year

Objective: Green Engineering Tools for design (II)

Subject 1: Environmental Technology

- Getting to Zero waste philosophy. Remove the word "residue" from our mind.
- Green Engineering Ethics
- Eco-efficiency and sustainability metrics

Subject 2: Control and instrumentation

- Real-time measurement of effluents
- Controllability principles for systems
- Interlock systems for safety

Subject 3: Unit operations. Separation

- Green Solvents Selection
- Supercritical Fluids for Separation
- Ionic Liquids

Subject 4: Reaction Engineering

- Efficient reactor design. Introduction to Computer Fluid Dynamics.
- Inherently Safer Design: (1) Intensification, from scale-up to scale-out (e.g. micro-reactors).
- Reactors using solar income.

Subject 5: Mass and Energy Integration

- Pinch technology: hydrogen, energy, etc.
- Renewable energy sources
- Renewable feedstock

Last year and Master students

Objective: Global perspective of Green Engineering and Sustainability. Case Studies.

Subject 1: Project Engineering

- Globalization
- Green Engineering Principles for design
- Green Engineering Case Study

Subject 2: Equipment design

- Sustainable material selection
- Material optimization

Subject 3: Industrial chemistry

- Examples of non green chemical plants and processes
- Examples of green chemical plants and processes

Subject 4: Macro and micro-economy

- Global economy and market
- Economy and sustainability
- Micro-credits

Subject 5: Safety and human health

- Green chemicals. Indicators of hazard.
- Inherently Safer Design
- Learning from accidents

New 1: Creativity for Green Engineering Design

- Biomimicry
- Nanotechnology
- Ionic Liquids and Supercritical Fluids
- Design for Sustainability

Conclusions

Incorporating Green Engineering into ChemEng curriculum is a commitment for the ChemEng Academia. Although this necessity seems to be obvious it is not always easy to achieve the goal. Sustainability looks attractive but too philosophical somehow and this causes conservatism within the traditional Engineering world. Comments like "but… what is the difference with we are doing already?" are unfortunately frequent. What is Green Engineering and what is not? Our students do not need nice definitions; they need tools and criteria for design towards sustainability. Traditional design practices are still valid, but need some refurbish, some fresh ideas. Hopefully this collection of possible ChemEng curriculum reinforcements together with the ideas of all other colleagues can see the light in the next few years.

References

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