Directions for the Future

Is it there...

the 3rd Paradigm of Chemical Engineering?

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Félicitation à Jeune ENSIC

Joyeux anniversaire
To say what I am going to say...

1. Framework - European Strategy for Development
   1. Life Today
   2. The Bologna Process
   3. The Directive for Recognition of Professional Qualifications

2. Academic Degree Structures
   1. Levels and profiles
   2. Basic design conditions
   3. Offer of programmes

3. Chemical Engineering Degrees in and for the future
   1. Paradigms
   2. Questions
   3. Contributions
   4. Guidelines

European Strategy for Development
I - Driving forces for changes

○ Last quarter of the 20th Century - Intense search of new routes for Europe and for the role of Europe in the World, driven by

✓ Progress observed in Science and Technology, namely
   ➢ in health and life sciences
   ➢ in digital systems and communications
   ➢ in material science

✓ Political changes that took place in Europe

✓ Expectations and demands of Society
   ➢ Education for All
   ➢ Quality requirements
European Strategy for Development
II - Life Today

- Economy and market forces
- Globalisation - Dramatic changes of the concepts of time and space
- Job market and opportunities - wider than ever
- The increase of Expectation of Life - Social sustainability
- Sharp increase in standards and competition - Worldwide and within the European Space

- Very Important with respect to young people -
  - Significant change in the concepts of individual career management
  - Work longer - Lifelong Learning

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European Strategy for Development
III - World Competition

(A) Geographic breakdown of world chemicals sales

![Geographic breakdown of world chemicals sales](image)

World chemicals sales in 2004 is estimated at € 1736 billion
The EU accounts for 33% of the total

Source: Cefic
Definition: Rest of Europe (excluding the new EU 10 countries)
Other (excluding Canada, Mexico, Africa & Oceania)
European Strategy for Development
III - World Competition

(B) Scientific development and the Market

Scientific Computing, March 2007
Drastic reductions in development time

European Strategy for Development
IV - A New Model...

- Culminated with the European Council of Heads of State and Governments, March 2000, Lisbon
  - The Lisbon Strategy for Growth and Jobs
  - Competitive positioning relatively to the other blocks of the Planet
  - Stating a strategic objective:
    “By 2010, making Europe the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion”
- Strengthened with the new Treaty of Lisbon, 13 December 2007
European Strategy for Development V - The three dimensions of the Strategy

- A strategy based on Knowledge and Transnational Cooperation, where we can recognize -
  - The Economy Dimension -
    - Including the movement that converged in the creation of the EURO
  - The Social Dimension -
    - In line with the European culture of humanism, reasoning, freedom and democracy
  - The Knowledge Society Dimension -
    - Identified with the Bologna Process and the creation of the European Higher Education Area

The Bologna Process Revisited
Building the European Area of Knowledge... till 2010 !!!
The Bologna Process revisited

I - What needs to be understood?

❖ Understand the Bologna Process as having two main groups of objectives, naturally interlinked
  ✓ Objectives of political, social, and economical nature
  ✓ Objectives of a dominant academic nature

❖ Understand that indeed these objectives mean, in many countries, a major reform (... a small revolution...) in Higher Education and in Society

The Bologna Process Revisited

II - Objectives

(A) Social, economical and political objectives

❖ From a social and economical point of view - to guarantee development and competitiveness through -
  ✓ The increment of transnational cooperation and mobility, both in higher education and in R&D

❖ From a more political point of view - to contribute for European cohesion
  ✓ Again, through mobility and cooperation, at all levels, of both students and professional

❖ Still at political level
  ✓ To promote the External Dimension of the European model
The Bologna Process Revisited
II - Objectives

(B) Objectives of a more academic nature

Political / academic

☑ Restructuring the offer of higher education - more attractive and nearer to the needs and interests of Society

Academic

☑ An evolution of teaching/learning paradigms - adapted to the concepts and perspectives of the modern society and to the available technical tools, projecting education to more adult phases of life

A major complementary policy instrument
The Directive for Recognition of Professional Qualifications (I)

Adopted in September 2005

Reaffirms previous Directive, accepting 7 professional areas with recognized specifications

☑ Medical training Minimum education - 6 anos IT
☑ Training of veterinary surgeons Minimum education - 5 anos IT
☑ Basic dental training Minimum education - 5 anos IT
☑ Training as pharmacists Minimum education - 5 anos IT
☑ Training of nurses Minimum education - 3 anos IT
☑ Training of midwives Minimum education - 3 anos IT
☑ Training of architects Minimum education - 4 anos IT

Engineering (as Law) is out of this group
A major complementary policy instrument
The Directive for Recognition of
Professional Qualifications (II)

- Distinguishes between professions that are ‘regulated’ with an Annex and the other professions

- Article 11 - Three levels of qualification particularly relevant for professions that are out of the Annex
  - 1 level, requiring short post-secondary education, not necessarily at higher education level, plus professional training
  - 2 levels of post-secondary education at higher education level, plus adequate professional training

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A major complementary policy instrument
The Directive for Recognition of
Professional Qualifications (III)

- Art. 11, e)
  ...completed a post-secondary course of at least four years’ duration...at a university or establishment of higher education...and where appropriate completed professional training...

- Art. 11, d)
  ...training at post-secondary level of at least three and not more than four years’ duration...at a university or establishment of higher education...as well as the professional training that may be required...

- Art. 11, c)
  ...training at post-secondary level other than that referred in d) and e) of a duration of at least one year...as well as the professional training which may be required in addition to that post-secondary course...
To say what I am going to say...

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   - Levels and profiles
   - Basic design conditions
   - Offer of programmes

3. Chemical Engineering Degrees in and for the future
   - Paradigms
   - Questions
   - Contributions
   - Guidelines

Academic Degree Structures
The Bologna Process, The Directive and Engineering Education

- Before the approval of the Directive, a major discussion took place at FEANI’s level about competences and education in Engineering

- FEANI accepts the existence of two main profiles
  - More theoretically oriented
  - More applications oriented

- Complementary, the Directive, in full agreement with Bologna’s Qualifications Framework, recognizes
  - Two main levels of education for professional purposes

- This fits remarkably well the offer of engineering education in several European countries
Academic Degree Structures
Concerning levels of qualification - (II) - Art. 11, d) and e)

- Two levels of qualifications associated to those levels approved in the Directive

- LEVEL 1 - Art. 11, d): (3-4)U + Professional Training >= Y, with Y=?
  - First Cycle Degrees are the basis for achieving the qualification of Technical (or Associate) Engineers, whatever the European designation

- LEVEL 2 - Art. 11, e): >= 4U + Professional Training >= X, with X=?
  - Second Cycle Degrees are the basis for achieving the qualification of Engineers, or equivalent European designation

Academic Degree Structures
Concerning Profiles

- Two main engineering profiles

- More Theoretically oriented
  - Programmes with a stronger emphasis on basic and engineering sciences in the first years
  - Generally linked to Second Cycle degrees

- More Applications oriented
  - Designed to qualify after First Cycle, independently of pursuit of studies through Second Cycles, be it directly or through bridging programmes
Academic Degree Structures
Prevaling concepts in the design of the Degree System

- More flexible paths - MORE differentiation (competences) offered
  - Either more research oriented, or more innovation oriented, or with a higher entrepreneurial spirit, etc....
  - Bringing in the concept of “Communication Pipes” between different profiles of education - Bridging programs

- More attractive offer in order to bring into the system students with different backgrounds and interests

- Promotion of a true offer for lifelong learning through
  - Complementary modules of (advanced) specialization courses
  - Implementing the concept of ‘accumulated credits’ for recognition of studies

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Academic Degree Structures
Offer of Programmes

- The offer of **First-cycle programmes**, aiming at fulfilling the level of requirements for accreditation and professional recognition of LEVEL 1

- The offer of **Second-cycle programmes**, aiming at fulfilling the level of requirements for accreditation and professional recognition of LEVEL 2

- The offer of **two-cycle programmes**, within a philosophy of integrated studies, aiming mainly at fulfilling the requirements of accreditation and professional recognition at LEVEL 2

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Why New Directions for Chemical Engineering?  
I - The Second Paradigm...Chemical Engineering Sciences

- The 2nd Paradigm transported chemical engineering away from the limited number of unit operations that dominated the conceptual approaches of the fifties
  - It has been possible to enlarge the frontiers of chemical engineering.

- Chemical Engineering, *latus sensus*, addresses a wide set of disciplines and industrial applications
  - The classical process engineering industries...
  - Environment engineering
  - Biotechnology
  - ...........

- What about Tomorrow?

Why New Directions for Chemical Engineering?  
II - Address problems, answer demands, incorporate new technology

- New concerns on environment problems and generally on sustainability
- Sharp demand for ‘performance products’ - specialties, food, personal care products...
- Process and product development times came down sharply (3 to 5 fold) - risk management...
- Technological developments - new paradigms on Unit Operations open for discussion - micro-systems, process intensification...
- ........
New Directions for Chemical Engineering Education
I - Questions... with no easy answers... (I)

What should be the structure and the core content of chemical engineering curricula for first degrees? And for second degrees?
- What, what depth, when, how, which teaching aids?

What should be the offer for complementary studies?

New Directions for Chemical Engineering Education
I - Questions... with no easy answers... (II)

Which skills and competencies should be promoted, thinking of both the needs of industry and the individual right of managing a career?

What is the role of cultural interchanges and how to use international co-operation for promoting such interchanges?

How to induce holistic thinking and concepts of integrated development?

To what extent should CEE approach (or combine with) industrial practice?

Should CEE rather be research oriented?
New Directions for Chemical Engineering Education

I - Questions... with no easy answers... (III)

- Should CEE be oriented towards societal needs such as environmental protection and sustainability?
- How can CEE include new disciplines such as industrial informatics, information technology, process intensification and miniaturisation technology?
- Should we shift from process design to product development?
- Which new methods and tools for teaching and how to induce self-learning?

New Directions for Chemical Engineering Education

II - Contributions

- Very many contributions addressing scientific, academic and political issues of the required reform or adapting of the degree structures and contents
  - AIChE Workshops on New Frontiers... Education (2003)
  - The proposals of E4 Thematic Network (2003)
  - The recommendations of EFCE-WPE (2005)
  - The CHEMENET Project (2007)
  - Individual views from the Industry
New Directions for Chemical Engineering Education
III - The WPE-EFCE Recommendations

Information in http://www.efce.info/wpe_studies.html

These recommendations cover
- Learning outcomes
  - General chemical engineering skills and knowledge
  - Transferable skills
- Achieving the learning outcomes
  - Core curriculum
  - Teaching and learning
  - Industrial experience
  - Review of the educational process
  - Student assessment

Core curriculum proposed covers only approx. two thirds of first and of second level degree studies

It fully fits in the European frameworks

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New Directions for Chemical Engineering Education
IV - The EUR-ACE Project and ENAEE (I)

Information in http://www.enaee.eu

European Project that aimed at establishing an European System for Accreditation of Engineering Education programmes

☑ to ensure suitability of programme as entry route to the [engineering] profession

☑ 14 European Institutions, among them ‘Ordem dos Engenheiros (OE) / Engineers Portugal’

☑ FEANI, SEFI, CESAER, EUROCADRES, ENQHEEI, ASIN, CTI, IEI, CoPI, UNIFI, OE. UAICR, RAEE, EC-UK

☑ EUR-ACE has been supported by the European Commission (DG EaC) within SOCRATES and TEMPUS programmes - Concluded in 2005

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New Directions for Chemical Engineering Education
IV - The EUR-ACE Project and ENAEE (II)

Programme Outcomes that must be satisfied

- 6 areas of competences are defined
  - Knowledge and Understanding
  - Engineering Analysis
  - Engineering Design
  - Investigations
  - Engineering Practice
  - Transferable (personal) Skills

- For each category, the EUR-ACE Framework Standards
  list the expected Programme Outcomes of First
  Cycle and Second Cycle Studies

New Directions for Chemical Engineering Education
IV - The EUR-ACE Project and ENAEE (III)

The Standards developed:

- Specify the Programme Outcomes that must be satisfied
- Accredit programmes, not Departments or Universities
- Accredit education, not whole formation
- Are valid for all branches of engineering and all profiles
- Distinguish between First and Second Cycle programmes, as
  defined in the European Qualifications Framework
- Are applicable also to “integrated programmes”, i.e.
  programmes that lead directly to a Second Cycle degree
- Describe what is to be achieved but not how
  - As such it can accommodate national differences of
    educational and accreditation practice
New Directions for Chemical Engineering Education
IV - The EUR-ACE Project and ENAEE (IV)

- The EUR-ACE project has lead to the creation in 8 February 2006 of an European Association
- The ENAEE - European Network for Accreditation of Engineering Education
- The ENAEE is responsible for maintaining and awarding the EUR-ACE label

New Directions for Chemical Engineering Education
V - The CHEMEPASS Project for enhancing Attractiveness of Chemical Engineering

- http://www.cpe.fr/chemepass/CPELyon-CHEMEPASS.htm
- Co-ordinated by Sebastien Gagneur, CPE Lyon
- Milestones
  - Identification of relevant general and specific Learning Outcomes for Chemical Engineering Programmes
  - Identification of knowledge to be tested among Chemical Engineering core subjects
  - Development of a database with test questions
New Directions for Chemical Engineering Education
VI - Today, we have to...

Today and for the future, we have to speak of
- Life sciences and of biology as one of the four basic sciences,
- Environmental issues and sustainability
- (Nano) structures and material science issues

We have to speak of ENERGY and OPTIMAL Operation
- An economy based on hydrogen and on other alternative energy resources
- Systems engineering and knowledge based methods for optimised, safe, simple to operate systems

We have to give an answer to the demand of Society for specificity and quality
- New products - competencies in product design

New Directions for Chemical Engineering Education
VII - Guidelines... not a single degree structure... (I)

Basic sciences, enlarged with life sciences, have to be there, with engineering core and complemented by electives and external training.

A decision has to me made on appropriate dosage of depth and scale of phenomena analysis
- Molecular modelling and microscopic scale?
  - Polymer properties, microporous materials, vapour-liquid equilibria...
- Macroscopic scale
  - Process modelling and process synthesis, full plant models for optimisation, computer-aided process operations
  - Modelling through knowledge integration
New Directions for Chemical Engineering Education
VII - Guidelines... not a single degree structure... (II)

- Teach and induce sustainability through everyday work
- Bring students nearer to the practice of chemical engineering
- Give sufficient practical experience, both in the laboratory, pilot plant and industry in the core curriculum
- Bring in product engineering issues
- Promote holistic thinking through integrated case-studies and strengthening of horizontal issues

New Directions for Chemical Engineering Education
VII - Guidelines... not a single degree structure... (III)

- Should include skills and competences valued by Industry
  - Job related skills
    - Teamwork, communication, leadership
  - Competencies (How tasks are done)
    - Holistic thinking, influencing, self-management, achievement of objectives...
  - Technical knowledge (depends on the type of industry)
    - Continuous processing, batch processing, systems engineering, process control, organics, biotech...
New Directions for Chemical Engineering Education

VII - Guidelines... not a single degree structure... (IV)

- Lifelong learning is the key for ensuring progress
  - It is the only way to avoid obsolescence
  - Early formal education for sure do not cover all relevant technical topics
  - Complementary offer - formal courses, ‘hands-on’ and ‘on-the-job’ training, distance and interactive courses... obviously the Internet...

- Paradox - some employers, promoting short-term jobs and forced mobility, are reluctant to educate staff - SOMETHING TO FIGHT AGAINST
  - In a number of countries there is pro-active legislation with incentives for innovation

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New Directions for Chemical Engineering Education

VIII - Third Paradigm? Is it so?

- If there is, it is of a different nature of the second paradigm

- Still fuzzy, can we see it?
  - Whole integrated approaches
  - Student centred learning methods
  - Skills and competencies
  - Cultural interchanges
  - Pro-active attitude for lifelong learning as the key for individual career management

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SO, New Directions for Chemical Engineering Education?
We should not forget the Sine Wave of Life (I)

**1st Paradigm - ~1920-1950/60**
- Unit Operations and the Practice of Chemical Engineering, Chemical Engineering Strictus Sensus
- The words of A.B. Newman, President AIChE, 1938:
  ‘Theoretical descriptions should be limited to illustrate the engineering fundamentals, because a manager does not hire a young engineer just because he is able to describe how a product is produced’

**2nd Paradigm - ~1950/60 onwards**
- Chemical Engineering Science, a priori design...
- Chemical Engineering Latus Sensus

SO, New Directions for Chemical Engineering Education?
We should not forget the Sine Wave of Life (II)

**Third Paradigm Today?**
- The words of Ralph Landau*, Stanford University, 1997:
  Landau, R. (1997), "Education: Moving from Chemistry to Chemical Engineering and Beyond,” Chemical Engineering Progress, AIChE, pp. 52-65:
  ‘I believe chemical engineering’s third paradigm, if there is one, is to return the discipline closer to the practices in industry’

**May I add that this means -**
Developing an interdisciplinary view of science, technology and societal needs in a framework of lifelong learning...
C’est presque tout!

Je tiens seulement à
remercier votre attention
et le privilège et l’honneur de cette invitation...