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Departamento de Engenharia Química
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Which Education of Chemical Engineers in 2020?

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**Words about the future...
How much are they worth?
(Time Magazine, p. 44, July 15, 1996)**

- ① **Thomas Watson, President of IBM, 1943**
 - ① **'I think there is a world market for maybe five computers...'**
- ② **Ken Olsen, President and Founder, Digital Equipment Corp., 1977**
 - ② **'There is no reason for any individuals to have a computer in their homes...'**

Acknowledgements

-  **Professor Rodrigo Guedes de Carvalho**
-  **Dr. John Gillett**
-  **Dr. Eugénio Ferreira, Dr. Jaime Villate**

An invitation to visit the new Facilities of the Old FEUP



Plan for the talk

- ① **Putting past, present and future in perspective...**
- ② **Today's Society and Industry - questions and issues**
- ③ **European efforts and directions for CEE**
- ④ **Skills and competencies for the profession**
- ⑤ **About curricula for first degree courses**
- ⑥ **Some final notes on main topics**
- ⑦ **3 key ideas elected for you to check them in 2020!**

2 relevant works and 1 relevant URL

- Guedes de Carvalho, R. (1998) História do Ensino da Engenharia Química na Universidade do Porto (1762-1995), FEUP^{Edições}, Porto, Portugal
- Gillett, J.E. (2001), *Chemical Engineering Education in the Next Century*, Chem. Eng. Tech. 24(6) 561-570.
- Site of The Working Party on Education in Chemical Engineering

<http://www.dechema.de/efce/education/eduframe.htm>

Paradigms / Mindset

- ① **Paradigms have to do with Mindset - individual thinking, values, beliefs and emotions, related with**
 - ① **Knowledge and experience gained during an individual lifetime and its universal recognition**
 - ② **Changes in Mindset – Paradigm shift**
 - ③ **Mindset / Paradigms in relation to areas of knowledge:**
 - ③ **Recognising firm theoretical foundations, successful applications, supported by textbooks, handbooks, professional societies, subjects and concepts taught to beginners...**

A Touch of History - First Paradigm

- ① **Key Words – Unit Operations**
 - ① **Equipment, its design and form of operation were the object**
 - ① **Arthur D. Little; Walker, Lewis and McAdams (1923); Coulson & Richardson (1954); Hougen and Watson (1943); Shreve & Brink (1956) ...**
 - ① **Maturity, namely in the oil and petrochemical industries**
 - ① **Tackling continuous process scale-up to millions of tons of production**
- ② **Improvement of design and operation by bringing into practice fundamental concepts of physical-chemistry, thermodynamics and kinetics**

A Touch of History - Second Paradigm - I

- ① A shift in Chem Engng R&D and Education
- ② **Transport Phenomena**, Bird, Stewart and Lightfoot (1960)
 - ② Understanding basic mechanisms and fundamental phenomena
 - ② *The Era of Chemical Engineering Science*
 - ② Wilhelm (1962), *Progress Towards the A Priori Design of Chemical Reactors*
- ③ A Priori Design... A goal not yet achieved

A Touch of History - Second Paradigm - II

- ④ A shift in Chem Engng R&D and Education
 - ④ Approaching teaching from research
 - ④ Transport Phenomena, Reaction Engineering, Separation Processes
- ⑤ The second half of this period already strongly influenced by the rapid development of digital technology and the computer industry
 - ⑤ Process Systems Engineering (Rudd & Watson, 1968)
 - ⑤ CAPO / CAPE – Computer-Aided Process Operations

A Tribute to the Second Paradigm New Identity(ies) – Chemical Engineering in *Lactus Sensus*

☞ Somewhere in the seventies

- ☞ Concepts and methods of Chemical Engineering applied to a space of disciplines and knowledge wider than those of the old chemical engineering as understood in a *Strictus Sensus*.

Chemical Engineering - widening application areas(*)

- ☞ 1930... Petrochemistry..
 - ☐ Heavy industry, nuclear
 - ☐ plastics, fine chemistry

**Economy
Products**
- ☞ ...1960... 1980 Agrochemistry, farmaceutical, food...
 - ☐ cosmetics
 - ☐ transports, software, systems

**Safety
Environment**
- ☞ ...1980...Biotechnology, Biomedical Sciences, health...
 - ☐ materials, specialties...
 - ☐ control, electronics and robotics...

**Economy vs.
Sustainability
Risk management**

(*) *Chemical Engineering seeks a new identity*, Chemical Engineering, August 2000, p. 33-37
SFA, DEQ/ISR-FEUP, Porto, Portugal

A Paradigm shift?

- ☞ **Changes in Mindset are caused by –**
 - **Evolution of human knowledge**
 - **Human effort to increase knowledge**
 - **Dominant driving forces in Societies in each historical moment or age**
 - **The pressure to fulfill societal needs and demands**

- ☞ **Yes, Indeed,**
 - **the birth and growth of the third paradigm...**

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Life Today...what matters for the discussion - I

- **Economy and market forces - driving force of Today's Societies**
- **The computer and communications era - dramatic changes of the concepts of time and space - *globalisation***
- **Job market and opportunities - wider than ever**
- **Significant change in the concepts of *individual career management***
- **Sharp increase in standards and competition - Worldwide and within the European Space**

Life Today...what matters for the discussion - II

- **Process and product development times came down sharply (3 to 5 fold) - risk management...**
- **New concerns on environment problems and generally on sustainability**
- **New paradigms on Unit Operations open for discussion - micro-systems, process intensification...**
- **Sharp demand for 'performance products' - specialties, food, personal care products...**
- **Management has acquired a new relevance**
- **Free Societies' new demands - *Education for All vs. distributed balance of skills***

Some Sensitive Questions / Issues - I

- **Which skills and competencies should be promoted?**
- **What role of cultural interchanges and how to use international co-operation for promoting such interchanges?**

- **To what extent should CEE approach (or combine with) industrial practice?**
- **Should CEE rather be research oriented?**
- **Should CEE be oriented towards societal needs such as environmental protection and sustainability?**

Some Sensitive Questions / Issues - II

- **Should we bring in disciplines from life sciences?**
- **Should CEE include new disciplines or topics 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?**

So What for Chemical Engineering Education?

- ☞ **This enlargement of the potential role of CE, together with new demands from the Society, brings the need for**
New Directions for Chemical Engineering Education
- ☞ **Key Words are:**
Whole integrated development; transnational co-operation
- ☞ **Structural decisions have to be taken on**
 - **What role and distinction at different levels of education**
 - **What structure and core contents of chemical engineering curricula for a first degree?**

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European efforts for CEE - I Bologna et al....

- ☞ Discussion dominated by the Bologna declaration and subsequent events
- ☞ Or, raising some further questions
 - ➔ Should we stick just for comparability, consistency of qualification titles, i. e. 'core standards of quality' ?
 - ➔ Should we have a core curriculum, in Europe, in the World...?
 - ➔ If yes, what, what depth, when, how...
 - ➔ A common structure?
 - ➔ $(4 + 1) + 3$?
 - ➔ $(3 + 2) + 3$?
 - ➔ ???

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European efforts for CEE - II ERASMUS /SOCRATES

- ☞ Diversity in chemical education is clearly desirable, so many are the options.
- ☞ *To take advantage of this diversity, student and educational staff exchanges between countries and cultures should be encouraged.*
- ☞ ERASMUS/SOCRATES

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European efforts for CEE - III Working Party on Education

- ☞ On June 25, 2001, the Web-site of the Working Party on Education in Chemical Engineering was formally declared opened, with the URL:

<http://www.dechema.de/efce/education/eduframe.htm>

- ☞ A link between everybody who is interested in education in chemical engineering in Europe or who wants to get latest information on the topic.
- ☞ It is offering links to education homepages of all the 21 countries participating (at the moment) in the WPE.

European efforts for CEE - IV EUROChE NETWORK

- ☞ A new initiative - EUROChE Network - 23 European Departments, aiming at:
 - Establishing an interactive forum between industry and academia concerning training needs, staff exchanges, student exchanges between university and/or industrial members
 - Working for recognition of each others chemical engineering degrees foreseeing transnational chemical engineers
 - Recommending curriculum changes to maintain interest in the field

Some Directions for CEE - I

- ☞ **At present, 1st degrees - close match between education and research**
 - ☞ **No doubts about the role of R&D&I for the progress of Humanity and consequently of its relevance**
- ☞ **But, we should adapt curricula to improve matching with Today's concerns, expressed in the question -**

What is it that the young engineer is going to find in practice and what skills and competencies does Society expect from a young engineer?

Some Directions for CEE - II

The Sine Wave of Life

- ☞ 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’.
- ☞ The words of Ralph Landau, from Stanford University, 1997:
‘I believe chemical engineering's third paradigm, if there is one, is to return the discipline closer to the practices in industry.’

Some Directions for CEE - III

About contents

- ☞ **Should decide 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**

Some Directions for CEE - IV

- ☞ **University first degree, though strong in fundamentals and depositing the seeds for research, will have to be directed to the more basic and practical requirements of industry and of the society**
- ☞ **Should leave for a second stage the effort for growing and developing new concepts, with formal courses, with compulsory and elective subjects, for a longer research oriented horizon**

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Skills, Personal Career and Lifelong Learning - I

- ☞ Contractors and employers do not so much at present provide opportunity for specialist training, expecting that the young engineer they hire will have sufficient technical background.
- ☞ Companies value nowadays competencies and skills that are not limited to the technical areas. Indeed, Companies more easily provide opportunities for developing those other skills and competencies that are of the short-term benefit of their organisations.

Table 1 – Functional structure of a Company, on the form of levels of internal contributions (adapted from Gillett, 2000)

Strategic perspective	Functional contents	Position in the structure
Decides future directions	Company strategy	Director/General Director
Links sectors of the global business	Business management	Departmental Director
Anticipates and manages required changes	<i>Innovation, R&D, liaison to process</i>	I&D or production group leader
Develops and makes improvements. Optimise activities	Adapts, improves process	Senior engineer or process director
Designs, performs commissioning and operates	Does.	Junior engineer

Table 2 - Some typical skills and competencies valued by Industry (adapted from Gillett, 2000)

☞ **Job related skills**

- ✓ **Teamwork, Communication, Leadership**

☞ **Competencies (How tasks are done)**

- ✓ **Holistic thinking, influencing, Self-management, achievement of objectives..**

☞ **Technical knowledge (depends on industry)**

- ✓ **Continuous processing, batch processing,, systems engineering, process control, organics, biotech...**

Skills, Personal Career and Lifelong Learning - II

- ☞ Lifelong learning is the key for ensuring progress,
 - 1st degrees for sure do not cover all relevant technical topics,
 - It is the only way to avoid obsolescence.
- ☞ Formal courses, 'hands-on' and 'on-the-job' training, distance and interactive courses...obviously the Internet...
- ☞ Paradox - 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

**Table 3 – Examples of different forms of continuing education
(adapted from Gillett, 2001)**

Delivery method	Providers	Customers	Comments
Formal courses (full-time)	Universities	Engineers between jobs Engineers in employment	e.g.: M.Sc., diplomas etc.
Formal courses (part-time)	Universities	Engineers in employment	e.g.: M.Sc., diplomas, etc.
Conferences and seminars	Professional organizations	Engineers in employment	Technology updating, etc.
<i>Workshops</i>	Professional organizations	Engineers between jobs Engineers in employment	Technology updating, etc.
Distance learning	Universities and Professional organizations	Engineers between jobs Engineers in employment	Technology updating, etc.
Computer-based learning	Specialist training agents		Task-oriented
In-house courses	Industrial employers	Engineers in employment	Personal skills and competencies
On-the-job training	Industrial employers	Engineers in employment	Task-oriented
Private study	Professional organizations	All engineers	Personal careers plans

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Chemical Engineering First Degree - I Developing capacities and competencies

- ✓ **Emphasis on fundamental - apply fundamental knowledge**
- ✓ **Work subjects for knowledge integration**
- ✓ **Design and conduct experiments**
- ✓ **Design systems for pre-defined objectives**
- ✓ **Identify, formulate and solve engineering problems**
- ✓ **Develop capacity for multi-disciplinary work**
- ✓ **Promote professional and ethical responsibility**
- ✓ **Promote communication capacity**

Chemical Engineering First Degree - I Developing capacities and competencies (cont.)

- ✓ **Incentive for cultural knowledge about contemporaneous questions**
- ✓ **Develop a pro-active attitude for continuous education**
- ✓ **Use modern technics and engineering tools for engineering practice**

Chemical Engineering First Degree - II Contents

- ✓ **Teaching fundamentals - mathematics, sciences and engineering**
- ✓ **Supply case-studies for integration of knowledge (industrial and systems problems)**
- ✓ **Strength (computational simulation, control, safety)**
- ✓ **Work on sustainability (environment, biochemistry, energy...)**
- ✓ **Develop programmes related to chemical engineering practice (dealing with real industrial problems)**

Chemical Engineering First Degree - III Major subjects to bring in? Yes...

- ☞ **In the core curriculum**
 - Life sciences topics
 - Computer-aided process engineering concepts
 - Students should be made aware of significant developments in process operations
 - Management
- ☞ **In electives or embedded in the teaching (e.g. in project work...)**
 - Product and formulation engineering
 - New paradigms in Unit Operations and processes...

Chemical Engineering First Degree - IV Forms and Methods

- ☞ **Improving procedures for learning/teaching**
- ☞ **Structuring courses, motivating self-learning (for Portugal)**
 - **Cut down on direct weekly contact time**
 - **Cut down on examination time**
 - **Define and implement new evaluation procedures**

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Sustainability and Holistic Thinking

- ☞ There is now a true and deep global concern, both in the scientific and the industrial society, for the environment and for the problems of overpopulation and industrialisation.
- ☞ This need for developing sustainable technology and for sustainability as an attitude has now become an active premise of work for chemical engineers.
- ☞ Sustainability can also be taught and learned indirectly through increasing knowledge on environmental problems, on biochemistry, on life cycle analysis and as well on economics, just to mention a few subjects.

Practical Training, Teaching Aids - I

- ☞ It all comes to the same, to bring students nearer to the practice of chemical engineering, to promote integrated approaches, to exchange cultures.
- ☞ The availability of teaching aids, namely interactive and distance learning computer-based aids is now impressive.
- ☞ The Internet lead to this extraordinary number of aids available, several free of charge, for basically all topics and disciplines.
- ☞ Also, at laboratory level, small pilot-rigs with high level of educational features, are Today available tha make it possible to increase engineering practice.

Practical Training, Teaching Aids - II

- ☞ **Appropriate choice of case studies and of practical pilot plant work for integration of knowledge**
 - **The operation of process units (in steady-state) can be optimised through methods of process systems engineering (strategy of process operation)**
 - **Strengthen horizontal subjects**
 - **batch or fed-batch process operation, allow discussing again inter-relations, now together with process control and safety procedures.**
 - **Pilot cases related to the practice -**
 - **Co-operation programmes with industry would allow the construction and operation of suitable pilot units related to real industrial problems**

Computer Aided Process Operation & Knowledge Engineering Approaches

- ☞ **Horizontal subjects appropriate for integration of knowledge**
- ☞ **From Unit to Plant or Multi-plant approaches**
- ☞ **New forms of structuring and combining sources of knowledge**
 - Hybrid modelling
 - Software sensors
 - Model-based control

In form of conclusions - 3 ideas to take with you and check them in 2020...

- ☞ **3rd paradigm - still fuzzy, but we can see it**
 - Whole integrated approaches
 - Skills and competencies
 - Cultural interchanges
- ☞ **Pro-active attitude for life-long learning as the key for individual career management**
- ☞ **European co-operation through Core Quality Criteria within diversity**

**All that remains is to thank you for the attention
you cared to pay to the talk!**

The End !