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Paradigms in Chemical engineering

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ABSTRACT
Chemical engineering as such, has just a little more than a hundred years of existence. During this time the teachingof this profession has changed as generated research, data, and books produced innovations in curriculum and new paradigms in education. The development of this discipline has influenced the creation or modification of others, such as environmental engineering, food engineering, bio-engineering, electrochemical engineering, metallurgical engineering, etc. The future presents new challenges and opportunities for interdisciplinary development such as nanotechnology, new materials, bio-fuels and the climate control.

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I. INTRODUCTION

A chemical engineer is not born, but he is made through study and daily practice. There are currently many universities and institutes of technology where the student receives the theoretical and practical foundations of the profession, but not always was like that.

Before the 18thcentury the chemical industry had developed without the help of the chemical science at the time. With the development of chemistry in the 18th and 19thcenturies the amount of substances, discovered or synthesized by the chemist increasedSome of these promised to overcome more than the properties of natural products or at least improve them. For the construction and operation of the required chemical plants it was not longer possible to relyon tradition, so they had to start from scratch, using knowledge of the industrial chemist and the mechanical engineer for the design and operation of the new plants. But as a mechanical engineer has no knowledge of chemistry and the chemist did not have knowledge on mechanical engineer or in processes on a large scale, the method was expensive and it was necessary to give and special training to these people so they could work together. Of course, it was not so much a problem that it prevented the great development of the chemical industry in Germany, England and France.

Towards 1880, some people realized that the design and creation of the chemical plants were becoming a specialized activity that could become a whole new discipline of study. In 1884, Henry Amstrong, in London, planned a four year course which included chemistry, mechanical engineering, mathematics, physics, drawing, chemical technology, workshops and modern languages. As the course was actually a mixture of chemistry with engineering it was unsuccessful. In 1887 Georges Edwards Davis, who was a consultant and inspector of the alkali industry, gave a series of lectures at the Technical School of Manchester on chemical technology. Instead of describing the processes of the contemporary industrial chemistry, Davis analyzed the behavior of them as a series of simple operations. In fact it was the first to consider the processes of manufacturing chemical as a sequence and combination of a small number of operations. After the publication of several of its presentations in l887 in the magazine *Chemical trade journal,* thathe founded, Davis left his publications until 1901, when it came to light his *Chemical Engineering Handbook* which gave a complete course on the subject. Subsequently, a second expanded edition, which was over a thousand pages appeared in 1904. (Davis, 1888). The book by Davis, which began the teaching of chemical engineering, has been a classic empirical topic. But despite the efforts of Davis and other men, the concept of *chemical engineering* was not well received in Europe, but in the United States.

The first chemical engineering courses were offered at the Massachusetts Institute of Technology, MIT, in 1888, at Penn in 1892, at Tulane in 1894 and at the University of Michigan in 1898. These courses were attended by a number of youngsters who dream to be what others had not been before: "chemical engineers ".

The curriculum of the first chemical engineering courses included the study of chemistry, physics, mathematics, mechanical engineering, electricity, drawing, etc..There were also given some courses related to the chemical processes in vogue and other courses in which it was described the type of equipment used.

The first paradigm

By that time it was also discovered the need for precise calculations of the matter and energy that took part in chemical processes. These calculations go beyond the simple stoichiometry, which was taught in chemistry classes, since they include the complexities of simultaneous, consecutive and reversible reactions along with recycling, purge, derivation and accumulation processes. They required precision and ability to measure currents, and characterize them from the point of view of composition, enthalpy and flow rates. Therefore at the beginning of the XX century the professors had to implement courses on balance of matter and energy and at the same time appeared the first books related to these issues. Material and energy balances have been exported to other engineering fields

Among the first books that were used to solve this problem were: *Metallurgícal Calculations* of J.W Richards (1906), *Industrial Stoichiometry of* W.K. Lewis and A.H. Radasch (1926) and *Industrial Chemical Calculations* of o. a. Hougen and K.M. Watson (1931). These books presented the first revolution in the teaching of chemical engineering, or what is considered the first paradigm.

The second paradigm

With the **g**rowth of the chemical industry and the departure of the first graduates it was realized the futility of imparting knowledge through the descriptive method and became more emphasis on techniques for the study of the *unit operations.* This concept comes from Arthur D. Little which pointed out the need of study the common operations that happens in many processes, such as fluid flow, transfer of color, distillation etc. . *(Little, 1933).*These manipulations have as characteristic thatthe materials do not suffer chemical changes , but physical ones, such as changes of state, concentration, pressure and temperature. The underlying idea behind this concept of *unit operations,* wasthat if specialists were created in each one of them is could be possible to combine the skills from them to design a new process. The emergence of the concept *of unit operations* allowed chemical engineering to be transformed gradually into a coherent whole and ceased to be a simple mixture of chemistry with mechanical engineering. The unit operations were the second paradigm of chemical engineering.

There were already a lot of knowledge onflow of fluids and heat transfer but chemical engineers perfected them and created other knowledge inthe operations such as distillation, absorption, drying and mass transfer These knowledge have been exported to other engineering

Chemical engineers proved to be a very important element in the design, construction and management of the chemistry-related plants; that is the reason why the career spread all over the world. However, the first chemical engineers had great difficulties in the design, as there was a great lack of physicochemical data and in the behavior of a lot of substances. Mechanical and civil engineers only had done thorough studies of fluids such as air and water, but chemical engineers had to work with a huge variety of them. The chemist were not interested in obtaining data about kinetic constants and physic-chemical properties, so the chemical engineers had to be put to the task of obtaining them. In almost all the universities in which the unit operation where taught the race began to make serious studies on the behavior of devices used in chemical plants and the properties of the substances that were processed there. As soonas there was sufficient information availablethe first book on unit operations appeared in 1923 : *Principles ofchemical engineering ,by* Walker, Lewis and Mc Adams, and in 1934 appeared the first edition of the *Chemical Engineers Handbook,* by John H. Perry.

The 1940s and 1950s saw the emergence of numerous books on unit operationsamong some of them were the books of Badger, McCabe, Brown, Foust and Geankoplis.

By that time appears a formidable trilogy *The principles of the chemical processes by*Hougen, Watson and Ragazt, the first volume was devoted to the balances of matter and energy, the second was over thermodynamics and the third, to the design of reactors.

The third paradigm

Early studies and books about reactors appeared around 1940. These studies opened the chemical engineering applications and were exported to other engineering fields. The study of chemical reactions, reactor design and catalysis can be considered as the third paradigm of chemical engineering. The first book that appeared was the third volume of the principles of chemical of Hougen, Watson and coworkers. Then followed the book by Smith, Wallas and Levenspiel.

After the second world war, the emphasis of the publications changed to the design of the plants and the economic study of them, examples of texts are *Chemical engineering plant design* (1959), Vilbrandt and *Plant Design & Economics,* M.S. Peters.

The fourth paradigm

With time it became apparent that there were common principles which sat the scientific basis of chemical engineering unit operations. The concept of *transport phenomena* leads to the knowledge that certain common phenomenaare present in the unit *operations* , such as *momentum, heat and mass transfer. The* study of these principles gave rise toa book that changed the study of chemical engineering *Transport Phenomena by* Bird, Ligthfoot& Steward. That book was followed by many others related to the subject, as those of Welty, Theodor, Rohsenow, Fahien, etc. From the study of *transport phenomena*thechemical engineering texts changed their orientation becoming increasingly more mathematical, more fundamental and less oriented towards the calculation for thedesign of equipment**.** This was also encouraged by the use of computers that allow programs written in floppy disks perform the necessary calculations for the design of most of the equipment used in the chemical industry. Transport phenomena can be considered as another chemical engineering paradigm, which has been exported to other engineering fields.

Fifth paradigm

At the end of the 1960s, the intensive use of computers at work, the laboratory and universities transformed the education of chemical engineers, and from this transformation emerged new subjects such as: optimization, simulation, control and analysis of processes, New fields could now be studied due to the computer equipment and the new books that appeared as a*Introduction to chemical engineering and computer calculations* , (1976) Alan L. *Myers, Optimization of chemical processes* (1975) *Holland; Process modeling, simulation and control for chemical engineers,* by William L. Luyben (1973); *Artificial intelligence in chemical engineering,* by Thomas Quantrille (1993), and so on. The use of the computer for the study of chemical engineering can be considered another paradigm that was exported to other engineering careers.

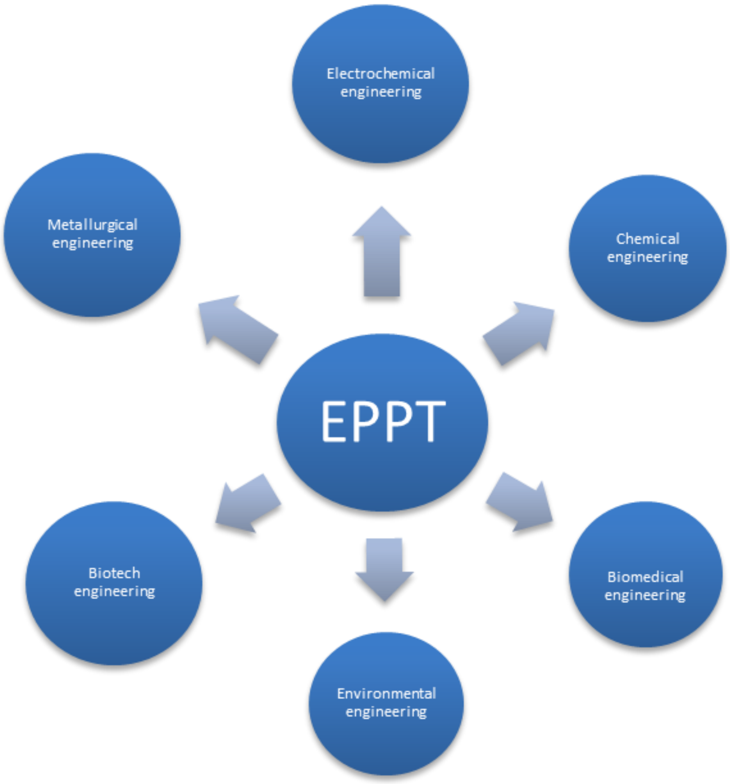
Sixth paradigm?

Biotechnology is a biology-based, green engineering and is especially used in agriculture, pharmacy, food science, chemistry, chemical engineering, biochemistry, forest science and medicine. Biology and biotechnology were introduced in many countries to supplement the curricula of chemical engineers. In the world there are careers asfood engineer , biochemical engineer, environmental engineer where biotechnologies are taught. Many believe that chemical biotechnology can be the sixth paradigm.

II. CHEMICAL ENGINEERING METHODOLOGIES

The methodologies employed in chemical engineering has been extended to other fields, giving rise to another series of engineering, including the biomedical, biochemistry, electrochemistry, metallurgy, agro-food and environmental, all of them linked around the problems posed by chemical and physical transformations of matter.Little by little, these methodologies have been disseminated and organizedas a set of applicable knowledge on all of the industrial processes that involve transformations of matter. This methodology, formerly exclusive of chemical engineering (*which could be described as discipline mother*), acquired in the early 1980s a maturity and was systematic enough to be transmitted to the teaching and be applicable to a wide range of activities. Industrial processes of transformation of matter form part of the area of competence of the process engineer, whose main task is not only to conceive and dimension from a practical economic and ecologically optimal manner, processes and equipment where these transformations take place.

Today it seems to be that this terminology oriented transformations of matter could give to understand that only the industrial chemical processes would be involved, while in reality there are many cases where the physical aspects give rise to changes rather than transformations that are of dominant importance. For this reason, it might be convenient and, to generalize, to point out the physical and chemical nature of transformations; so we should speak, perhaps of the Engineering of the Processes in Physicochemical Transformation (EPPT). **(Coeuret, 1992)** The EPPT functions as a methodology tank connected to a peripheral network of application sectors. Each sector has its own characteristics, but it is clear that they can be connected through the EPPT. So it is that today's chemical engineering is related to the biochemical engineering, the environment, the metallurgical and vice versa.



III. NEW TRENDS IN CHEMICAL ENGINEERING TEACHING.

The winds of change are blowing in the universities, which are considering replacing some old fashioned materials by those that will teach the emerging technologies which include biotechnology, genetic engineering, microelectronics, space engineering, robotics, the specialty chemicals, agrochemicals, industrial and environmental safety, kinetics, thermodynamics of reactions and chemical balances , etc. Within a few years the combined effect of intellectual progress, technological challenges and economic forces will transform the nature of chemical engineering and the chemical engineers work. One of the main driving forces of this evolution will be the number of new products and materials that will enter into the market in the next two decades. Whether they come from the biotechnology industry, electronic industry or industry of high performance materials, the usefulness of these products depend critically on the design and structure at the molecular level. They require manufacturing processes that allow precise control over its structure and chemical composition. Those demands will generate new opportunities for chemical engineers, both in the design of products and in the renewal of the processes. The second force that will contribute to the new paradigm of chemical engineering is the increased competition on the world market. The quality and the performance of the products are more important than ever for success in this competition. The third force that will shape the future of chemical engineering is the growing awareness of health and environmental risks of the production, transportation and the use of chemicals and their waste disposal. The profession must assume the responsibility to act as guardian from the cradle to the grave of chemical products, ensuring their use in environmental safety. The fourth and most important of the forces that will affect the evolution of chemical engineering is the intellectual curiosity of own chemical engineers. To extend the limits of ideas and previous conceptions, in chemical engineering researchers create new knowledge and tools that will deeply affect the formation and practice of the next generation of chemical engineers. The focus of chemical engineering has always been in industrial processes that change the physical state or chemical composition of the materials. Chemical engineers work in the synthesis, design, testing, scaling, operation, control and optimization of such processes. The traditional level of magnitude and complexity in which they have worked could be described as a Mesoscale. As examples of this scale are the reactors and the equipment for simple processes (unit operations) and the combinations of these operations in industrial plants. In the future, the Mesoscale research will be complemented by a more in-depth study of the phenomena that occur on the molecular dimension - micro - and the dimensions of extremely complex systems - Macroscale.

Chemical engineers of the future will integrate within its works one greater variety of scales than any other branch of engineering. For example, there will be those who work to relate the Macroscale of the environment with the combustion Mesoscale and microscale of molecular reactions. They will Integrate research and practice new tools and concepts from other disciplines as : Biology molecular, chemical, physics of the solid state, electrical engineering, materials science. They will make more use of computers, artificial intelligence and systems engineering for the resolution of problems, the design of products and processes and industrial production.

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