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RECENT DEVELOPMENTS OF ChE EDUCATION IN MEXICO

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THE CHEMICAL AND PETROCHEMICAL industries in Mexico have had an enormous growth rate during the last three decades (averaging 10-12%/year) and the demand for chemical engineers and other related professionals has grown accordingly. As a matter of fact, from 1973 to 1979 there was an annual increase of 75% in the demand for engineers in these industries.

Because of this demand, the Mexican Government has promoted the establishment of undergraduate programs in chemical engineering all over the country. There are now 54 institutions offering such programs, compared with only half that number six years ago [1]. This has resulted in an explosion of the number of incoming students as well as in those receiving degrees, which oddly enough has exceeded the real demand of chemical engineers by about 25%

This rapid growth has been counterproductive in terms of the quality of the programs offered and of the performance by students and professors. Because of this lack of quality, the larger industries have had to develop training programs to supplement the deficiencies of the new engineers at the beginning of their careers. Also, the most established institutions of higher education have opened graduate programs (M.S. degree only) in order to provide industry with highly qualified engineers, as well as to supply the universities and research institutes with badly needed teachers and scientists. These engineers are beginning to do research and development—activities that, due to the nature of the Mexican industry, were practically non-existent ten years ago [2], and are only now starting to achieve their just dimensions.

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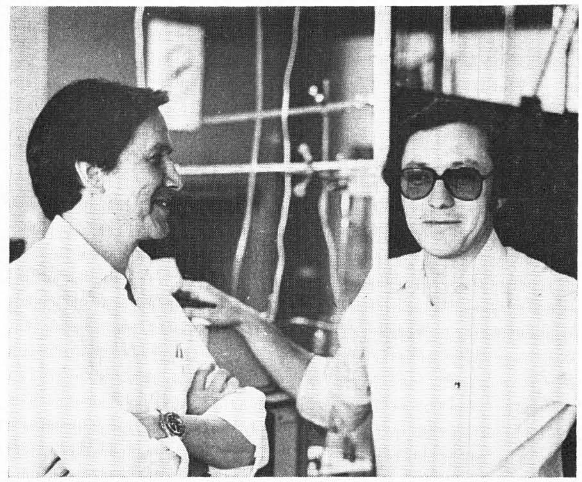

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BRIEF HISTORY OF CHEMICAL INDUSTRY IN MEXICO

At this point we will analyze the development of the chemical industry in Mexico, as it has been determinant in the development of the chemical engineering profession and the curricula at the universities that offer undergraduate and graduate programs.

The most relevant single event that changed the course of development of Mexican industry was the nationalization of oil resources in 1938. The resulting growth (from 1940 to 1950) increased the number of chemical enterprises from 379 to 1710. During this period the industry also started to diversify into production of chemical intermediates, pesticides, fertilizers, dies and inks, paints and pharmaceuticals. Employment in the chemical industry rose 13% annually, while it increased by only 6% in the manufacturing industry as a whole. Furthermore, the investment rate had a growth of 25.7% per year versus 10.5% for the manufacturing industry [3].

The Mexican government established control over the petrochemical industry through legislation giving Petroleos Mexicanos (PEMEX) the

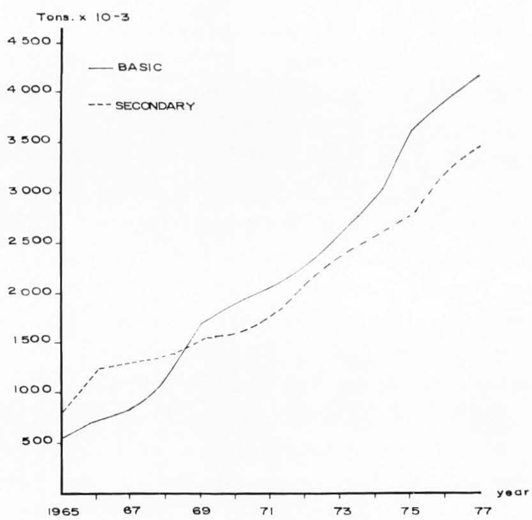

FIGURE 1. Petrochemical Industry: Production

right to produce and/or import all "basic" petrochemicals; "basic" petrochemicals being those products derived through a first transformation of oil and natural gas components. Moreover, private enterprise can use those basic petrochemicals to produce "secondary" petrochemicals if 60% of the share (minimum) corresponds to Mexican capital. Thus, a company fulfilling that requirement can obtain a "Petrochemical Permit" to produce a given secondary petrochemical, such as PVC, phenol, carbon black and other similar products.

An illustration of the development of the petrochemical industry (which by 1975 was already 41% of all basic chemical industry) is shown in Figs. 1, 2, and 3, for the production, imports, and exports of that sector of Mexican industry. All the data were taken from reports by the Mexican

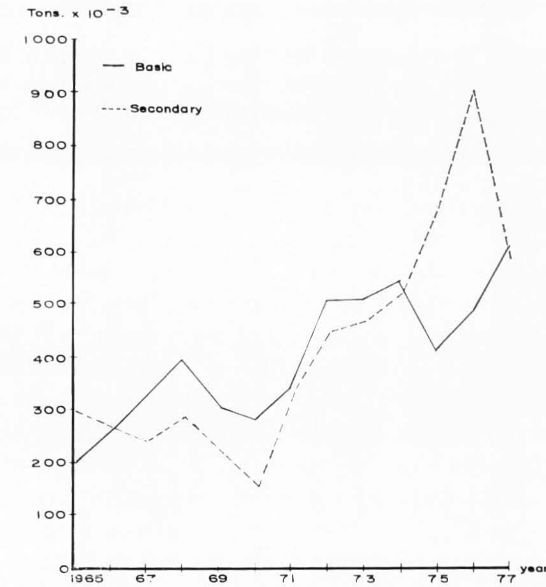

FIGURE 2. Petrochemical Industry: Imports

Petrochemical Commission [4]. It should be pointed out that the deficit in the balance of payments has been growing since 1960, and that most of the equipment and technology for both the petrochemical industry and the chemical industry in Mexico comes from abroad. This fact, as we will see later, has tremendous importance in the development of the chemical engineering profession in the country.

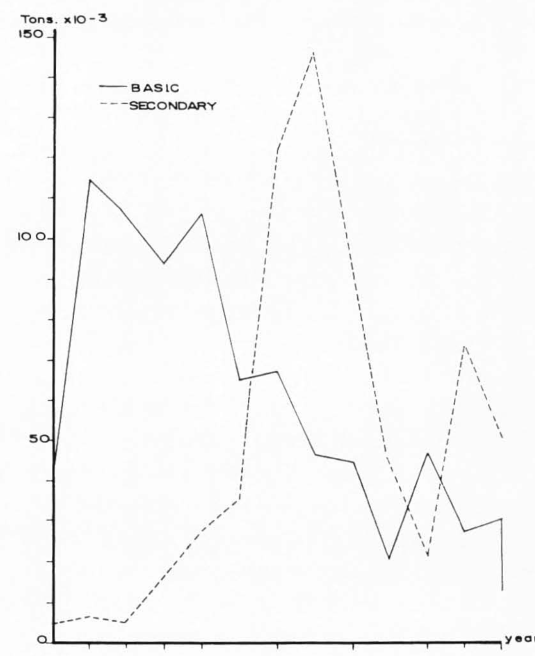

FIGURE 3. Petrochemical Industry: Exports

Because of this demand, the Mexican Government has promoted the establishment of undergraduate programs in chemical engineering all over the country. There are now 54 institutions offering such programs, compared with only half that number six years ago.

The Mexican Government also offered an extraordinary stimulus for creation of the chemical industry in Mexico, with the sole purpose of reducing imports of foreign goods. This policy led, in many cases, to inefficient and expensive production of chemicals, resulting in products that were highly priced internally, with no possibility for export. This situation did not stimulate the development nor the adaptation of technologies, and only required chemical engineers for the operation of plants, the administration of chemical firms and the commercialization of commodities.

At the beginning of the seventies, the government changed its policy in order to reduce foreign debt and to support a healthier industrial development. Emphasis was put on technological independence and the creation of appropriate technologies. The emphasis nowadays is on the creation of enterprises that produce goods at competitive international prices rather than solely for the consumption by the internal Mexican market.

Several facts are indicative of the above; the Mexican Petroleum Institute (IMP) was created in the late sixties with the purpose of performing research and development in oil and petrochemical technology, as well as process and project engineering mainly for PEMEX. The National Council for Science and Technology was founded in 1971; in 1972 the Law of Technology Transfer was published, and in 1973 the Law for the Promotion of Mexican Investment and Regulation of Foreign Investment. Also, a major program for exploration of oil and mineral resources was launched, resulting in the discovery of important oil reserves in Mexico.

Therefore, the challenge faced today by the chemical engineering profession in Mexico is tremendous. As we will see in paragraphs to follow, the curricula of the main institutions have been greatly influenced by the nature of the development and the requirements of industry; but it has not been intended to prepare professionals for the main activities that they perform in developed countries, such as process engineering and research and development. Furthermore, since the most established institutions are slow in changing their programs, new engineers have been educated in sufficient numbers, but at the expense of a loss in quality. A significant lag exists between the real needs of the chemical industry and the supply from the universities [5].

DEVELOPMENT OF CURRICULA IN THE PAST

Since 1940, the demand for chemical engineers has been growing in phase with the chemical industry, and this has produced an explosion of both students and professionals through the years. Fig. 4 shows this situation graphically.

The first institution to offer a chemical engineering degree was the National University (UNAM), starting in 1918. In 1936 the National Polytechnic Institute (IPN) opened the second program in the country. Since then, these two institutions have been the main suppliers of chemical engineers, due mainly to their location in the middle of the densely populated and highly industrialized metropolitan area. Table 1 shows revealing figures in this respect.

Therefore, it is not surprising that the two main schools of chemical engineering (UNAM and IPN) have had a strong influence on the programs and development of most of the schools created later. Actually, most State Universities in the country have been founded by UNAM graduates and their curricula have been, in many cases, the same or very similar to that of the National Uni-

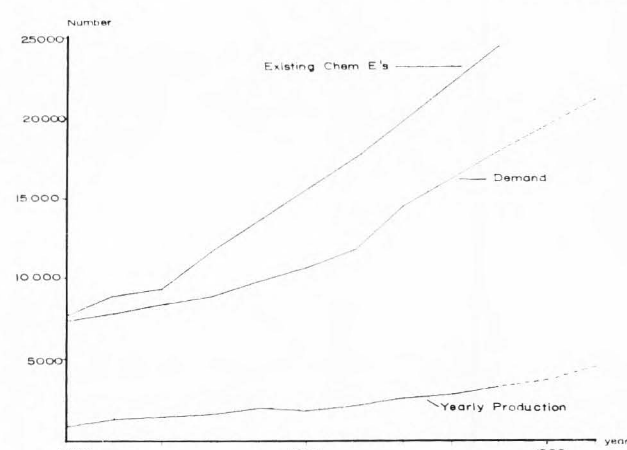

FIGURE 4. Supply and Demand of Chemical Engineers in Mexico

versity. Even the private institutions had exactly the same curriculum from 1943 to 1973. The Ministry of Public Education has opened a good number of Regional Technological Institutes throughout the country in which chemical engineering programs are offered, and these institutes have traditionally followed the programs of IPN.

TABLE 1
Graduates from Chemical Engineering Schools in Mexico (1971-76)

INSTITUTION	NO. OF GRADUATES	%
I.P.N.	6086	35
U.N.A.M.	4560	26
Univ. Aut. de Puebla	1097	6
Univ. de Guadalajara	754	4.25
Univ. Aut. de Nuevo León	546	3
I.T.E.S.M.	480	2.75
All Others	3901	23
Total	17424	100

Therefore, if we analyze the curricula of the two main institutions, we will have a situation representative of the whole country.

The curriculum at UNAM has been shaped according to the needs of Mexican industry and has remained practically unchanged for the last 40 years. The main features are a strong emphasis on chemistry and a wide variety of subjects related to activities that chemical engineers in Mexico have traditionally been involved with, such as aspects of civil, mechanical and electrical engineering. Activities that in developed economies are handled by the respective specialist, but which in Mexico (due to the nature and dimensions of the industry) are given to the chemical engineers to take care of.

Therefore, if we look at the curricula at UNAM and IPN, we notice that they involve a large number of subjects in general, but do not emphasize the fundamental knowledge of basic sciences such as physics and mathematics. Such important disciplines as transport phenomena and process dynamics and control are not a part of the curriculum, but are offered as elective subjects. The same happens with computer programming and numerical methods.

Until 1967, a student had to complete five years of studies in order to get a B.S. in chemical engineering at UNAM; now the program is nine semesters long. At that point, the curriculum was changed from year courses to semester courses, but there was no change in the content. At IPN the program was also five years long and it was only modified to a semester structure in 1975. Also, in order to get a degree, the student had to write a thesis and comply with a Social Service requirement that involves 400 hours of free work as a service to society, since higher education is highly subsidized by the state and is practically costless to the student.

As mentioned in the introductory paragraphs, the number of schools that offer chemical engineering degrees has grown tremendously in the last ten years. Of the present 54, only 9 are private institutions; of these, the most relevant are ITESM at Monterrey and UIA in Mexico City. Both these institutions have contributed significantly to the education of chemical engineers, mainly from the standpoint of quality graduates. In the case of ITESM, its development has been somewhat independent from the large institutions, and in that respect it has pioneered in chemical engineering education, following the patterns of American universities such as Wisconsin. However, as we can see from Table 1, the contribution of ITESM to the supply of chemical engineers amounts to less than 3%.

Another characteristic of undergraduate education in Mexico is that most of the professors teach on a part-time basis and come from industry to teach one or two courses a week. This contrasts with education in developed countries where most of the professors are fully devoted to teaching and research. Table 2 shows figures for some of the most representative schools of chemical engineering.

The government answer to the demand for in-

TABLE 2
Composition of Faculties

INSTITUTION	FACULTY		
	Full Time	Half Time	Part Time
U.N.A.M.	35	8	330
I.P.N.	186	102	142
Univ. Aut. de Puebla	6	18	20
Univ. de Guadalajara	9	—	37
Univ. Aut. de Nuevo León	24	2	47
I.T.E.S.M.	13	1	14
U.I.A.	6	2	12
I.T.R. Celaya	—	—	15
I.T.R. La Laguna	4	3	12
Univ. Veracruzana	10	2	28

creasing numbers of chemical engineers was the creation of a large number of institutions offering the program (22 in the last 6 years). Also, UNAM has opened two new schools in the metropolitan area of Mexico City and, more significantly, the government created the Metropolitan University (UAM) with two campuses offering programs in chemical engineering in Mexico, D.F.

The characteristics of this new university are different from those of other government sponsored universities in several respects. Outstanding are the following facts: there is a tuition fee that is considerably higher than the one charged at UNAM, the academic structure is similar to that of American universities (by departments), and the ratio of students to professors is quite low. In a way, we could say that UAM represents a model of the type of university that the government wants to have in this new stage of development of the Mexican economy.

Thus far, thanks to support from the government, the demand for chemical engineers has been satisfied, in excess, in terms of quantity, as can be seen in Fig. 4. However, the main problem in the last ten years has been quality. According to the opinion of recruiters, only 10% of the graduates have "satisfactory" quality, about 30% are "capable or able to be trained," and 50-60% are "deficient."

GUIDELINES FOR CURRICULUM DEVELOPMENT

The present problem is one of supplying engineers capable of facing the challenge that the development of modern chemical industry poses. Quality should be emphasized, as well as a sound formation in the fundamental principles of chemical engineering that are common to all chemical industries. Also, in order to develop appropriate technologies and to assimilate those imported from abroad, the graduate programs should be strengthened to provide researchers and teachers capable of supporting the proposed new curricula. Therefore, any attempt to develop a curriculum in chemical engineering should be based on two principles:

- **A knowledge of what chemical engineering is, and**
- **A knowledge of the requirements of the chemical industry.**

The first condition seems to be easy to achieve. However, experience has shown that in Mexico most failures in curricula design can be blamed on a lack of knowledge of what chemical engineering is. Although the discipline has reached a great degree of maturity in places like the USA, in Mexico there are very few people with enough background to give a precise definition of the field.

A feasible proposal to solve this problem has been set forth in a previous publication [7]. Basically, this recommendation consists of a definition of those aspects of science that are most important for sound development of chemical engineering, in order to establish a basic structure of knowledge for the first year of the curriculum. Clearly, the fundamental core of any chemical engineering curriculum consists of mass and energy balances, thermodynamics, applied mathematics, transport phenomena and chemical reaction engineering. The basic structure of knowledge should prepare the student to face these disciplines successfully, and should include general physics, general chemistry, and mathematics. All these should have a strong practical support through carefully planned laboratory sessions.

. . . this basic structure of knowledge, as well as the fundamental core, should be established and developed on a national basis through the government sponsored schools.

We believe that this basic structure of knowledge, as well as the fundamental core, should be established and developed on a national basis through the government sponsored schools. In order to do this, an "Academic Commission" should be formed by representatives with high academic standing from each area of the country, calling upon nationally recognized researchers and specialists to work as consultants.

The main purpose of these consultants would be to supply the information needed for the second item of our basic principles; i.e. the requirements of our chemical industry. In this paper, we have given a very brief review of the requirements from our point of view. These have served for the design of the curriculum at our own institution. UAM-I, which we consider to be the model to follow. Therefore in the next section we will deal with it in some detail.

THE PROGRAM AT UAM-I

Fig. 5 shows a schematic of the general activities of a chemical engineer and the interconnec-

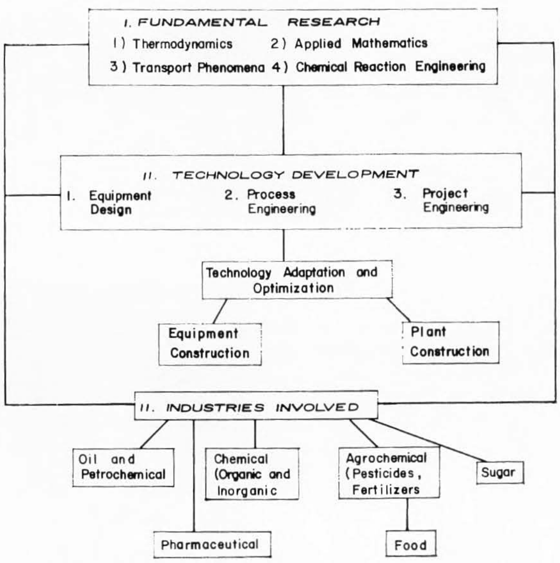

FIGURE 5. General Activities of a Chemical Engineer

tions and relationships with the main industries in Mexico. As can be seen, a wide variety of activities is involved and the industries have large differences among them. Therefore, it is very difficult for a program to attempt to cover every aspect that the future engineer may require, because of the inherent risk of wasting resources and effort. Rather, whatever resources we have can be employed more efficiently if we follow the guidelines given in the previous section of this paper. This would provide a general program with strong chemical engineering fundamentals, flexibility, and adaptability to the different working environments which will confront the engineer.

The objectives of the program at UAM-I are:

- **To educate chemical engineers with a high academic standard, so as to enable them to contribute to the development of the Mexican industry.**
- **To provide the future professional with a strong scientific background that will give him the capability to perform in any given field of chemical engineering, and to solve the inherent problems with the required depth and flexibility.**
- **To provide the future engineer a continuous contact with the problems and needs of the Mexican industry in order to facilitate his finding a role within the context of his future working environment.**
- **To prepare professionals capable of continuing their education in a graduate program, in Mexico or abroad, to strengthen teaching and research in the country.**
- **To prepare professionals with capabilities for developing new and appropriate technologies in accordance with the specific needs of our country.**

Fig. 6 shows a schematic of the curriculum at UAM-I. The foundation of the program is the "General Core" of basic science and engineering. This core is taken by all science and engineering students in the first three quarters at the university. The second stage of the program is a "Common Core of Engineering," which is a group of seven courses in applied mathematics, including computer programming, numerical methods, operations research, optimization and engineering economics. This second core is taken by all engineering students between the fourth and ninth quarters of the curriculum, while they are also taking the fundamental chemical engineering courses.

The last stage of the curriculum is what we call a Major Area, and in particular at UAM-I we offer a major in process design and development. During this stage, the student takes a "Process Design and Development Laboratory," where he is given a comprehensive project with the purpose of developing a technology for manufacturing a product for the Mexican market, under the supervision of our entire faculty. This course is three quarters long and the student is supposed to use bench scale and pilot plant facilities to solve the problems posed by a real project.

The quarter structure of our program leaves room for five elective courses, which should be selected from those offered by other engineering,

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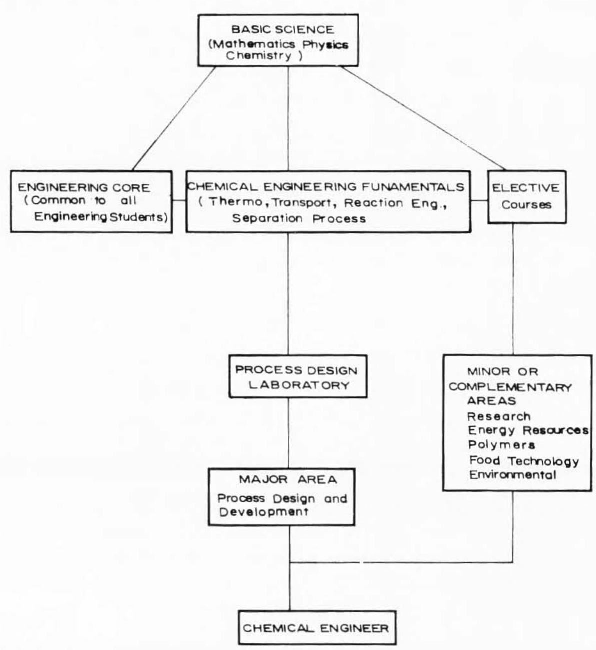

FIGURE 6. Chemical Engineering Curriculum at UAM-I

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or related, programs to form a coherent complementary, or minor, area. All students must spend one summer in industry in a regular job after their junior year, and they must also comply with the Social Service requirement mentioned previously. However, in contrast with other programs, there is no thesis requirement for graduation.

At this point, we should mention that similar programs have been proposed at UNAM, but are still pending approval for their implementation [8]. Also, private insittutions (such as UIA) are already operating with a curriculum whose basic philosophy coincides with ours, but with differences in the form of implementations. This is due to the fact that their faculty is fundamentally part-time, whereas at UAM-I most of the faculty is on a full time basis. This brings up the point that, in order for any program to be successful, the level of preparation of the faculty members should be the highest possible, and the composition must be shifted from primarily part-time to mostly full time teachers. It is in this respect that the graduate programs in Mexico have become increasingly important, and therefore should be strengthened.

CONCLUSION

A brief review of the development of chemical industry and of the chemical engineering profession in Mexico shows that they have been in phase in terms of supplying the quantity of engineers required by industry. However, quality has been a problem, particularly in the last five years.

Mexican industry now requires a different type of chemical engineer; one capable of assimilating the imported technologies and developing new processes more suitable for the efficient utilization of our resources.

We propose the formation of an "Academic Commission" on a national level, formed by highly qualified professors from all parts of the country, in order to coordinate the design of a curriculum which could be implemented at all government sponsored schools. This curriculum should contain a fundamental core of basic science with a strong interaction with practice through lab sessions. The second stage of the curriculum must emphasize the fundamentals of chemical engineering and, finally, the third stage can be flexible and concentrate on several aspects, depending on the region of the country or the strength of the faculty at hand.

It is obvious that the implementation of the proposed curriculum requires highly trained teachers and researchers. These people should be prepared through the graduate programs now existing in Mexico. Such programs must be strengthened and should be strongly supported at the main government sponsored institutions. An overview of graduate education in Mexico will be published in a later issue of *Chemical Engineering Education.* □

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