ChE EDUCATION IN MEXICO - Methodology And Evaluation

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THE ACCELERATED DEVELOPMENT of Mexican Industry the past thirty years has required an equally accelerated production of engineers and technicians, causing a tremendous overpopulation problem in universities and polytechnics around the country.

Analyzing the situation, we can focus the problem of ChE education in terms of the development of the chemical and petrochemical industries, and in general, in terms of the development of national production. Besides, the country has reached a stage where said development cannot take place without the creation of its own technology. This creation of technology requires high level scientific research, and this is not possible without high level college education. Therefore, the role ChE schools, in terms of national production, is that of producing high level education.

When we speak of production, we understand that the universities are centers for production of high level professional education as a necessary stage for the production of technology at different levels. Therefore, if we focus the problem in these terms, we have to analyze the organization required to produce higher education, as well as the present situation of most universities in Mexico.

Due to historical reasons beyond the scope of this analysis, higher education in Mexico is, in general, free or very unexpensive. This has brought about one of the greatest problems of our universities, population explosion.

This population problem produces the dispersion of the resources available which, in addition, are limited. This particular problem is unsolvable; therefore, we must find the solution through a rational distribution of resources for their more efficient utilization. Among these resources we must consider very prominently the students themselves, taking into account their characteristics in order to employ them correctly in the teaching-learning process. Therefore, the organization required for the production of high quality education must rest upon the students and the professors socially organized for that purpose, keeping in mind the particular situation in which they have to work, in order to devise a teaching system which allows an optimal utilization of every resource available.

FUNDAMENTAL ELEMENTS

ANALYZING THE PRESENT situation of most ChE schools in the country, we can see that, while the formal structures of administrators-teachers-employees are reasonably organized; among the students, who represent the majority, the only elements of organization are:

- **The term in which they are registered.**
- **The class to which they belong.**
- **The subject they are taking, their schedule, the classroom, and the name of the teacher.**

Under these conditions, it is only natural that the mobilization of students to perform any definite task is practically impossible, in fact, it is not possible to count on representative democratic student organizations.

If we do not analyze this problem correctly,

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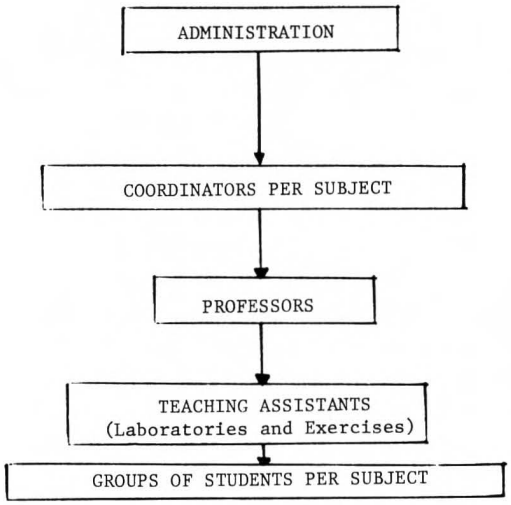

FIGURE 1. Organization at the National University.

we may reach the wrong conclusions, and in fact it is normal, for a good number of teachers and administrators, to concentrate on the students all the causes and consequences of the malfunctioning of our educational system, and so we just hear about the "irresponsibility and apathy" of the students, their "perpetual lack of preparation," their "immaturity and lack of motivation," etc. This conclusion, the result of criticizing individuals instead of the process, produces confusion and frustration when trying to work-out solutions to the problem.

On the other hand, the students also have a tendency to judge their teachers, and thus they also have a long list of negative elements about the professors. At this point, we find ourselves within a vicious circle, which shows up every time that students and teachers get together to discuss the problems of their school and their university.

The key to a democratic organization and its performance, is given in terms of centralizing such an organization from the bottom to the top, and this makes it necessary to redefine the functions of the professor and the student in the educational process. Therefore, we may conceive the professor as an organizer and the student as an organizing element.

History has demonstrated that one of the best ways to achieve a democratic organization, starts by setting up a restricted organization, with very clearly defined general principles, shared by their members, to permit the initial centralization and coordination of activities, necessary for a later systematic action on the whole group of people involved in the process.

In addition, due to our population explosion problem, it is necessary to have a linking element between our present teachers and our present students. This implies a careful revision of the current teaching methods in most of the ChE schools of Mexico.

Actually, there have already been attempts to do the above mentioned things; for example, at the National University, we find the following organization seen in Figure 1.

This structure represents, at the beginning stage, the correct way of solving the problem. However, the sufficient centralization level has not been achieved, nor has it been possible to find a consequent system to produce education efficiently. Therefore, starting from this first level of action, already given, we can set forth the following points to analyze in terms of an organization for the production of education:

- **The role of the professor with respect to his teaching assistants.**
- **The role of the teaching assistants with respect to the students.**
- **The role of the students with respect to the assistants and professors.**
- **The role of the students with respect to the administrative structure of their school and university.**

Our first experience was with a course on chemical reaction engineering . . . The teaching assistants were teaching from industry and from the school itself as volunteers.

In view of our previous analysis, and with these four points in mind, we can set forth the following proposals:

- **Determine the necessary number of assistants in terms of the number of students.**
- **Define the function of an assistant as an agent for organization, communication, information and tutoring.**
- **Define the function of the professor as a generator of academic material, evaluator of the educational process and first level of centralization.**
- **Define the role of the student in the process as an active and productive being, as a direct participant of its organization, and fully capable of making decisions within said process.**

In addition, we must clearly establish, that every organized action taken by administrators, professors and assistants, has to be directed

towards the development and strengthening of the students' own organization in the process, in order to integrate them representatively when decisions affecting the operation, objectives, and development of the school are taken.

The planning and implementation of the system needed to produce the above mentioned interaction, may begin taking the following general principles as a basis:

- **The process is highly heterogeneous, and therefore, any attempt to homogenize it must be avoided.**
- **Every student is different and he can advance, in the learning process, according to his own capabilities and limitations.**
- **As well as the professor has a work to perform, and concrete obligations, the student must also do his work and have his concrete obligations.**
- **The students and the professors must be in an equal position to demand of each other the performance of each other's work and obligations.**
- **According to these principles, the current administrative structure must be conceived as an organism representative of all the groups involved in the educational process, and whose main function should be that of centralizing such process in terms of the fundamental interests and objectives of the great majority involved, that is, students and professors.**

THE TEACHING METHODOLOGY

STARTING FROM THE principles set forth in the previous section, we can propose a general action scheme that consists of two stages; first, the construction of the necessary infrastructure for the overall change, which will comprise the following:

- **Construction of the teaching material.**
- **Training and updating of existing professors, as well as selection and training of the necessary additional personnel.**
- **Define timetables for implementation of the new system, first in one of the biggest schools, i.e. the Chemistry School at the National University, in preparation for nationwide action in a later stage.**
- **Focus the action on the first semesters of study in 1976, at the chemistry school, for this initial stage.**

In this respect, we take as a fundamental element, the integration of theory and practice in one single space, the laboratory. In order to achieve this, it is necessary to design model study "units" or modules containing the following parts:

- **One or more laboratory practices in terms of the basic principles to be learned, in which the objectives must be, to observe, explain, predict and control the phenoma involved, in a systematic way.**
- **Theoretical material associated with the principles to be learned, which must be constructed from a selection of the materials existing in the literature.**

The purposes of this part are to develop verbal and written ability as well as the handling of numerical and logical operations around the basic principles included in the unit.

This theoretical part must be accompanied by a study guide to help to introduce the student to the subject of the unit. This guide consists of a series of questions directed towards calling the student's attention to the most important aspects of the material under study. The guide must be handed out before the laboratory practice, and it must be pointed out that it is not a homework, but rather an orientation for a better study and analysis of the material.

- **One lecture, at least, with the participation of two or more specialists in the subject, in order to have a stimulating dialogue between them, and thus encourage the participation of the students in the discussion.**
- **Audiovisual material, prepared according to the requirements and the real possibilities of the school.**

In every unit, the materials of theory and practice must be referred to the socio-economical situation, in historical terms, that gave way to the discovery of the principles being studied, as well as some of the relevant scientific and humanistic aspects of the individuals that contributed to said discovery. This may be done at two different levels, a short summary with the most relevant aspects and their relation with the current situation of Mexico as far as technology and socio-economical development are concerned;

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and second, to direct the student toward more ample bibliographical references on the subject.

EVALUATING THE PROCESS

The Laboratory Practice—This evaluation is two-fold, first before the practice to determine if the student has "done his homework" and is ready to perform in the laboratory. A short in-

dividual interview is sufficient. Second, the student must write a report, which is evaluated by the teaching assistant in terms of clarity of writing, results and conclusions.

Theoretical Part—The first evaluation is a personal interview between the student and the professor or a teaching assistant, in order to determine whether the student can or cannot handle the material, if he does, he takes a written test (one or more problems), if he does not, the possible causes are discussed, in order to indicate to him what aspects he should review more carefully before he has another interview. A student can take as many interviews as necessary in order to be sure that he has learned the principles included in a unit. In practice, however, it never takes a student more than three interviews.

The student must hand in, after every unit, a graph indicating the number of study hours per day of a week devoted to a unit. The teaching assistant will keep a record of interviews and written tests, as well as of the units passed as a function of time.

In general, we pretend to reach two objectives in a study unit. First, that a student can handle the greater amount of variables possible about a problem, once this is achieved, to try to work on his behaviour in such a way that he can start from the general principles down to a precise analysis of the particular cases. The second objective is for the student to develop an improving mastery of the concepts involved. It is worthwhile mentioning in this respect, that the response will be extremely variable from one individual to another, given the previous history and the limitations of everyone in particular.

We consider that if a student can handle the theoretical principles for observation, revision, explanation, control and systematization in the laboratory, we are reinforcing his capability to face any kind of particular problem in a variety of chemical industries, and therefore we can achieve our goal of producing high level professional education.

It is worthwhile mentioning that, the fundamental principles that we have outlined for the methodology, organization of material, and evaluation, were first established by Keller [1], and have already been applied, with some variations, in several American Universities [2, 3], as well as at the Instituto Tecnológico de Monterrey in México [4]; in all these cases, the results reported are highly satisfactory. At the Universidad Nacional de Mexico's school of chemistry, we have already applied said principles with success [5], and we shall comment on the experience later in this work.

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EXPERIENCES AND RESULTS

OUR FIRST EXPERIENCE, performed in the Chemistry School of the Universidad Nacional, was with a course on chemical reaction engineering the second semester of 1972 [5]. The material used consisted of chapters 7 through 14 of Smith's text [6], which were the 7 study units for the semester. The teaching assistants were recruited from industry and the school itself as volunteers. The results at the end of the semester were highly satisfactory; we actually incorporated, as teaching assistants, 5 students that finished the course in 10 weeks. Two of these students continued working as assistants the following semester, besides joining the school's research group on Heterogeneous Catalysis under our supervision.

The number of students in this group was 35, most of which were considered "irregular" because they had flunked one or more times any of their previous ChE courses, which caused them to fall behind the pace of their class. Despite this, in our course, 80% of them passed and more than half the passing grades were A.

The results of this experience created great expectation among the students that were about to take reaction engineering during the first semester of 1973, as well as among some professors. Therefore, we decided to open 2 groups of 80 students each, this time with support from the school's administration to allow for a sufficient number of teaching assistants.

The total number of students registered for this course was 169, out of which, 131 passed (77.5%), 33 did not show up or abandoned early in the semester (19%), and 5 completed 3 out of 7 units but finished the course on the following semester. Among the passing grades 54% were A, 41.2%, B and 4.7%, C. This distribution of

TABLE 1
Comparison of Results For Experiences Performed

EXPERIENCE	No. OF STUDENTS REGISTERED	No. OF STUDENTS PASSED	GRADES	No. OF PROFESSORS	No. OF ASSISTANTS	No. OF HOURS-WEEK PER ASSISTANT
1. Second Semester '72	35	28	52% A 38% B 10% C	1	4	Volunteers
2. First Semester '73	169	131	54% A 41% B 5% C	2	9 3	5 10
3. Second Semester '73	146	106	44% A 45% B 11% C	2	4	20

grades was practically in direct relation to the velocity with which the students finished the course.

The course was again divided into 7 units, that were evaluated on the basis of a hundred percent performance by the students, in consequence, some individuals required more than one evaluation per unit to achieve the degree of excellence required.

The personnel involved in this second experience consisted of 9 teaching assistants with 5 hours-week, 3 with 10 hours-week, and two professors with 10 hours-week. The general results of this and the previous experience are summarized in Table 1 for an easier comparison.

Since every assistant kept a detailed record of every student in his subgroup (see Table 2), we were able to obtain additional information about the process.

The students finished the course within the eighth and the twenty first weeks, with the mean finishing by the thirteenth week. Analyzing the response from the students as a function of time, we could observe that, at the beginning, they respond slowly; by the fourth week they respond fast and stably; by the end of the semester they accelerate their execution and wind up handling the last two units with great flexibility.

The students organized themselves in a natural way through the teaching assistants, who were previously and carefully instructed in the basic principles of the system. The correct handling of the basic principles by the assistants, permitted the experience to take place without incidents, and favored the development of adequate personal relations between teachers and students.

As a result of this assistant-student interaction, the communication was enhanced beyond the school boundaries, which avoided the usual let down during and after the mid-semester vacation period. The sustained interaction between assistants and professors made possible the consolidation of a high level working group.

The mean period needed for an interview was of 40 minutes at the beginning, but it was cut in half by the eighth week. Therefore, the work required of professors and assistants is intense at the beginning of the course and it is reduced to a minimum towards the end.

The space required to work with the students was equivalent to 60% of a classroom for 80 people, from which we conclude that the real needs for space are concentrated in the laboratory and not in the theoretical courses.

The material used for the course was, again, the text by Smith [6], in English. Many students actually translated into Spanish the chapters under study, also in discussion with the assistants they actually revised the material, corrected misprints and attempted to improve the treatment of the subjects to make them more accessible for the majority of the group. The final result was actually the first stage towards the construction of a new material.

STUDYING PERFORMANCE

IN VIEW OF THESE results, we decided to continue with a third experience, again with two groups of students in the same subject, during the second semester of 1973, with the purpose

of studying the performance of the system if we reduced the time employed by the two professors to a 10% of that employed in the previous experience. Also, we wanted to reduce the number of assistants to 4 with 20 hours-week, in order to make the cost of applying the system more accessible for the school.

Therefore, the results of this third experience were analyzed in terms of the more efficient application of the resources available. First, we address ourselves to the progress of the students as a function of time in every study unit. If we plot said progress as shown in Figure 2, we obtain a S-shaped curve in the upper part of which, we locate the fastest students; in the long intermediate part, we find the bulk of the group, and in the lower section we find the slowest students. The length of each section changes from one unit to another, and the dispersion was reduced as the semester advanced. Unit number 2, which includes the kinetics of homogeneous reactions, represented the unit that required more time on the average, this was due mainly to the fact that it comprises most of the fundamental material for the remainder of the course, and the majority of the students required more than one interview to master the concepts.

The advanced students that integrate the group in the upper part of the curves, exert a favorable effect on the remainder of the group due to the wide communication developed within the learning process. When the bulk of the students find out about the existence of several fellow students that have advanced quickly, they react positively and feel that the road towards the end might not be so difficult.

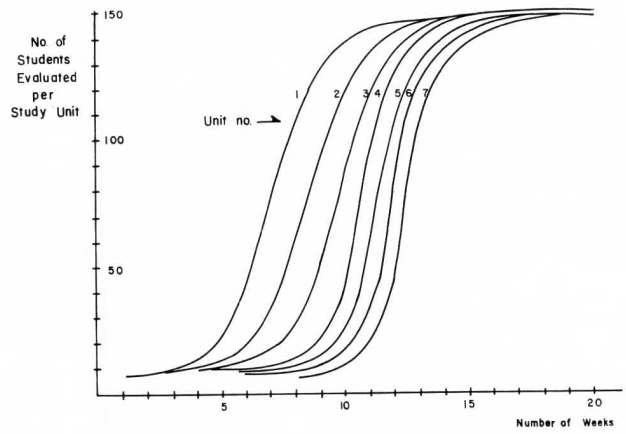

FIGURE 2. Progress of students as function of time.

Due to the control that we can have on the teaching-learning process with this system, it is possible for us to detect the most important factors that influence the development of said process, such as:

The System—Since there is no fixed limit date to pass the first unit, the students start working very slowly, therefore, there are too many requests for interviews at the end of the semester. The source material in English was also responsible for delays, since many students had difficulties with the language and took more time to prepare the units.

The Teaching Assistant—Every assistant has a particular way to conduct an oral interview, hence these varied in time and depth from one assistant to another.

Missed sessions by assistants, cause a delay in all the students of their sub-group and have a

TABLE 2
Assistant's Record

FIRST SEMESTER 1973 NAME OF ASSISTANT: _____

UNIT	1	2	3	4	5	6	7
STUDENT	Dates of Evaluation/Grade						
(Name of student)	5/29 C	6/8 B	6/15, 17 C				
(Name of student)	5/21 A	5/29 A	6/8 A	6/16 A	7/2 B	7/15 A	
(Name of student)	5/23 A	5/29 B	6/15 B	6/28 A			

negative effect on their behaviour within the learning process. If by any reason, a student had to take one or more interviews with different assistants, this had an equally negative effect.

The Student—The defective preparation in basic knowledge, such as mathematics, transport phenomena and thermodynamics, caused the students to need more time to study the units.

The students are used to respond only under pressure, and therefore, most of them start working hard until the end of the semester.

The personal problems of each student, such as an excess of courses, time limitations due to part time jobs, health problems and others, also reduced the global performance.

Regarding the general results, these were very similar to those obtained in the previous experiences. Out of a total of 146 students registered, 72.5% passed the course, the distribution of grades was 44%, A, 45%, B and 11%, C.

The length of the semester was 18 weeks, and we were able to determine that it is perfectly possible for an assistant with 20 hours-week, to take care of 40 students, if the students respond from the beginning.

CONCLUSIONS

FROM THE EXPERIENCES detailed before, we can obtain the following general conclusions:

The majority of the students that enter the program pass the course; we consider that there are no students flunked, since they simply do not enter the program.

There is a very short number of students that take the course by stages, since there is no need to repeat the units passed. This has a tendency to eliminate the traditional problem of repeating full courses and falling in the vicious circle of taking again a subject, from the beginning, with the same drawbacks that caused them to fail in the first chance. We consider that the problem of repeaters should cease to exist in the long run.

Due to the division of the course in units, to the oral and written evaluations, and to the utilization of sufficient assistants, we have been able to establish that it is possible to have groups of 40 students under the supervision of an assistant with 20 hours-week, and that it is possible to take care of a class of 160 students with just 4 assistants and one professor. Another important point, is the real possibility of incorporating the most advanced students as secondary assistants, considering that a good number of them completes the course in 10 weeks or less.

The role of the professor finds a new definition as follows: A person holding a B.S. degree with well rounded preparation, whose functions are to manage and coordinate the working team, to design the exams and numerical problems, to evaluate the performance of the assistants and of a random sample of students, to gather and classify the information from the assistants and send it to the school's evaluation department in order for them to supervise the global development of the course.

. . . it is possible to have groups of 40 students under the supervision of an assistant with 20 hours/week, and it is possible to take care of a class of 160 students with just four assistants and one professor.

The analysis of the students' progress with time, allows us to take adequate action with every group, isolating the students that fall very far behind in order to devote more attention them according to their characteristics. On the other hand, it is possible to further motivate those students concentrated in the central part of the curve, through adequate utilization of audio-visual material and lectures, and so we avoid mixing a greatly heterogeneous population for specific activities.

In the traditional teaching system, it is very difficult to do what we are talking about here, since there, we do not have the necessary information nor centralization to take adequate action when it is needed.

The system contributes to improve the academic level of the professors and assistants, and to the training of future teachers. It allows us to select the best students from the beginning in order to strengthen basic research in the future. That is, those students that show positive characteristics and motivation toward research, can be trained by means of a specific program of activities to further direct them to scientific research.

The teaching material can be constantly generated and revised through the performance and demands from the students, discussions with the assistants, and the centralization of all this

information by a commission of high academic standing.

It was observed that the students are able to cope with the problem of material written in a foreign language, and given the characteristics of the system, it is possible to help them whenever they need it.

As far as the student-professor relationship is concerned, the fundamental characteristic of the system consists in, completely eliminating adverse stimuli and substituting them by positive reinforcement. Incompatible conducts are also suppressed by simply not stimulating them. During our three experiences, there was not a single authority problem, on the contrary, magnificent relationships were developed.

RECOMMENDATIONS

IN VIEW OF THE pressing need to face the academic and political problems of our Chemistry School and the country in general, we propose to give priority to the teaching system, taking as a basis the general principles indicated in this document. Said system must constitute the basic platform and must generate the fundamental infrastructure to establish the general project for change in ChE education within a period no longer than 4 years.

Starting from an investigation of needs in terms of the activities of a ChE, define what aspects of science are most important for the development of Mexico and develop a basic structure of knowledge to be taken by students in their first two semesters of college. Consequently, the resources should be distributed preferably to those areas requiring more development and depth according to the peculiarities of our situation.

We consider as the basic platform, a first semester with General Physics, General Chemistry, Mathematics and Laboratory. In this platform, our basic academic activity must be the integration of these subjects with the activity of a ChE.

In order to develop the basic platform, we must integrate an "Academic Commission" formed by representatives from each area of the country, with a high academic standing; with nationally recognized researchers and specialists working as consultants.

The experience and results achieved by this commission during the first year of work, should permit us to create, one year in advance, the academic commissions for each area of the country, in order to generate the new plans, programs and materials for every area.

It is necessary to form a "Technical Group" whose task will be to work in close contact with the Academic Commission, in order to centralize the evaluation of the learning process for all the groups participating in the first level of basic science. This Technical Group should gather the greatest amount of information possible concerning the current distribution of resources in a ChE school, as well as their characteristics, so that the Academic Commission can use this information, for a more logic development and implementation of the teaching methodology and the material associated with it, according to our current conditions in a university and in the country. □

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