Chemical Engineering Education in a Developing Nation (Indian Scene)*

by

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1. Introduction

As compared to its inception in U.K. and U.S.A. In the later part of. the 19th. century,; chemical engineering education for India is fairly young. Though the first course in chemical engineering was introduced in the country more than fifty years ago, the development of chemical engineering education has been fairly rapid only during the last two decades. In the last ten years alone progress has been quite spectacular, having kept pace with the rate of growth of the chemical industry. This is evident today from the "establishment of more than thirty institutions in the country (India stands second in the world next to the United States in terms of number of institutions offering first degree course) with a sanctioned capacity of about 1500 at the undergraduate level, compared to barely ten institutions established by 1948 with a total intake of only 200 students. Twentyfive institutions now offer master's degree courses and twenty of them have facilities for doctoral research.

Chemical engineering education in India has gone through several changes. The variations that existed earlier in the form of courses in industrial chemistry, chemical technology and chemical engineering have been brought within a more or less uniform pattern through the efforts of the All India board of technical education in chemical engineering and technology. In. 1959, a uniform five-year integrated undergraduate course leading to the first degree was accepted and implemented in many institutions. The main features of the five-year integrated course as recommended by the board are illustrated in Table 1.

While the general pattern of the undergraduate curriculum in chemical engineering is more or less satisfactory today it should be subject to constant periodical reviews recast, if necessary, to include new courses which will meet the latest demands on chemical engineers requiring increasingly higher levels of professional competence and a fuller preparation for new and varied responsibilities. With this end in view, the chemical engineering education development centre was set up at I.I.T. Madras by the Ministry of Education and Social Welfare, Government of India in 1971. The objectives of the centre are depicted in Fig. 1.

2. Feedback **from** practising engineers:

Before taking any positive steps as regards some salient alterations in the existing curriculum, the centre (C.E.E.D.C.) wanted to collect information about various aspects of chemical engineering education and profession from the practising engineers, since our education must cater to our industrial needs. Accordingly a questionnaire was sent to 2000 members of the Indian Institute of Chemical Engineers in industry. The information obtained was summarised and analysed under the, following heads, which served subsequently as important guidelines in formulating an appropriate and time-oriented curriculum.

2.1 Engaged engineering activities:

Keeping in view the engineering activities in which chemical engineers are engaged in their professional life, the curriculum for the first degree course should be modified from time to time. Table 2 gives the data showing the mode of employment of the Indian chemical engineers along with a comparison to their counterparts in U.K. and USA. This indicates that the percentage of chemical engineers in operation, supervision and maintenance is very high compared to U.K, and USA. On the other hand, a small percentage of the Indian chemical engineers are engaged in administration and management.

2.2 Application of the subjects taught in the curriculum to the profession:.

The assessment of the usefulness of the subjects taught in the curriculum of the profession was collected from the practising engineers in the questionnaire and a quantitative picture of the data compiled is given in Table 3. The analysis further revealed that out of 47.5% of chemical engineering science 33.8% (i.e. 71%) is the contribution of unit operations i.e. this is the subject with highest usage frequency. There may be some justification for lowering the content- of "other engineering sciences" since industries engaging chemical engineers always engage mechanical and electrical engineers. But this is not true for chemical engineers engaged in small scale industries and those self-employed for whom knowledge of "other engineering sciences" will be of great value. This point deserves careful examination as the future of many chemical engineering graduates seems to be linked up with small scale industries or self-employment.

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2.3 Views of respondents regarding the recent chemical engineering graduates:

The following weak points of the fresh chemical engineering graduates have been brought out by the practising engineers:

(I) Lack of practical approach to problems of industry

(II) Inadequate training in design and drawing of equipment and plants

(III) Inadequate written and oral communication skills

(IV) Lack of knowledge of behavioural sciences.

The last three points are to be critically noted In view of the active involvement of chemical engineers of industry in preparation and/or use of reports and in management duties as is evident from Tables 4 and 5. As ability to communicate information in clean, concise and logical manner is essential, considerable time and effort should be devoted to develop communication skills in the undergraduate students. Similarly the courses in management and behavioural sciences should form an essential component of the first degree curriculum.

3. Important remarks about the existing curriculum:

Keeping in view the feedback from the practising engineers on the existing curriculum, the curriculum committee of the chemical engineering education development centre made a critical analysis of the same and indicated the following significant points:

(I) The curricula are rigid and the students have little choice in the subjects.

(II) The number of lectures is generally high and is at the expense of practicals.

(III) Training in industry is very often not an integral part of the curricula and is not a requisite for the award of the degree.

4. Suggested curriculum for the first degree course:

Based on the suggestions of leading chemical engineers in universities and industries, the C.E.E.D.C. has formulated a curriculum keeping in view the report of the Education Commission and the National Policy of Technical Education. This is to be adopted for the first year degree course with ten semesters each of sixteen weeks duration. The details of the curriculum are given in figure 2. The percentage time distribution for different subjects in curriculum given in figure 2 is compared with that in other countries in Table 6.

4.1 Scope of the curriculum:

The proposed curriculum defines the objectives of chemical engineering education. It adequately provides for the choice of electives, in as much as electives offer considerable flexibility and scope for. specialisation in subjects of interest to students, and enable them to choose careers in design, operation,, management, technical services, etc. The curriculum also provides for training in industry, adaptation to the 'sandwich' system and to the use of the credit or unit system so that the time to complete the programme will depend on the individual ability of a student.

4.2 Successful implementation — need for cooperation from the industries:

Industries have to play a vital role in the successful implementation of the curriculum. The industries have to cooperate with the universities in various ways like:

(I) providing facilities for useful visits to their works from time to time,

(II) deputing their engineers for part-time teaching,

(III) providing facilities for effective and useful practical training for the students,

(IV) sponsoring design and research projects,

(V) engaging faculty members as consultants.

These means of direct contact for the engineering students with the practising engineers and the problems of industry will not only develop a practical bias in them but will bring about a better appreciation for the subjects they are studying in classrooms and laboratories also.

4.3 Critical notes on the curriculum:

Some critics have brought about the following two critical notes on the curriculum:

(a) Excessive load on students.—The curriculum suggested comprises of a load of 2352 lecture hours and 2448 laboratory and tutorial hours over a period of five years or 470 lecture and 490 laboratory and tutorial hours with a total of 960 hours per year as compared to about 750 hours per year on the average in a Canadian university. The load on the students looks a little excessive. However, it is difficult to compare it based on the load only, as the work assigned to the students should also be counted for a fair comparison.

(b) Reduced importance of basic science courses: It is evident from table 6 that the percentage of science context is comparatively less with respect to those of USA & Canada. However, the value is in agreement with the science context of the curricula followed in West Germany and U.K. The current tendency of restricting engineering instruction to courses in mathematics and basic science in the curricula of the universities of Canada and USA has aroused some criticism especially from industry. It will be apt in this connection to quote the following lines from Dodge Guthrie and Antwerpen.

"There is however a new breed of engineering professor and consequently a new teaching emphasis on research, largely scientific in nature. The trend toward science to the exclusion of engineering in chemical and engineering education has, in our opinion, gone too far. Industry needs men with an application viewpoint, which the science-oriented curricula do not provide. As one engineering administrator in industry put it, 'Industry needs scientific engineers, not engineering scientists.'".

Increased weightage to basic sciences in the under-graduate curriculum of USA or Canada has been given at the cost of 'other engineering sciences'. But it is not possible to do so in the Indian curriculum for the obvious reasons already discussed.

5. Status of post-graduate education:

Post-graduate programmes in chemical engineering, reorganised on the basis of the so-called Thalker committee report of 1962, are running in quite a good number of universities and institutions in the country. These programmes can either be of two years' duration leading to a Master's degree in chemical engineering or of one year duration in which post-graduate diploma in a specialized field of chemical engineering can be obtained. The courses are motivated in most cases by an engineering science approach involving a study of material science, transport phenomena, instrumentation etc. in addition to advanced chemical engineering subjects.

It has, however, been the experience "of a good number of our institutions that the sanctioned capacity in the post-graduate programmes is not fully utilized during the period of the programmes. The programmes have been a little unattractive to the students because of the following reasons:

(I) The duration of two years is longer as compared to the programmes of many other countries.

(II) Many of the industries do not give due consideration to high academic qualifications from Indian universities and still continue to have the fancy of recruiting engineers with educational orientation from foreign universities.

(III) Most of the potential employers of post-graduate engineers in industry do not offer greater differentials in salary and status between the engineering graduates and post-graduates as is given in research and design organisation and academic institutions.

5.1 Suggested means of improvement:

(I) The duration of Master's degree course can be reduced from two years to one by carrying out the programme more rigorously (e.g. forty weeks of six days each divided into three semesters).

(II) The industrial leaders should carefully consider the whole situation and try to utilize the best and qualified engineers, who, otherwise, will leave the country for better prospects elsewhere.

(Ill) The industrialists along with the academic staff can discuss on a common platform as regards the type of orientations or background they expect from the post-graduate degree holders from time to time and the institutions, in their turn, should be in a position to mould their curriculum accordingly.

(IV) Higher academic degrees can be awarded to the students working on specific projects relating to "live problems" of industry under the joint guidance of faculty members and practising engineers under the so-called "Practice School systems".

6. Continuing education:

"The gap between industry and university is becoming wider. This may be due to graduates entering industry with techniques which the managers, who had left the university ten or fifteen years back and had never cared to look back at the academic side, do not understand or appreciate.

(Prof. D. C. Freshwater)

This was undoubtedly a relevant observation. Knowledge in Science and technology is expanding in such an ever-increasing rate that continuing education is the only solution of the problems of obsolescence among professional chemical engineers. A few years ago, Sir Frederick Warner, a distinguished chemical engineer, declared the "half-life" of a chemical engineer to be five years. It is obvious that continuing engineering studies are essential for practising engineers to remain informed and to retain the ability to make appropriate decisions in this rapidly advancing technological age. A pas't president of the Institution of Engineers (London), E.S. Sellers, has put this problem into the shape of a mathematical model, the solution for which indicates that a practising engineer needs to spend *15%* of his working time in order to keep his theoretical knowledge up-to-date. Continuing education programme can be organised as short refresher, advanced and appreciation courses, seminars and conferences and workshops of short duration on specific subjects of current interest to industry. The courses can be conducted at the teaching institutions with the help of experts from the institutions, industries and research organisations.

Although the importance of continuing education for engineers in industries has been very well realised in the developed countries, the position has not been very satisfactory in India. But the need for such programmes as a means to direct their engineers to acquire more knowledge and improve professional competence is being gradually realised by the progressive companies.

7. Areas of social relevance in chemical engineering education of the developing countries:

Education cannot be isolated from the current challenges facing the country and teaching should reflect an awareness of contemporary problems and techniques used to solve them. A critical examination of most of the undergraduate programmes in chemical engineering would reveal that the scope of those programmes has been restricted to more basic educational exercises. What is explicitly lacking is the input of knowledge concerning those areas of chemcal engineering which are related to the greatest social needs in the country to-day. Examples of a few of such areas can be given here for a careful consideration.

TABLE 1:
A.I.B.T.E. CURRICULUM FOR THE FIRST DEGREE COURSE IN CHEMICAL ENGINEERING

No.	Subjects	% time distribution in curriculum
1.	Humanities and Social Sciences	5.1
2.	Basic Sciences	31.3
3.	Other engineering Sciences	24.7
4.	Chemical engineering	38.9
5.	Elective	—

TABLE 2:
MODE OF EMPLOYMENT OF CHEMICAL ENGINEERS

No.	Mode of employment	% distribution India	U.K.	U.S.A.
1.	Production, operation supervision & maintenance ...	37.5	12.5	13.0
2.	R & D (Product and equipment)	25.4	27.1	21.0
3.	Design, construction, installation and commissioning	20.2	20.1	10.0
4.	Management and administration	8.8	25.6	27.0
5.	Teaching, Consultancy, Self-employment, sales etc. ...	8.1	14.7	29.0

TABLE 3:
APPLICATION OF THE CHEMICAL ENGINEERING SUBJECTS TO THE PROFESSION

No.	Subjects	% Usage frequency	% time distribution in A.I.B.T.E. curriculum
1.	Chemical engg. Sciences	47.5	38.9
2.	Other engg. Sciences	14.0	24.7
3.	Pure Sciences	21.0 }	31.3
4.	Mathematics	6.0 }	
5.	Social Sciences	7.5 }	5.1
6.	Communication	4.0 }	

TABLE 4:
INVOLVEMENT OF CHEMICAL ENGINEERS IN PREPARATION AND/OR USE OF REPORTS

No.	Type of involvement	% frequency
1.	Technical reports	14.4
2.	Drawings, sketches etc.	11.6
3.	Specifications of equipment	10.3
4.	Plant layout	10.3
5.	Instruction manuals	9.3
6.	Raw material specifications	9.0
7.	Work schedule	8.5
8.	Technical publications	8.2
9.	Test reports	7.9
10.	Contract documents	5.7
11.	Specifications relating to fuel & power supply	4.7

TABLE 5:
INVOLVEMENT OF CHEMICAL ENGINEERS IN PROFESSIONAL ACTIVITIES (technical and managerial)

No.	Type of activities	% frequency
1.	Checking material balance	8.8
2.	Commissioning of plants	7.9
3.	Training of new employees	7.6
4.	Performance evaluation of plant and equipment	6.8
5.	Production, planning and control	6.7
6.	Purchase of equipment and materials	6.5
7.	Job analysis	4.1
8.	Preventive maintenance	3.9
9.	Promotion & selection of personnel	12.5
10.	Policy making	4.6
11.	Sales	6.7
12.	Public relations	2.8

TABLE 6:
COMPARISON OF THE SUGGESTED CURRICULUM WITH THAT IN OTHER COUNTRIES

		% time distribution in curriculum				
No.	Subjects	India	Avg. of U.S. Universities	Inst. of Chem. Engrs., London	Proc. engg. Soc. W. Germany	Canada
1.	Humanities & Social Sciences ...	7.3	20.0+	13.0++	—	3.3
2.	Basic Sciences	32.9	41.0	29-35 + + +	35.0	53.5
3.	Other engineering sciences ...	22.0	10.0	3-8	33.0	10.7
4.	Chemical engineering sciences	32.8	28.0	49-50 + + +	23.0	29.2
5.	Electives	5.0	—	—	9.0	3.3

\+ Includes elective
++ Classified as social sciences & communication
+++ Variation between chemical process & design groups.

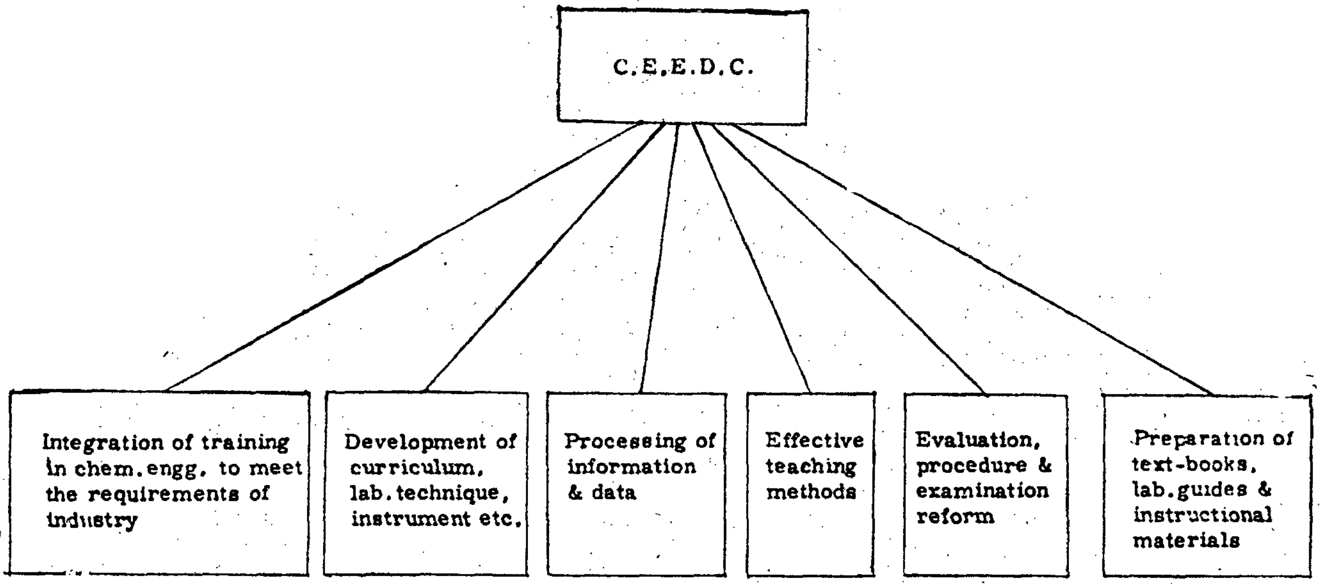

Fig. 1: Objectives of the Chemical Engineering Education Development Centre.

Subjects	SEMESTER										L	T/P
	I	II	III	IV	V	VI	VII	VIII	IX	X		
I BASIC CORE												
Humanities	+	+	+	+	+	+					288	64
Mathematics	+	+	+	+	+						288	80
Physics	+	+	+								208	240
Chemistry	+	+	+	+	+						272	432
Workshop			+	+							16	176
Engineering drawing					+	+					—	128
Engineering (other than Chemical Engg.)				+	+	+					288	304
II DEPARTMENTAL CORE												
Unit processes						+					48	—
Process calculations						+					32	64
Chemical technology							+	+			96	48
Unit operations							+	+	+	+	288	128
Chemical engineering thermodynamics							+				48	32
Chemical reaction engineering								+			48	32
Process equipment drawing & design							+	+	+		48	176
Instrumentation and process control									+		48	—
Economics and management of chemical industries										+	48	—
Chemical engineering laboratory							+	+	+		—	256
III ELECTIVES							+	+	+	+	288	—
IV PROJECT AND SEMINAR										+	—	288
											2352	2448

\+ Indicates the semester in which the subject is covered

L Lectures

T/P Tutorials/Practtcals

Fig. 2: Presentation of the suggested curriculum for the first degree course.

The devastating effect of energy crisis due to the continuously soaring prices of petroleum crude has tipped the economy, of petroleum importing - countries like India into a recession and continued inflationary situation. This has been a challenge to the engineers and scientists to look for some suitable substitutes Chemical engineers will be in a position to save the situation either by exploiting suitable alternative energy sources like the bio-gas energy and coal etc. or by conserving energy in chemical plants by an efficient energy .management.

Another important area of social relevance is the protection of environment. The phenomenal growth of the chemical industry in most of the developing countries during the last two decades has necessitated the development of specialised engineering knowledge to handle environmental problems like the pollution of air and water and the disposal of solid wastes. The current syllabi of most of our institutions do not incorporate an adequate and appropriate treatment of the subject either at the undergraduate or post-graduate level.

• Food engineering is another activity in which chemical engineers of the developing countries; have shown little or no interest primarily because they are not exposed to this subject at the universities. Unfortunately, the present courses in food technology offered by several universities generally do not provide sufficient training in the chemical engineering sciences to make them effective in the practices of food engineering.

": Search for alternative processes based on microbial participation and on available raw materials for the production of a large variety of materials to the fulfilment of some of the vital social needs is equally important in the educational curriculum of the developing countries like India. •••.-: • >,r *. • , •

The chemical engineering areas discussed above have not been given the necessary support in the developing countries for reasons difficult to establish, The sooner this position is corrected, the better it will be in the larger interest of these nations. As a concrete step to achieve the proposed objective, institutions having facilities,. offering courses and carrying out projects in the above areas should be given more support to see that the very basic objective of chemical engineering education is applied and extended to the needs of society. I conclude my speech with the following lines of Prof. F, A, Hengleiri, which emphasize the social relevance aspect of chemical engineering education:

"Technology as a creative power is culture and calls for ethical responsibility. Consequently, chemical technology has become- an intellectual and material factor in the economic and social life of nations.".

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