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Enhancing chemical engineering curricula in Pakistan to adapt to the new challenges of industrialisation

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ABSTRACT: In Pakistan, the chemical industry has developed steadily over the last 58 years. However, during this period, the gap between chemical education institutions and industry has widened, and inevitably the educational institutions have failed to tackle the problems faced by the local industry. In earlier years, the chemical engineering curriculum was dominated by chemistry courses with only a few chemical engineering courses. Yet in the last 50 years, the curriculum has developed progressively to replace the chemistry courses with core chemical engineering courses. The massive restructuring of industry in Europe has resulted in the transfer of traditional high-volume commodity businesses moving to developing countries, mainly in Asia, and the curriculum in chemical engineering needed to be developed further to meet the challenges of a nations' industrialisation. Specialised courses are required to be added in order to address the energy crises that Pakistan now faces. At the same time, new courses need to be introduced to bring the pharmaceutical industry in focus, which has yet to be established in Pakistan. In this article, the author draws upon recent history, together with some projections about the direction of the chemical engineering profession in Pakistan.

INTRODUCTION

At the time of independence, Pakistan had a predominantly agrarian economy, exporting primary commodities, mainly raw jute and cotton, and importing manufacturing goods, mainly consumer goods. There was hardly any manufacturing capacity; with the exception of an oil refinery, few sugar mills and cotton mills, cement-manufacturing units and some tea processing and mining activities.

Industrial development in the chemical and process engineering sectors in Pakistan were instigated in the mid-1950s with the establishment of the Pakistan Industrial Development Corporation (PIDC). The PIDC was responsible for Pakistan's development by promoting indigenous industry, the exploitation of national natural resources and attracting foreign investment from multinational companies. The PIDC become the pioneer of the modern chemical industry in Pakistan by putting up large-scale projects, including the Pak American Fertiliser Plant and the Karnafulli paper mill from 1955 onward. Pakistan's labour surplus conditions also promoted industrialisation [1].

THE HISTORY OF CHEMICAL ENGINEERING IN PAKISTAN

The facilities to educate chemical engineers in Pakistan were adequate from the beginning, although not of a very high standard compared to most foreign universities. Initially, a two-year course, leading to the BSc degree in technical chemistry by the Punjab University, was started in 1917 at the FC College Lahore; this was replaced by a three-year BSc (Hon.) in 1925 [2]. The Department of Chemical Engineering at the University of Engineering and Technology (UET), Lahore, was established in 1962 and was the first institution to offer Bachelor, Master's and Doctoral degree courses in chemical engineering [3]. The Dawood College of Engineering and Technology (DCET) in Karachi, established in 1964, was the first to offer programmes in chemical engineering in the industrial city of Karachi [4]. At present, the chemical engineering programme is offered at the following institutions in Pakistan:

- Punjab University (Institute of Chemical Engineering and Technology);
- The University of Engineering and Technology, Lahore;
- Dawood College of Engineering and Technology (DCET), Karachi;
- Mehran University of Engineering and Technology, Jamshoro;
- NWFP University of Engineering and Technology, Peshawar;
- NFC Institute of Engineering and Technological Training, Multan;
- The NFC Institute of Engineering and Fertilizer Research, Faisalabad [5].

The primary objective of chemical engineering education has been to prepare professional engineers with a comprehensive engineering education and the capability to work at the highest engineering and managerial levels in various Pakistani industries.

CHEMICAL ENGINEERING CURRICULUM

The BSc chemical engineering programmes in Pakistan are organised as a four-year programme. The chemical engineering curriculum was initially dominated by chemistry courses with only a few chemical engineering courses. With the passage of time, the curriculum has developed to meet the challenges of the industrialisation of Pakistan. Courses were added that were based more on general principles, rather than the description of

various chemical processes**.** To look after curriculum revision at the Bachelor level, the Federal Government of Pakistan appointed a Higher Education Commission (HEC) as the competent authority. In reviewing the chemical engineering curriculum, the HEC constituted a national committee that comprised senior faculty members nominated by every institution and exporter of national organisations. The National Curriculum Committee on Chemical Engineering set by the HEC finalised the draft curriculum in March 2003 [6]. A comparison of the curricula of the DCET for the academic year 1975-1976 and 2004-2005 and the HEC draft curriculum on the basis of basic, core, and allied and specialised courses is given in Table 1 [4][6][7].

Courses determined by the HEC were divided into four subject groups: basic subjects (27 credits hours), core subjects (76 credits hours), allied subjects (18 credits hours) and specialised subjects (3 credit hours). An academic year was divided into two semesters of 14-16 weeks each. In each semester, students attempted approximately 20 credits worth of subjects. Students have to complete at least 124 credits, depending on their university's policy.

The basic courses are a prerequisite for engineering core topics. Students receive a rigorous direction in the basic science subjects of mathematics, physics, chemistry and mechanics, and are introduced to computer applications in engineering. Mathematics continues up to the third year of the course. Laboratory work is carried out in parallel with classroom studies. Allied courses are of a general nature, as well as topics needed for further studies. The core courses include an introduction to chemical engineering, chemical engineering thermodynamics, transport processes, reaction engineering, separations, industrial stoichiometry, unit operations, transport phenomena, and chemical plant design. Chemical engineering core courses are introduced progressively in the second and third years. In the fourth year, core courses are supplemented by the study of specialised courses, such as environmental engineering, petrochemical engineering, petroleum refining engineering, biochemical engineering, fuel and combustion, petrochemical engineering, polymer engineering, process analysis and optimisation, and minerals processing technology.

In their final year, students are assigned a major project wherein the class is split into groups of 4-5 students. The student goes to industry to complete the project, based on the problem that the particular industry is facing. This project draws together all the major elements of encourages them in the development of students' analytical and experimental skills, and introduces them to chemical engineering research. Both theoretical and applied projects are provided. Students make a formal presentation of their work and write a project report. This activity gives them an opportunity to test their ability to work in a team and exercise their leadership skills.

CURRICULUM DEVELOPMENT

In order to cope with the changing opportunities and challenges faced by graduating chemical engineers in Pakistan as a consequence of technological developments and globalisation, it is appropriate to bring drastic changes in the existing chemical engineering education process. These changes should be based upon an assessment of the capacity of the following in order to meet the current challenges, namely: syllabus/subjects; teaching courseware; teaching methodology; and learning materials:

As with other countries, the faculty in Pakistan also face the problem of what subjects to omit or include within the basic four-year engineering degree. Whatever the outcome, the country expects that the degree programme developed provides engineers with a balanced education in the technical, as well as non-technical disciplines of engineering, in order to broaden their skills and knowledge, and increase their job prospects by better meeting industrial requirements.

Globally, the field of chemical engineering has now expanded into areas like reducing traditional products, with shifts to the pharmaceutical industry, sustainable development, renewable energy resources, microelectronic industry, etc. Developments in this field in Pakistan will naturally take time. Early initiatives by chemical institutions to develop human resources in the above fields will help the industry to meet swiftly national obligations.

Pakistan expects universities to implement modern equipment and update applied courses according to modern industrial technology and requirements. The professional environment has changed drastically after large investments by multinational companies in Pakistan. Most multinational companies provide their own technical, theoretical and practical training to fresh graduates. They expect universities to develop students' personal skills. This implies that the general applicable part of the university education can be summarised in the first two years, when mostly common courses for all engineering fields are taught.

The next two years of a Bachelor programme entail a closer collaboration between industry and university, which need to be established in order to specifically describe required courses. Although it is not possible to reprogram the university curriculum for professional courses more specifically to meet all the demands of various industries, the establishment of closer interdisciplinary activities among different fields seems to be necessary.

Because chemical engineering is concerned with large scale plants, it is important that chemical engineering candidates have an appreciation of the scale and complexity of modern plants before they graduate. This can only be imparted through a training period in industry. In their sixth semester, students undertake practical work in industry, which normally covers two months. In this period, students have the opportunity to review and digest academic content, to apply this knowledge to real engineering situations and to obtain some understanding of how industry works. This maturing enables a student to obtain the maximum benefit from the final period of academic study. During the practical work period in industry, students produce a report on their training. They must also give a presentation about their work and submit a report.

The energy sector is one area where the chemical engineering department is expected to play vital role for to develop indigenous resources. The economic development of any society is crucially dependent on energy. Pakistan's remaining recoverable reserves of crude oil is estimated at 310 million barrels, which indicates that there is no prospect for Pakistan to reach self sufficiency in oil [8]. It has 26.8 trillion cubic feet (Tcf) of proven gas reserves, and currently produces around 0.8 Tcf of natural gas per year [8]. At a time when the energy demand is surging in Pakistan, coal is likely to play an important role as a primary and an inexpensive source for power generation. The estimated coal reserves in Pakistan are

about 185 billion tonnes, with local coal production estimated at 3,214.4 tonnes, out of which merely 1% is utilised for electric power generation [8].

Biochemical engineering is another area where chemical engineering education is expected to play a vital role for developing the pharmaceutical and allied sector. In Pakistan, almost 95% of the basic raw materials used for manufacturing of medicines are imported. The pharmaceutical industry in Pakistan in still at an early stage, with few firms producing the raw materials locally. Involving chemical engineers who specialise in biochemical engineering will bring the pharmaceutical industry into focus. The pharmaceutical industry can play a pivotal role in the economic development of Pakistan by ensuring better health for people through the supply of cheaper quality drugs. Besides the pharmaceutical industry, chemical engineers who specialise in biochemical engineering are expected to occupy vital role in fields like the design of biological waste treatment systems, the production of bio-fuels, the separation/synthesis of cells in bioreactors, and food processing and preservation. Research in the health sector, in collaboration with medical science and chemical engineering, can advance major progress in the health sector in Pakistan.

HEC GUIDELINES

The HEC has set certain conditions for universities and institutions offering the chemical engineering programme. These conditions include the following factors:

- The BSc curriculum should be of four academic years' duration.
- The minimum number of teaching weeks per academic year should be 24.
- The minimum number of contact hours for theory, practical and tutorial should be determined so as to make a total of at least 124 credit hours. For this purpose, one theory hour should be one credit hour, two to three practical hours should be one credit hour, while a tutorial has zero credit hours.
- Practical/laboratory work should comprise at least one third of the total credit hours.
- All universities/institutions should make arrangements for the practical training of their students at industrial organisations during summer vacations, especially in students' third year.
- Students should be evaluated during the session through tests, quizzes and assignments, followed by a comprehensive examination at the end of the year.
- A minimum of 75% attendance should be made compulsory for all year levels [6].

PROFESSIONAL RECOGNITION

A primary function of chemical engineering education is the preparation of students to fulfil their professional role as chemical engineers. This is achieved initially through an undergraduate degree programme. The recognition of the chemical engineering degree, through the accreditation processes of the Pakistan Engineering Council (PEC), is an important element in the continued success of the degree programme in attracting students of a very high quality. The PEC is a statutory body constituted under the PEC Act No. V of 1976 enacted by the Parliament. The PEC's statutory functions relate to the recognition of engineering qualifications for the purpose of registering professional engineers, and consulting engineers and the promotion of engineering education, safeguarding the interests of its members and fostering high professional standards in Pakistan. In October 2004, the PEC registered 5,153 chemical engineers, out of which 83 were female [7].

THE ROLE OF FACULTY

At present, almost all faculty use traditional classroom teaching methods; some subjects are taught in combination with laboratory experiments. Written examination, normally of 3 hours duration, for each subject are taken at the end of the semester for assessment.

Frequently at the majority of engineering institutions, new faculty members are taken into service directly from school. Most instructors are devoid of industrial experience, yet teach chemical engineering core subjects in the best educational institutions of the country. They are unable to realise the needs of industry and to perceive future trends. This is one of the major reasons for slow progress in developing new techniques and improved procedures. An instructor with significant industrial experience will have no problem seeing and adhering to new tends and expectation. Until now, low salaries at educational institution have kept experienced engineers away from engaging in educational instruction. To re-engineer the current education process and bring experienced faculty to educational institutions, it is vital to make salary packages compatible with the market. Institutions must change their recruiting pattern.

The steps required to encourage and help faculty to improve their teaching effectiveness include the following:

- Provide funds for travel to education-related workshops and conferences;
- Give teaching allowance on the basis of proof of effective teaching;
- Purchase good books on teaching for libraries;
- Establish and support an Engineering Centre for Teaching and Learning;
- Establish an Engineering Teaching Fellows programme in which faculty members in their first few years of teaching receive observation and individual consulting by teaching centre personnel, and regularly attend seminars or learning communities devoted to good teaching and educational scholarship;
- Devote some of the regular departmental or college seminars to topics related to teaching;
- Require faculty members seeking promotion and/or tenure to prepare a teaching portfolio containing evidence of teaching effectiveness and educational scholarship;
- Recognise teaching achievements at faculty and advisory board meetings, and in departmental and university publicity releases;
- Foster publication in engineering education research journals.

In order to improve the present conditions, the Government recently began different scholarship programmes for instructors/researchers to complete their research work at western universities, but most educational institutions are already short of faculty, and it is not possible to spare them for four to five years. Further, most of the work instructor/ researcher carried out at western universities failed to amass

research between institutions and industry. Joint programmes between key engineering institutions, the PEC and the Federation of Chamber of Commerce and Industry Pakistan (FCCP) to train new faculty in industry could be helpful in bringing educational institutions closer to local industry.

WOMEN IN CHEMICAL ENGINEERING

The enrolment of women in chemical engineering programmes in Pakistan is very low, despite their equal demographic percentage. As of October 2004, the PEC had 5,153 registered chemical engineers, out of which only 83 were female, that is only 0.016% of registered chemical engineers are female [7]. In Pakistan, the field of chemical engineering has been dominated by men. The masculinity surrounding the image of engineering over the years has remained very powerful and, in turn, reinforced the belief that the field is unsuitable for females. A structure and culture has been developed around the lifestyles and interests of men, and represents a significant barrier to female participation. Gender disparity in education in Pakistan seems to have also been influenced by cultural practices. Pakistani men are still very traditional and chauvinistic. Although women are known to handle tough and strenuous jobs in Pakistan, there has been a belief that a man must earn salary and a woman must remain as a housewife, resulting in women choosing or being made to choose less rewarding jobs, and study courses predominantly known to be female areas of study. This situation is due to tradition and the chauvinism of men, lack of counselling and information on engineering, discouragement from people, among others.

The rate of feminisation among chemical engineering lecturers is even lower than the rate of feminisation among students. At present, there is no female faculty employed by the Chemical Engineering Department at the DCET. The situation is not significantly different at other Pakistani institutions. In essence, this means that there are very few, if any, role models for female engineering students. Usually, men, in one way or another, scare females away from the field. Men and the public at large need to be educated through the media about gender and the acceptance of women as equals. The Government must offer incentives to women who want to study chemical engineering. Successful women chemical engineers must act as role models. Engineering schools should apply increased effort to provide women with the incentive to pursue careers in engineering, to improve their participation in engineering education, and to ensure that the environment is conducive to their staying. More and more women engineering lecturers should be invited to teach engineering at universities. This would eliminate some problems faced by girls. Career counselling must start early in students' school life and gender disparity must not be so pronounced in so far as choices and preferences for subjects are concerned.

THE CHEMICAL INDUSTRY OF PAKISTAN AND CHEMICAL FACULTY

The liaison between industry and educational institutions is mandatory for the formulation of an effective curriculum. The chemical and petroleum industries have maintained a close and supportive relationship with chemical engineering faculty in the early period. This relationship was generally recognised as mutually beneficial and unique within engineering. Unfortunately, faculty let this relationship slip over time. This has been proved once again during the current revision of the curriculum when the National Curriculum Committee on Chemical Engineering sent a feedback questionnaire to various offices of the FCCP, but received no response.

Several studies have been carried out regarding the importance of the relationship between universities and industries. Upgrading training laboratories at universities with modern state-of-the-art advanced equipment, with the assistance of local industries, will not only attract competitive students to the engineering fields, but also trains them for modern industries. The method of evaluation of engineers should be based on their productivity, skills and progress in job environments; this should be monitored closely, regardless of their GPA or even their university degree.

CONCLUSION

Some of the new frontiers to which chemical engineers contribute increasingly in Pakistan are coal technology, polymer engineering, biochemical engineering, advanced materials energy resources and their processing, and environmental protection and remediation. Chemical engineers are embracing new trends while continuing their strong contributions in more traditional areas. A pedagogical shift is needed to improve programmes by placing students closer to the centre of the whole learning process.

The Government and engineering schools should apply increased effort to providing women with the incentive to pursue careers in chemical engineering, to improving their participation in engineering education, and to ensuring that the environment is conducive for girls to pursue careers in chemical engineering. Women engineering lecturers should be invited to teach engineering at universities to ease problems faced by girls. Also, joint programmes between chemical engineering institutions, the PEC and the FCCP to train new faculty in industry is likely to narrow the present gap between industry and educational institutions.

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Table 1: DCET chemical engineering curriculum comparison on the basis of basic, core, allied and specialised courses.

	1970 Curriculum Subjects (Duration Hours)	2004 Curriculum Subjects (Credit Hours)	Curriculum Proposed by the HEC Subjects (Credit Hours)	Curriculum suggested by the author Subjects (Credit Hours)
Basic Courses	1. Mathematics-I (3) 2. Mathematics-II (3) 3. Mathematics-III (6) 4. Mathematics-IV (3) 5. Chemistry-I (4) 6. Chemistry-II (Physical) (4) 7. Chemistry-III (4) 8. Applied Physics (4) 9. Mechanics-I (4) 10. Mechanics-II (4) 11. Strength of Material (3) 12. Workshop Practice (3) 13. Humanities (3) 14. Humanities (3) *Credit Hours (51)*	1. Applied Calculus (4) 2. Linear Algebra and Analytical Geometry (4) 3. Workshop Practice (2) 4. Pakistan Studies/Islamic Studies (4) 5. Differential Equations and Fourier series (4) 6. Introduction to Computers and C++ Programming (5) 7. Complex Variable and Laplace Transforms (4) 8. Numerical Analysis and Computer Applications (5) 9. English (4) 10. Chemistry-I (5) 11. Chemistry-II (5) 12. Engineering Mechanics (5) *Credit Hours (51)*	1. Engineering Mathematics-I (3) 2. Engineering Mathematics-II (3) 3. Chemical Engineering Mathematics (Numerical Analysis) (3) 4. Chemistry-I (3) 5. Chemistry-II (3) 6. Engineering Mechanics (3) 7. Physics (3) 8. Computer Programming (3) 9. Pakistan Studies and Islamic Studies (3) *Credit Hours (27)*	1. Applied Calculus (4) 2. Differential Equations (4) 3. Numerical Analysis (4) 4. Application of Computer in Chemical Engineering (5) 5. General Chemistry (5) 6. Physical Chemistry (5) 7. Biochemistry (5) 8. Physics (5) 9. Engineering Mechanics (5) 10. Pakistan Studies/Islamic Studies (4) 11. Workshop Practice (2) 12. Personnel skills (4) 13. English (4) *Credit Hours (52)*
Allied Courses	1. Engineering Graphics-I (4) 2. Engineering Graphics-II (5) 3. Electrical Engineering (4) 4. Properties of Matter (4) 5. Graphic Design (4) 6. Industrial Engineering (3) *Credit Hours (24)*	1. Engineering Drawing (5) 2. Basic Electrical Technology (5) 3. Maintenance Engineering (4) 4. Material Science (4) 5. Quality Control (5) *Credit Hours (23)*	1. Engineering Drawing and Graphics (3) 2. Material Engineering (3) 3. Communication Skills (3) 4. Industrial Management (3) 5. Electrical/Mechanical Technology (3) 6. Maintenance Engineering (3) *Credit Hours (18)*	1. Engineering Graphics (5) 2. Quality control (4) 3. Electrical Technology (5)] 4. Process Safety and Loss Prevention (4) 5. Industrial Management (4) *Credit Hours (22)*
Core Courses	1. Industrial Stoichiometry-I (3) 2. Industrial Chemistry-1 (4) 3. Industrial Chemistry-II (Organics) (4) 4. Unit Operation-I (4)	1. Basic Chemical Engineering (4) 2. Chemical Process Technology-I (5) 3. Chemical Process Technology II (5) 4. Unit Process (5) 5. Chemical Engineering Thermodynamics-I (5)	1. Chemical Process Technology-I (4) 2. Chemical Process Technology-II (4) 3. Chemical Process Principles (4) 4. Chemical Process Principles-II (4)	1. Basic Chemical Engineering (5) 2. Chemical Process Calculations-I (4) 3. Chemical Process Calculations-II (4) 4. Chemical Engineering Thermodynamics (5) 5. Unit Operation-I (Particulate Technology) (5)

	5. Chemical Engineering-1 (Stoichiometry-I) (3) 6. Chemical Engineering-II (Stoichiometry-II)(3) 7. Chemical Engineering-III (4) 8. Chemical Engineering-IV (4) 9. Chemical Engineering-V (Thermodynamics) (3) 10. Chemical Engineering-VI (Unit operation –I) (4) 11. Chemical Engineering-VII (Unit operation –II) (4) 12. Administration and Production Engineering (3) *Credit Hours (43)*	6. Chemical Engineering Thermodynamics –II (5) 7. Industrial Stoichiometry-I (4) 8. Industrial Stoichiometry-II (4) 9. Fuel and Combustion (5) 10. Fluid Mechanics (5) 11. Unit Operation-I (5) 12. Unit Operations –II (5) 13. Unit Operation-III (5) 14. Heat Transfer (5) 15. Chemical Engineering Plant Design and Economics (4) 16. Transport Phenomena (4) 17. Instrumentation and Control (5) 18. Environmental Engineering (5) 19. Industrial Management (4) 20. Chemical Engineering Kinetics (4) *Credit Hours (93)*	5. Chemical Engineering Thermodynamics (4) 6. Chemical Reaction Engineering (4) 7. Fuel and Combustion (4) 8. Transport phenomenon (4) 9. Particulate Technology (4) 10. Fluid Flow (4) 11. Heat Transfer (5) 12. Mass Transfer (5) 13. Simultaneous Heat and Mass transfer (4) 14. Chemical Plant Design (5) 15. Process Engineering Economics (4) 16. Process Instrumental and Control (4) 17. Chemical Plant Design Project (5) 18. Environmental Engineering (4) *Credit Hours (76)*	6. UOP-II (Fluid Flow) (5) 7. Unit Operation-III (Heat Transfer) (5) 8. Unit Operation-IV (Mass transfer) (5) 9. Unit Operation-V (separation Process) (5) 10. Unit Process (5) 11. Chemical Process Technology (5) 12. Chemical Kinetics (4) 13. Sustainable Energy (4) 14. Transport Phenomena (4) 15. Environmental Engineering (5) 16. Process Engineering Economics (2) 17. Chemical Engineering Plant Design (2) 18. Developments in Chemical Engineering (2) 19. Petroleum Refinery Technology (5) 20. Process Dynamics and Control (4) *Credit Hours (85)*
Specialised Courses	1. Petroleum Technology (4) 2. Petrochemicals (4) 3. Fuel science (4) 4. Chemical Engineering-VIII Design (6) *Credit Hours (18)*	1. Petroleum Refinery Engineering (5) 2. Petrochemicals (5) 3. Nuclear Engineering (4) 4. Biochemical Engineering (5) 5. Thesis Project (4) *Credit Hours (23)*	At least one subject (3 hours) should be selected from the following 1. Petroleum Refinery Engineering 2. Petrochemicals 3. Nuclear Engineering 4. Biochemical Engineering 5. Polymer Engineering 6. Minerals Processing Technology 7. Computer Aided Design 8. Process Analysis and Optimisation *Credit Hours (03)*	(At least four courses should be selected, the project is compulsory) 1. Fuel and Combustion (5) 2. Biochemical Engineering (5) 3. Petrochemical Engineering (5) 4. Polymer Engineering 5. Introduction to Chemical Engineering Research (4) 6. Coal Technology (5) 7. Sustainable Development and Appropriate Technology (4) 8. Project (6) *Credit Hours (20)*
Total Credit Hours	136	190	124	182