

## Chemical Engineering Education Holistic Assessment and Resuscitating Issues

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**Abstract**—After few years the Chemical Engineering Education in the country will celebrate the Century of existence. The global chemical enterprise is going to expand invariably and its impact and requirement will decide the future of Chemical Engineering Education. At this important juncture, by means of comprehensive analysis with respect to industrial scenario and job potential vis-à-vis education facilities available and challenges faced by existing Chemical Engineering Education and using them as course of action, the main purpose of this study is to improve Chemical engineering competence; to commemorate its distinction and enthuse the next generation; and to initiate debate among the stake holders by channeling informed thinking including SWOC analysis of chemical engineering education. The present paper is a humble attempt in the direction to fetch up the issues and concerns of chemical engineering education and future development in the country.

**Key Words**—SWOC analysis, improve the competence, issues and concerns for future development, chemical engineering education

### I. INTRODUCTION

Engineers accurately plan and erect much of the human surroundings. It has been said that the history of civilization is the history of engineering. The human civilization has changed from agricultural society to cybernetic age where knowledge is considered as capital and knowledge industry is considered as the most demanding industry in the world [1]. But strangely enough this societal change has little impact on engineering education. Consequently the need for monitoring and evaluation of engineering education came in existence as various accreditation authorities. In India, engineering education is regulated by All India Council for Technical Education, AICTE and under that framework close look of our traditional Engineering Education expose that it is highly sequential, a pyramid of prerequisites, highly specialized within majors with little flexibility (few free electives) and it stress scientific analysis rather than design and synthesis while having too much technical content at the expense of a broader, liberal education. The figure 1 depicts it in general for any degree level engineering program [7].

Year 1	Year 2		Year 3	Year 4
Functional Core of Engineering Up Front			In-Depth Disciplinary Engineering	
Hands-on Lab, Design, System Methodologies				
Integrated Humanities / Social Sciences				

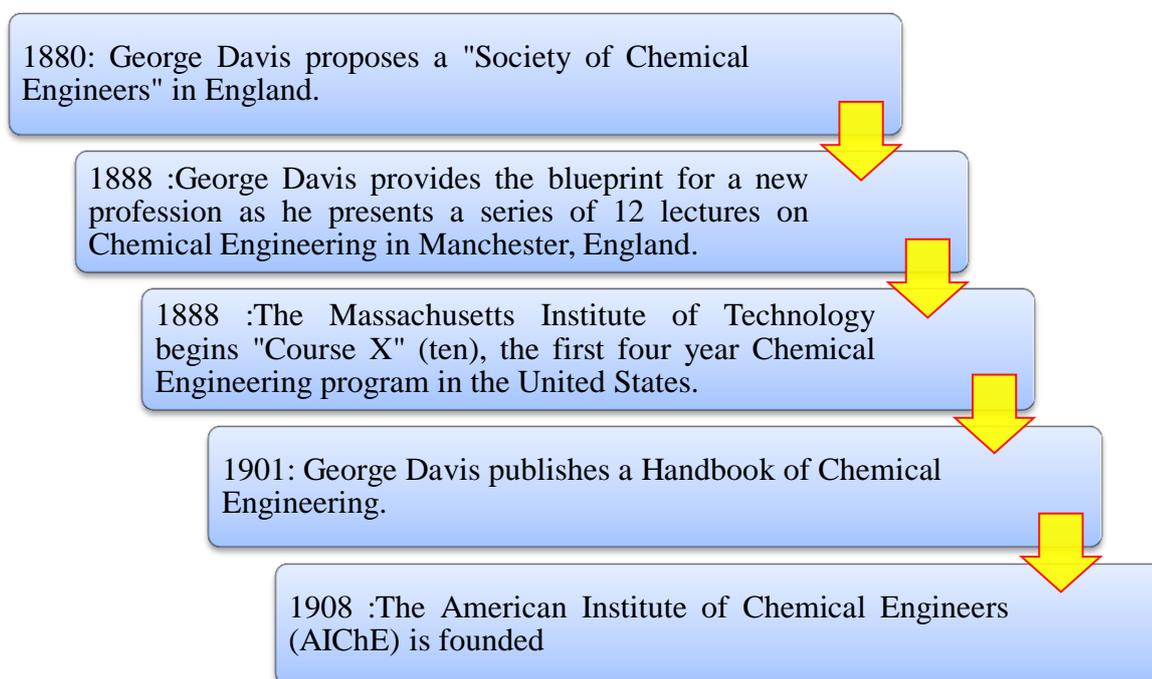
*Figure 1. Schematic Presentation of Engineering Course*

## 1.1 Chemical Engineering:

Xi Jinping, the President of the People's Republic of China, Mukesh Ambani, CEO, Reliance Industry, Harsha Bhogle, The famous Indian Cricket commentator, Najma Akhtar, a British singer, Elizabeth Anne Holmes, CEO of Theranos, a blood test company, Nitin Nohria, Dean of Harvard Business School and Dr. Gharda, Gharda Chemicals need no introduction and are well known personalities. Common among them all is that each of them is Chemical Engineer by education. Chemical engineering deals with chemicals throughout process and energy use either to create or convert them and is mainly concerned with combined application of pure sciences and life sciences jointly with mathematics and economics. Many products are impacted by chemical engineers. The Chemical industry is critical for the economic development of any country, providing products and enabling technical solutions in virtually all sectors of the economy [8]. Presently the world's one of the high paying careers is in Chemical Engineering.

## II. HISTORICAL ASSEMBLE OF CHEMICAL ENGINEERING

Tough, heavy, stinky, and dirty are the words that compose the popular image of Chemical engineering profession [3]. The cultural image of engineering is perceived as a masculine profession. Many of Chemical Engineering graduates have not been pursuing conventional careers in industry, and are moving to different disciplines. The global chemical enterprise is going to expand invariably and its impact and requirement will decide the future of Chemical Engineering Education. The current status and past efforts will be central to the future of Chemical engineering. Reference [10] is modified to the following figure 2, which quickly recapitulates the initial progress and evolving of chemical engineering at International level.



*Figure 2. Initial Milestones of Chemical Engineering Development*

Initial curriculum consisted of separate courses in chemistry and conventional engineering and gradually it was developed by passing through the filters of time. Reference [11] is modified to the following table 1, which promptly summarizes the focus of chemical engineering education.

*Table 1. Summary of focus subjects per decade*

Period	Major Subjects of Study
1905-1915	Industrial Chemistry, Metallurgy, Electrochemistry, Steam and Gas Technology, Chemical Manufacturing, Hydraulics, Surveying
1915-1925	Unit Operations, Descriptive Geometry
1925-1935	Materials and Energy Balances, Reduction in Mechanics, Machine Design
1935-1945	Chemical Engineering Thermodynamics, Process Measurement and Control, More Physical Chemistry, Unit Operations, Foreign Languages, Mechanics
1945-1955	Applied Kinetics, Reactor Design, Process Design, Report Writing, Organic Chemistry, Metallurgy, Machine Design, Steam and Gas Technology
1955-1965	Transport Phenomena, Physical Measurement, Differential Equation, Computer Programming, Process Engineering, Less Unit Operations, Less Material and Energy Balances
1965-2005	Minor Changes
2005-2015	Molecular Engineering, Biology, Product Design, System Analysis

### III. CHEMICAL INDUSTRIES SCENARIO

Global industry size was around USD 3 trillion excluding pharmaceuticals in 2012. European Union and US are biggest export and import market. Petrochemical production capacity is concentrated around Asia followed by North America [8]. Indian chemical industry ranks 12 in the world by volume in the production of chemicals. Gujarat, the hub of chemical industry in India, accounts for 62 % of India's petrochemical production, 53% of other chemicals production and 18% of India's chemical exports. The chemical industry in Gujarat is a significant component of State's economy with revenues at Rs. 4,50,000 crore in 2012. Gujarat's chemical & petrochemicals industry comprises of about 500 large and medium scale industrial units, about 16,000 of small scale industrial units and other factory units and provides 16% of employment. Government support, world class infrastructure, strategic location, availability of skilled workforce and raw material makes Gujarat a preferred location for chemical plants. About 6600 chemicals & petrochemicals are produced in the state [9].

### IV. CHEMICAL ENGINEERING EDUCATION

A career in chemical engineering can be started as a technician. Vocational education directly develops procedural knowledge to cover all aspects of the trade. A diploma is a document given and mainly subject centric. A Bachelor's degree is acquired after completing the predetermined course work of the University at a college level and developed analytical skill passing through that study. Dr Hira Lal Roy was the great visionary and pioneer of chemical engineering education in India. The digging of history reveals that in 1921 College of Engineering And Technology, Jadavpur started Chemical Engineering course in India. While in 1963, Faculty of Technology and Engineering, M.S. University of Baroda, Vadodara offered first graduate level course i.e. BE Chemical and in 1968, DDIT Nadiad introduced

Diploma in Chemical Engineering in the State of Gujarat. Table 2 summarizes the facilities available for chemical engineering education at present in the State of Gujarat. The Gujarat Technological University which is the largest affiliating technical University of the State of Gujarat for Degree as well as Diploma Chemical Engineering and Gujarat Council of Vocational Education / National Council of Vocational Education for certificate level syllabus as made available in their respective websites are referred for subject and content comparisons for chemical engineering education.

**Table 2. Available facilities of Chemical Engineering Education in Gujarat**

Level of Course	Annual Seats Available	No of subjects covered /course	Duration	Findings
Certificate	1184	18	2 Years	13 Subjects* are common with different content.
Diploma	1480	32	3 Years	
Degree	2190	49	4 Years	
Masters	192	12	2 Years	

\*List of 13 Common Subjects per Semester taught at different levels

Sr.	Name of Common Subject	Certificate	Diploma	Degree
1	Mathematics-I	1	1	1
2	Physics	1	1	1
3	Engineering Drawing	1	1	1
4	Fluid Flow Operation	1 & 3	3	3
5	Chemical Process Industries	2 & 3	3	3
6	Physical And Inorganic Chemistry	1	1	4
7	Chemical Engineering Thermodynamics	5	4 & 5	4
8	Process Heat Transfer	2&3	4	4
9	Mass Transfer Operation	4	4 & 5	5 & 6
10	Mechanical Operation	4	3	5
11	Utilities And Instrumentation In Chemical Plant	3	5	5
12	Pollution Control & Effluent Treatment	4	4	6
13	Petroleum Refining & Petrochemicals	4	5	8

## V. EMPLOYMENT SCENARIO

Reference [4] identified four relevant engineering career routes: (1) technical (2) managerial (3) project to project, and (4) technical transfer. This is very well applicable to chemical engineers also. The spectrum of position and emoluments are variable and usually entry-level salaries depend on specialization, grade of education, responsibility as well as accountability associated, and the geographic location, size, and type of industry of the employer. The campus recruitment data of different institutes engaged in chemical engineering education is found to be as per table 3. Further tracer study and interaction with working chemical engineers revealed that during first 5-9 years 60 % were happy with their job, the satisfaction % increased to about 80 % after 10-19 years of service and reached to 100 % after 20 years or more service as a chemical engineer.

Table 3. Entry level Salary spectra for chemical engineers

Sr	Level of Course	Salary / Month, Rs.	Average across the State
1	Certificate	7000-11000	8000
2	Diploma	13500-21000	15000
3	Degree	35000-60000	45000
4	Masters	40000-60000	52000

## VI. APPREHENSION

As narrated above for Chemical Engineering, promising and developing industrial sector, and huge investments with growing job opportunity at reasonable competitive salary and satisfaction thereof is available in plenty in the State of Gujarat. Simultaneously there exists persistent boost in number of eligible pass outs from school education for diverse course of Chemical Engineering. With this backdrop, the trends for utilization of potential of chemical engineering education in last four years are disgusting. The increase in facility and seats remaining vacant are rising concurrently. The efforts of offering special subject focus like Nano, Polymer, Petrochemical, and Computer Aided design etc. at Masters Level could not improve the anticipated inflow of chemical engineering graduates. The exhibits of lackadaisical attitude by the students for Chemical Engineering Education are reflected in figure 2.

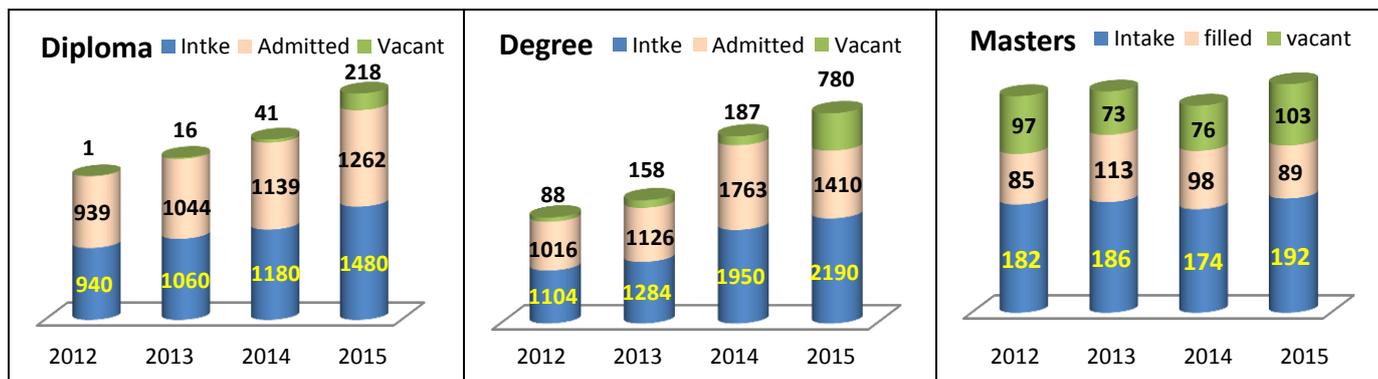


Figure 2. Concurrent increase in Intake and Vacant seats from year 2012 to 2015.

## VII. SWOC ANALYSIS OF CHEMICAL ENGINEERING EDUCATION[6]

Strengths	Weakness
have the broad mathematics and science background to take the leadership position the transport background the design background the ability to lead and contribute to interdisciplinary teams the ability to adapt	need to establish themselves as leader in this area (unlike environmental/ bio/ Nano) reshape their curriculum to strategically position themselves for innovation and change allow flexibility and change look at design in new ways (e.g, factories on a chip, nano medical delivery systems for customized medicine, etc) reestablish dominance in innovation

Opportunities	Challenges
Can become first to “molecular engineer and molecular design” maintain their broad base..just broaden! again be at the cutting edge not following or just one of the crowd drive commercial activities, while developing designs, processes, and strategies for sustainable and environmentally sound products	Paralysis by analysis Unwillingness to change Lack of timely, relevant and actionable acceptance by authority Direction is not clear Other Disciplines move more quickly and Chemical Engineers are again following Disciplinary arrogance

### 7.1 The Analysis

At present Chemical Engineering has to face two difficult challenges. The first is to overcome low student’s interest. The second challenge is to retain the best and brightest professionals [5]. In the circumstances when traditional petroleum and fine chemicals is a mature industry and activities going off shore, the students are to be equipped to work in Biotechnology, Biomedical devices, Nano technology and Advanced materials. Thus Chemical Engineering educators are challenged to devise liberal education for students who can apply Engineering principles and modes in the world of the future. There should be more emphasis on information rich science (e.g. biology), humanities and synthesis rather than technical material and analysis. The designing and developing curricula to promote chemical engineering education should use the following guiding criteria [7].

Career Paths	Skill Set	Student’s Interest
<ul style="list-style-type: none"> <li>• Sustainable development: avoiding environmental harm; energy / materials efficiency</li> <li>• Life cycle / infrastructure creation and renewal</li> <li>• Micro / nanotechnology / microelectromechanical systems</li> <li>• Mega systems</li> <li>• Smart systems</li> <li>• Multimedia and computer-communications</li> <li>• Living systems engineering</li> <li>• Process quality / control</li> <li>• Management of technological innovation</li> <li>• Enterprise transformation</li> </ul>	<ul style="list-style-type: none"> <li>• Systems integration; synthesis</li> <li>• Engineering science; analysis</li> <li>• Problem formulation as well as problem solving</li> <li>• Engineering design</li> <li>• Ability to realize products</li> <li>• Facility with intelligent technology to enhance creative opportunity</li> <li>• Ability to manage complexity and uncertainty</li> <li>• Teamwork; sensitivity in interpersonal relationships</li> <li>• Language and multi-cultural understanding</li> <li>• Ability to advocate and influence</li> <li>• Entrepreneurship; management skills; decision making</li> <li>• Knowledge integration, education and mentoring</li> </ul>	<ul style="list-style-type: none"> <li>• See the world whole; sense the coupling among seemingly disparate fields of endeavor</li> <li>• Perform synthesis in balance with analysis</li> <li>• Build connections between the world of learning and the world beyond</li> <li>• Innovate</li> </ul>

## 7.2 Issues for further deliberation

- Increase girl enrolment.
- Assessment of faculty with respect to their tutoring, research, and administrative work load and possibilities of faculty “burnout”?
- Ensure the priority of the Chemical Engineering within the Professional Education.
- Adapt learning paradigms like shifting focus from “teaching” to “designing” learning experiences.
- Restructure research activities with respect to sponsored research and team research replacing single investigator.
- Form more strategic alliances with the top engineering institutions / key industry / national laboratories.

## VIII. CONCLUSION

It is important to realize how rapidly windows of opportunity open and close. The Chemical Engineering Education enjoys an outstanding faculty, good infrastructural facilities, computing environments along with extraordinary opportunity! But, to take advantage of this chance, Chemical Engineering has to have to change its basic paradigms: For teaching, for service, for financing its activities, for its intellectual organization and for achieving leadership. These would come when the change will become its “strategic intent”! In turn these changes necessitate the commitment from the top, consistency and persistence, a clear Strategy involving available best people working closely as teams. The policy makers and the concerned management should make the strengths of chemical engineering education productive and its weakness irrelevant.

## REFERENCES

- [1] D. Mukhopdhyaya, “Education and Empowerment of Women: an Issue for India” in Women Education and Development-Perspectives, Issues and Concerns. Shipr Publications, Delhi, pp.183-205, 2009.
- [2] C. Leao, C. Pimental and C. Prodrigues, “Being Female Industrial Engineer: A Portuguese Case”, in Women Education and Development-Perspectives, Issues and Concerns. Shipr Publications, Delhi, pp.113-135, 2009.
- [3] A.Powell, B. Bagihole, A. Dainty and R. Neale, “Does the engineering culture in UK Higher Education advance women’s careers?” in Equal Opportunities International, 23 (7/8), pp. 21-38. 2004.
- [4] M. Ismail, “Men and women engineers in large industrial organization: interpretation of career progression based on subjective-career experience” in Women in Management Review, 18(1/2), pp 60-67, 2003.
- [5] S. Newman, “Where have all the engineers gone?” in Education and Training, 40(9), pp. 398-404, 1998.
- [6] Al Sacco, Jr. and George A. Snell, “Chemical Engineering: the next twenty years” Northeastern University. Boston, MA 02115 Retrieved from: <https://www.wpi.edu/News/Conf/ASEE/PPTs/2-d-sacco.ppt>
- [7] Engineering Education. for the 21<sup>st</sup> Century. Retrieved from : [milproj. dc. .edu / publications /engin.../UM%20Eng%20Future.ppt](http://milproj.dc.edu/publications/engin.../UM%20Eng%20Future.ppt)
- [8] “Knowledge cum Strategy Paper” Theme: The Potential of Specialty Chemicals Industry in Gujarat, Gujarat Specialty Chemicals-Conclave-January 2013, Retrieved from : [http:// www.ficci.com /spdocument/20215/Gujarat-Specilty-Chemicals-Conclave-2013-Background-Paper-Final.pdf](http://www.ficci.com/spdocument/20215/Gujarat-Specilty-Chemicals-Conclave-2013-Background-Paper-Final.pdf)
- [9] VIBRANT GUJARAT MANUFACTURING: SECTOR PROFILE Retrieved from: [http:// www.vibrantgujarat.com /images /pdf/manufacturing-sector-profile.pdf](http://www.vibrantgujarat.com/images/pdf/manufacturing-sector-profile.pdf)
- [10] History of Chemical Engineering Retrieved from : [www:pafko.com/history/h\\_time.html](http://www.pafko.com/history/h_time.html) Copyright 2000, Wayne Pafko
- [11] Chemical Engineering Curriculum Retrieved from : Esin Gulari, Division Director Chemical and Transport Systems, NSF WPI 2004.

