

THE ROLE OF INDUSTRY IN GUIDING THE PEDAGOGY OF CHEMICAL ENGINEERING DESIGN

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Today's chemical engineering graduates work in a diverse range of industries many that are operating at the innovation, technological and business frontiers. Educating graduates with modern, relevant, design skills requires careful curriculum development and critically should combine input and feedback from industry.

Curriculum development is explored based on the Henley report (2006). This report identifies at least five broad areas of changes which it is felt will have a major impact on engineering:

1. Providing customer solutions, with the need to being focused on all of the customer's requirements and in doing whatever is necessary to solve them.
2. Increasing complexity of the technological domain leading to manufacturing incorporating numerous different technologies across different disciplines into a single product.
3. Globalization and recognition that even at the highest skill levels engineers are subject to international market competition.
4. Sustainability, emphasizing ecoefficiency, corporate social responsibility and operating these principles within the markets.
5. Innovation and creativity as forces which will differentiate products in an increasingly competitive marketplace.

A review of the current status of chemical engineering practice and education is presented alongside the drivers for educational change. Using questionnaires, opinions are compiled from students, lecturers and industry professionals evaluating the design teaching environment including the appropriate mix of defining and enabling skills.

The information and data collected provides a valuable insight into the development of chemical engineering design teaching. A future curriculum development scenario is presented for the enhanced teaching of plant & process design.

Keywords; design, education, curriculum, industry, questionnaire.

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1. INTRODUCTION

Chemical engineers are responsible for the conception, design and operation of processes for the production, transformation and transportation of materials. Design can be defined as the creative process whereby we generate ideas and then translate them into equipment and processes for producing new materials or for upgrading the value of existing materials. The importance of design, R&D and production activities for engineering graduates can be seen from figure 1. It is also evident from figure 1., that engineering graduates are assigned across a very wide spread of duties. This is principally due to the skill of chemical engineers as technology integrators with an ability to provide scientific/engineering solutions to range of customer problems.

The nature and type of design activities that engineers are engaged in is not fixed. Increasing worldwide competition is mandating major changes in the way plants are to be designed. As a result, we are witnessing dramatic new developments that go beyond “traditional” chemical engineering. New equipment technologies and novel techniques are emerging that potentially could transform our concept of chemical plants and process engineering, leading to compact, safe, energy efficient, environment-friendly, flexible processes and plants. (Pamuntjak, 2006). New commercial opportunities in biotechnology, pharmaceuticals, electronic device fabrication, sustainable technologies and environmental engineering are increasingly important sectors for chemical engineering input.

The question arises that with all of this change, is academia providing appropriate teaching to meet the expectations of graduate employers. According to (Shinksey, 2002) the industrial-academic gap in the specific area of process control has been a persistent impediment in design education. Shinksey states that the papers on process control presented at the American Automatic Control Conference in the year 2000 showed little if any improvement in the direction of industrial practice from the 1965 version of its predecessor, the Joint Automatic Control Conference. “No progress in 35 years”!

2. THE CURRENT STATUS OF ENGINEERING EDUCATION

Typical design activities undertaken by students include; process selection and design, safety reviews, development of piping and instrumentation diagrams (P&IDs), development of plant layout, estimation of operating costs, and equipment design.

To be able to carry out design activities, the chemical engineer requires a complete and quantitative understanding of both the engineering and scientific principles underlying the technologies employed. The Chemical engineering courses are built on a foundation in the sciences of chemistry, physics and increasingly nowadays biology, engineering knowledge is

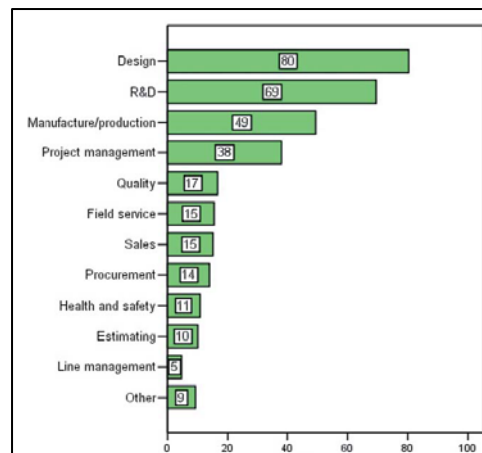


Figure 1. Graduate roles within two years of recruitment. (Royal Academy of Engineering, 2006)

developed through the study of mathematics, material and energy balances, thermodynamics, fluid mechanics, energy and mass transfer, separations technologies, chemical reaction kinetics and reactor design, plant and process design..

Education as currently practiced involves the “batch” processing of students, with the obvious desirable attribute of creating uniform patterns of thinking and knowledge in future graduates. Batch processing is necessary to facilitate the task of educating large numbers of functionally equivalent units (4 year degree cycle).

The assumption that batch processing is still the only way to produce educated graduates has been rendered obsolete by advances in information communication technology (ICT) that make personalised education technically possible. (Allenby, 2009).

Current educational practice involves a wide range of activities; classroom teaching (chalk and talk), laboratory exercises, continuous assessment both open and closed book, group and individual tasks final examination. Most of these activities are batch in nature and very few are found in any real employment situation. Even much touted teaching tools such as “Blackboard” bare little relevance to life outside of college. The challenge to educators is to create a learning environment which is in harmony to the graduate’s career experiences.

3. DRIVERS FOR EDUCATIONAL CHANGE

Developments in the world of chemical engineering such as cutting edge technologies, business acumen and market expertise are instigating major changes in the skills and competencies required by engineers. According to (Fauve et al., 2008) these rapid changes of chemical industry, together with the emergence of new scientific and teaching tools, pose a formidable challenge to chemical engineering teaching. The evolution of existing curricula demands the identification of a subtle balance among competing constraints:

New developments go well beyond the boundaries of “traditional” chemical engineering and have the potential to transform our concept of process engineering. These changes are leading to compact, safe, energy efficient, environment-friendly, flexible processes and plants. The new paradigm for engineering graduates is to be capable of tackling the major emerging issues:-

- Customer Based Solutions
- Complexity of the technical domain
- Globalisation
- Sustainability
- Innovation & Creativity

Even in the current recessionary times world markets are expanding. With the immergence of both China and India as major industrial powerhouses almost 2 billion people are being added to the marketplace. This is a totally different world for young graduate engineers and will not only affect how they are educated but also what they are educated in. Education must focus no longer simply on content, but also on context.

Global competition places enormous market pressures on companies to bring their innovations to market faster than competitors. This is likely to change how we think about education. Specifically, there will be greater interest placed upon:-

- Solving multi-dimensional and multi-disciplinary problems
- Integrating economics consistently into the problem-solving context;
- Acquiring skills related to project management and team dynamics;

- Reintegrating engineering with invention and creativity
- Effective oral and written communications.

Put very simply, “process engineering” skills have never been more important to the global workforce. The ability to convert an idea into a salable product, at the fastest time, lowest cost, and with the least environmental and safety impact, is of critical important to today’s company above all else. (Roman , 2009)

Engineering progress should also be viewed within the context of global environmental constraints. The decisions graduating engineers make in their work will be informed by the concepts, values and methods of analysis passed to them during their educational career. Degree curricula need to ensure that environmental and sustainability concepts are embedded throughout a student's entire education.

The past decade has witnessed international interest in incorporating the skills, attitudes and concepts of sustainability into undergraduate university courses across a range of disciplines (Wright, 2002). The Institution of Chemical Engineers (ChemE) CEO, David Brown has commented: “Students are increasingly recognising the value of a chemical engineering degree and the doors it can open professionally.” And added “The scientists and engineers of tomorrow will be responsible for finding solutions to many of the problems facing our planet. I passionately believe that the process industries have a key role to play in our transition to a more sustainable society.”

4. QUESTIONNAIRE

A questionnaire was developed and sent out to academia and industry to assess the current opinion on design teaching. The drivers for educational change already highlighted, formed the backdrop for this questionnaire. The analysis was developed using “Survey Monkey” and a link to the online questionnaire was distributed via e-mail. In total 71 academics, students and industry based engineers responded. The questionnaire was a combination of open questions and multiple choices.

Where the correspondent was required to choose an option these were ranked in the following order:- Not Relevant (1) -Relevant (2)- Important (3)- Very Important (4)-Vital (5)

THE QUESTIONS POSED WERE AS FOLLOWS:-	
I. Are you a student, academic or industry based engineer	i. Student ii. Academic iii. Industry Based Engineer
II. In your opinion, what do you consider to be most important aspect in the teaching of chemical engineering design?	Open Answer
III. In your opinion, what do you consider to be the greatest weaknesses in the teaching of chemical engineering design?	Open Answer
IV. In your opinion does the teaching of chemical engineering design currently address the changing chemical engineering work environment in terms of technology and business trends?	Open Answer
V. What importance would you give the following for creating a good learning environment for engineering design	i. Use of multimedia (TV/ VIDEO/ Interactive White Boards) ii. Dedicated student design office iii. Availability and use of process simulation and modeling software iv. Structured group learning v. Individual task responsibility vi. Skills related to project management and team dynamics vii. Integrating economics into the problem solving context

	viii. ix. x.	Integrating sustainability into the problem solving context Effective oral and written communications Other
6. Over the next 10 years how relevant do you think each of the following employment/technology sectors will for the design skills of Chemical Engineering graduates?	i. ii. iii. iv. v. vi. vii. viii.	Pharmaceutical Bulk Chemical Biotechnology Nuclear Energy (including domestic / biofuels) Research / Innovation Startup Companies Consumer and Food Products Other
7. How do you think universities might better integrate the teaching of design with industry:	ix. x. xi. xii. xiii. xiv.	Peer Mentoring with Industry Based Engineer Industrial Site Visits Guest Lectures from Industry Real World Industrial Case Studies Design Focus prior to Industrial Placement Other
8. What skills do you think industry based engineers can bring to the study of engineering design:	xv. xvi. xvii. xviii. xix. xx. xxi.	Theoretical Understanding Practical Application Creativity & Innovation Team Working Business & Management Skills Ethics & Professionalism Entrepreneurship Other
9. In the assessment of student work how would you rate the following:	i. ii. iii. iv. vi. vii. viii. ix.	Academic supervisor assessment & marking Industrial supervisor assessment & marking Combined academic/ industry supervisor assessment & marking Student peer marking (students grade each others work) Student peer assessment (students critique each others work, supervisor then grades the work) No assessment & marking Open Book Exams or Design Exercise Closed Book Exam or Design Exercise Other
10. If there was one thing you could change to improve the teaching of chemical engineering design what would it be?	Open Answer	

Table 1. The online questionnaire / survey

4.1 Questionnaire analysis

The questionnaire was completed by 48% industry based engineers, 36% students and 16% academics. In general the student and industry based responses were most similar. This was an interesting and unexpected linkage. The strong underlying theme with respect to identifying the most important aspect in the teaching of chemical engineering design was to incorporate more active participation of industry in education. When considering what was the greatest weakness with regards to engineering design education; students largely identified the gap between theory and practice, Industry based engineers also identified

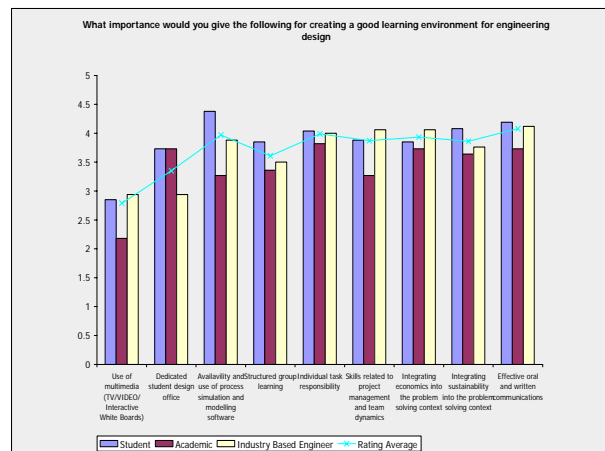


Figure 2. Factors contributing to a good learning environment (1 = not relevant 5 = vital)

issues such as the teaching of outdated or irrelevant design material. Academics highlighted issues relating to the teaching environment such as rote learning being rewarded. The opinion with respect to whether the current engineering design education met the technology and business trend is best illustrated by one of the more insightful student answers declared, “I don't know- but the fact that I don't know shows a weakness in the teaching of chemical engineering design. Any student should be aware of the business and technology trends in the subject being taught” Figure 2. shows the various factors contributing to a good learning environment, students identified process simulation and modeling software as a key contributing factor, presumably as they view this as a “real world technique” but also because such software enables them to handle complex multivariate problems. A dedicated design office was favored by academic, with industry valuing management, economic and communication skills. When examining the relevance of future technologies, figure 3. shows that respondents considered biotechnology energy and R&D as key strategic development areas. In figure 4 the role of assessment is examined, student’s preferences were for joint industry/academic or industry only assessment followed by academic assessment. The academic response on the other hand strongly favoured the standard academic assessment for student work. Figure 5 shows a preference across all sectors for more real world examples as am means of integrating industry and academia.Finally the questionnaire posed the question “If there was one thing you could change to improve the teaching of chemical engineering design what would it be?” and table 2 shows a synopsis of the replies received, indicating a range of options which

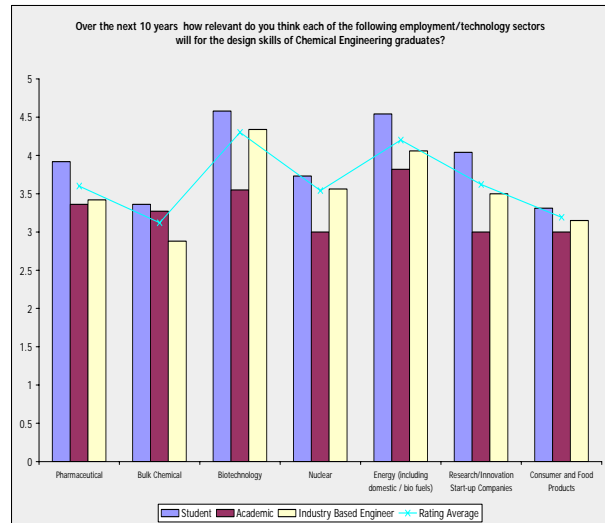
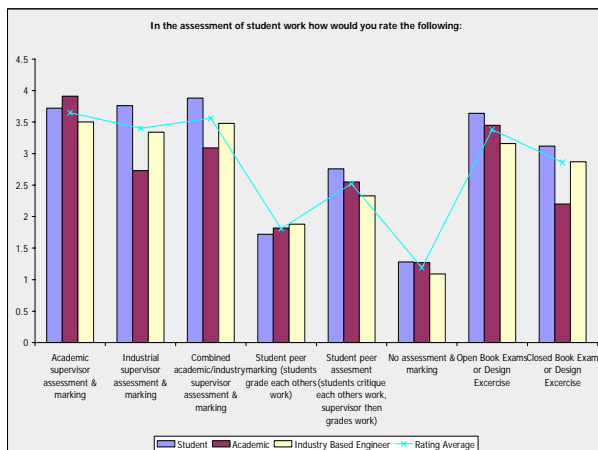


Figure 3. Relative importance of future technology sectors (1 = not relevant 5 = vital, Blue)



could be considered.

Figure 4. Evaluation of student assessment techniques (1 = not relevant 5 = vital)

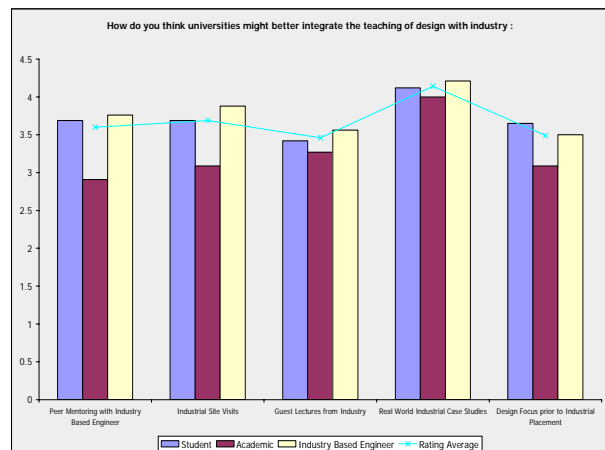


Figure 5. Integration of the teaching of design with industry (1 = not relevant 5 = vital)

IF THERE WAS ONE THING YOU COULD CHANGE TO IMPROVE THE TEACHING OF CHEMICAL ENGINEERING DESIGN WHAT WOULD IT BE?	
–	Real industrial case studies with greater contact between students and industry
–	5 year degree course with two 6 month industrial placements
–	feedback should be given on assignments handed up- where you went wrong, how to improve
–	Smaller peer assisted tutorials with hands on help for designing specific parts of projects
–	Exams should be less abstract
–	More hands work on in earlier years of degree
–	More emphasis on what can go wrong with machinery/ processes and how they are dealt with. Not catastrophic problems, but ones that happen on a regular basis and dealt with as such
–	More notes should be put on blackboard

Table 2. Factors influencing the improvement of the teaching of chemical engineering design compiled from all correspondents)

5. FUTURE CURRICULUM DEVELOPMENT SENARIO

Any curriculum change should according to (Favre et al.,2008) retain the core identity of a chemical engineer. The curriculum should enable engineers to effectively, communicate and work with chemists, physicists, biologists, and find solutions to problems “from beaker to plant”. Curriculum development which is guided by practicing chemical engineers providing; case studies/technical expertise consultation/direct student instruction is identified in the survey as desirable and could include some or all of the following concepts:-

- Introduce “current industry design practice” workshops taught by accomplished practicing engineers. This could be achieved with evening classes or alternatively use retired engineers for daytime workshops.
- Consult with industry based engineers to provide regular team-based multi-dimensional, multi-disciplinary “real industry world” design challenges.
- Discuss design management and the economics of decision-making in the curriculum with practicing project engineers. Engineers need excellent business/administration skills;
- Introduce technical innovation startup companies / engineering entrepreneurs presentations to design courses. Students need to understand how an idea becomes a new product, as well as how to manage and lead this type of project.
- Incorporate structured role-play in team-based design challenges as an important way for students to learn how to be followers as well as project managers. Students should understand the crucial relationship between management and leadership.
- Give students more responsibility with some amount of peers assessment and grading. Discuss with industry based engineers how they assess/critique their own designs.
- Include wider geo-political perspectives in the same context as enterprise innovation and sustainability.

6. CONCLUSION

The evidence gathered from the questionnaire suggests that the “design education” students currently receive has still some distance to go to better reflect graduate practice and experience. The survey indicates that industry has a fundamental role in education; in providing real world case studies and in giving academia access to contemporary thinking on technical and business challenges. The unfortunate observation of Shinksey nearly ten years ago “no progress in 35 years” is to a certain degree, reaffirmed in this survey. The possibility exists in this modern era of dynamic change, digital communications and information dense environments of unprecedented complexity design; to break free from anachronistic pedagogical models. Opportunities for the active contribution of industry based engineers and experiences have been suggested in the curriculum development scenarios. If nothing else the information sharing interchange would be hugely beneficial to course development.

Academic survey responses generally placed less emphasis on nearly all areas in comparison to both the industry and student replies, this perhaps reflects the unique perspective of the educator, but also could indicate a certain level of isolation from, employment realities facing both students and graduates.

The word engineer is from the French word 'ingénieur', which itself is derived from the classical Latin word 'ingenium', which means 'ability' or 'genius'. This survey has indicated that there is a significant role for industry in guiding the pedagogy of engineering design, and that much of this potential remains untapped. Increased involvement of industry based engineering can only strengthen the “ability and genius” in education.

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