New Approaches to Teaching and Learning for Industry-Based Engineering Professionals

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ABSTRACT

It is no longer possible for the profession and academia to assume that all chemical engineers can be educated, trained and developed in the way that prevailed in the latter part of the 20th century i.e. by means of conventional under-graduate degree courses targeted at school leavers. In the UK, the Chemical Processing Industry has a key challenge to meet the need for employment-based education. It also has a demand for continuing professional development to provide core and advanced engineering knowledge and skills that also encourages a multi-disciplinary approach.

Strathclyde University's Department of Chemical and Process Engineering has pioneered several undergraduate and postgraduate distance learning courses for industry-based students that are unique in the UK and are attracting interest on a world-wide basis. The design and development of the courses was undertaken with a wide range of partners including industry, Professional Institutions and other Universities. The course delivery involves new methods of teaching, learning and communications that are not found in conventional U.K full-time under-graduate programmes. These teaching methods range from text-based to internet-based delivery and have a strong emphasis on employment-based project work.

The undergraduate course provides a 'mainstream' first degree in chemical engineering for industry-based students who have some prior qualifications and experience. The postgraduate masters-level courses are designed for a wider range of professionals with backgrounds in engineering and/or chemistry. They provide a technology-based version of an MBA and feature a strong multi-disciplinary theme that integrates advanced process technologies, management and business (with a strong emphasis on the process of innovation) and IT strategy. Since the distance learning courses started in 1990, a total of around 60 companies (on an UK and world-wide basis) have sponsored students and the current total enrolment is around 150 students. Both programmes have a student age profile of 26-36 years and feature a wide-cross section of disciplines holding qualifications ranging from Diploma to PhD at entry.

The paper covers:

- The key features of course and curriculum development and the role of partnerships
- The most effective methods of teaching, learning and communication

- The most effective use of work-based projects
- The methods of achieving team-work with widely dispersed students
- The importance of mentoring and 'pastoral care' for geographically isolated students
- Case Studies illustrating the diversity of students' background, learning experiences and outcomes from the courses
- Conclusions and wider implications for engineering education.

1. INTRODUCTION

It would be relatively easy to develop a paper on a topic covering "*Teaching and Training Chemical Engineering Professionals*" by reporting what we do at the University of Strathclyde as a case of history. It would be full of detail and we would add a few "warts", just to show that we are not perfect (yet). We do have a good story to tell, one of success based on:

- Industry participation in course development
- A strong work based assignment approach
- Development of collaboration across companies and countries
- Widening access to Chemical Engineering
- Good examples of academic participation from different universities

However, the value to the reader of this paper is perhaps a message that the Chemical Engineering community could learn from our model, and that there are valid reasons why the model adds value to the whole UK Process Industry community in particular, as well as its individual members.

Lets start with a quote from December 1996 issue of the Institution of Chemical Engineerrs magazine (IChemE) "*The Chemical Engineer*" (**TCE**) [1]

> "*Industry needs technical graduates who can communicate and have people skills*"

Well, **TCE** might not be the most academic of journals to start a paper, but it is a common theme that prevails right across industry.

The Institute of Personnel and Development magazine, "*Personnel Today*", again not an academic journal, but just think in terms of the powers and influence of the Human Resource Department in your organisation, - "*I am only here in a advisory capacity*?"- in order to realise the power of the message.

> "*Employers want graduates who are…able to communicate, share their skills, and appreciate their place in a wider organisation"*
>
> *" Those graduates with technical degrees lack the important personal skills"*
>
> reported from Institute of Employment Studies Report [2]

Alternatively, look at what the world's competitors think:

> "*Without some form of shared experience, it is extremely difficult for people to share each others' thinking processes."*
>
> The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation. [3]

So perhaps this paper is more about;

"*What do academic establishments and professional institutions do to aid individuals to achieve this level of skill*?" and "*Is industry really involved in playing a part in the process*?"

It's worth starting out looking at a few models of teaching and learning that might apply as we explore these issues. A **Traditional Model of U.K. Education** might be in Fig 1. Most would agree that we would peak in our learning ability around 16-35 years of age and in fact our careers are set in place by then, i.e. the **Conventional Model** shown here**.**

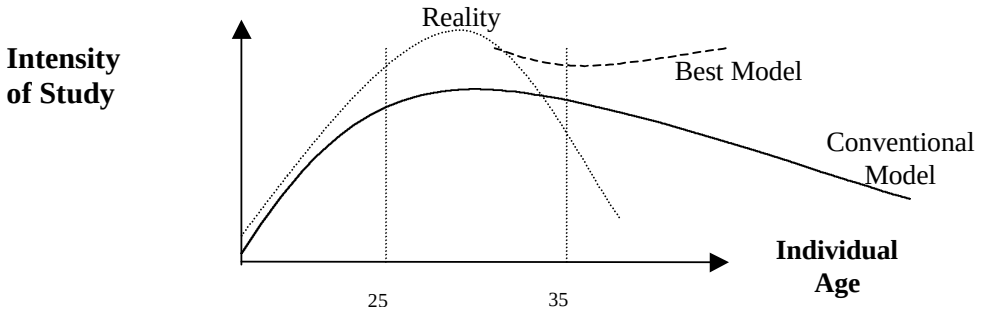

Fig 1: Model of Education over time

However, James Thurber, the humorist suggests,

> *"In times of change the learner shall inherit the earth, while the learned will be equipped for a world that no longer exists."*

As a result, the practice of life-time learning, is suggested as much more the way forward in management education and in many industries. A "*re-learn, or atrophy and die*" could now be the policy, i.e. our **Best Model**.

Regretfully none of these two models are actually the prevalent ones and it is reasonable to suggest that the **Reality Model** is a quick burst to first degree and then IChemE accreditation to Chartered status, then not much else, as a common approach amongst Chemical Engineers in the UK.

There is now sufficient academic research and industry data that suggests organisations need to spend between 1-3% of annual turnover in training to continue to develop competencies amongst its employees and in many companies that expenditure has a direct link to improvements in business performance. [4]
If you have not heard it yet – *the "Human Resource Director"* will soon be knocking on the door quoting the latest text.

Senge's	*"Learning Organisation"* [5]
Nonaka's	*"Tacit/Explicit Knowledge"* [6]
Drucker's	*"Knowledge Worker"* [7]
Brown & Duguid's	*"Communities of practices"* [8]

A **Learning Organisation** is a developing organisation, and there are now many definitions of a learning organisation

- Where "*people continually expand their capacity to create the results they truly desire, where new and expansive patterns are nurtured, where collective aspiration is set free and where people are continually learning how to learn together".*
  (Peter Senge in `The Fifth Discipline')

- Organisations that "*experiment more, encourage more tries and permit more failures; they interact with customers more; they maintain a rich informal environment heavily laden with information."*
  (Tom Peters and Robert Waterman in `In Search of Excellence') [9]

- Who are "*skilled at creating, acquiring and transferring knowledge and at modifying its behaviour to reflect new knowledge and insights.*"
  (David Garvin in Harvard Business Review) [10]

If you are not into this new form of management, then you might just be out!

Our conclusion is therefore that

"Industry wants graduates who have team based learning skills"

and that it might expect its employees to

"develop these skills based on a model of lifetime learning."

2. UNIVERSITY OF STRATHCLYDE'S CONTRIBUTION TO LIFELONG LEARNING

That's really where our two case studies come into play, since they both build on a model of skills development and continued learning.

Our **BEng Distance Learning programme** (**BEng DL**) is a full IChemE accredited Chemical Engineering course with a wide range of qualification intake:

- Sub degree Chemical Engineering (Diploma level)
- Non Chemical Engineering first degrees, particularly chemists (BSc and PhD),

all with up to ten years of industrial experience and mainly from the Pharmaceutical, Oil and Gas and Chemical Industries.

The course's inception resulted from an industry need to up-skill experienced process/shift staff in order to allow them to make process improvements on plant without waiting for a "*White Knight*" Chemical Engineer from Central Services to come around. There might be a lesson here for professional Chemical Engineers, but it was primarily about increasing the skills of individuals who could have a direct influence on the business. (The *Learning Organisation* in practice?). This **Industrial Partnership** came from a brief from two major UK based international chemical companies and unusual for the world of academia was subject to a formal competitive tendering process for the "business", with the companies subsequently contributing development funds and an initial entry stream. Here they were making the decision to sponsor their employees in training to be chemical engineers rather than competing on the job-market for qualified experienced individuals or recruiting new graduates from government sponsored Higher Education programmes.

The form of delivery is high quality text based material, use of worked examples as learning practice and assignment submissions supplemented by a regular programme of tutorials at Strathclyde University. This, in academic jargon, is **"Supported distance learning teaching**". The important teaching lesson here is substantial feedback on performance at all stages throughout module delivery. Students have access to telephone, fax and email contact on a routine basis with all academic staff as well as 24 hours of face to face contact at tutorials.

Importantly from a quality and accreditation point of view, it's the same material, assignment and exam profile as our full-time BEng programme whose intake would be school leavers entering Higher Education at 18 years of age. It is the only part-time distance learning first degree course in Chemical Engineering in the U.K.. Course evaluation questionnaires give comparable results with our full-time undergraduate programmes for delivery, understanding and lecturer/student relationships, and score very highly on the importance of **pastoral care** as important for distance learning students being able to continuing participation.

So apart from the intake profile and teaching methods what's really different – the output, not only do we produce a "better" student, the evidence suggests that we produce a more "industry relevant" student. External examiners say, "*Distance Learning students add application to their studies*", which is perhaps not surprising since they bring that experience with them to the course

and share it with their peers and our teaching staff. The IChemE accreditation panel review (2000) confirmed that "*The quality of graduates is exceptional*", which is perhaps more surprising since many will have left school without sufficient qualifications to enter Higher Education (University). They will have had to use day-release Further Education (College) to gain their current qualifications or perhaps had insufficient school qualifications to enter chemical engineering courses initially (Typically having scored poorly in Maths). As a result, award levels for the 98 graduates from this programme are all at Honours level compared with 87% from the full-time under-graduate programme.

This exit profile allows the students to become much more mobile in the job market (inside and outside their companies). Much to the chagrin of one organisation who chose to "down size", a number of our BEng DL students returned as Environmental Agency Inspectors, and guess what *"they knew where the skeletons were buried*" and all the shortcuts.

Qualification plus experience can be a powerful tool.

That is perhaps the biggest benefit that we bring to the Chemical Engineering Community, this mix of industrial application and formal qualifications taken at a maturer stage in an individual's career. It meets industry's needs for experience, formal qualification and a perspective on business objectives that conventional undergraduate programmes cannot provide. We too have drawn on this lesson. As a result, one of our "learning outcomes" from this programme is to introduce a class in "*Business Management Practices*" into our 2nd year of our full-time under-graduate programme and use past distance learning students as speakers to bring "real-life" to the class.

Returning to our Model of Learning, our **BEng model** may in fact look more like:

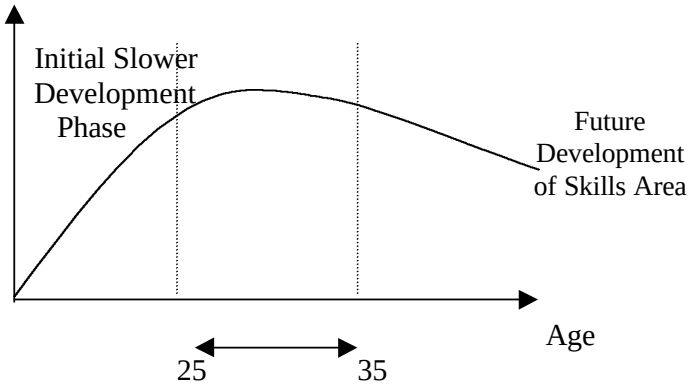

Fig2: Work Based Learning

Our **Masters level programmes** have been developed under a generically funded package of Integrated Graduate Development Scheme (**IGDS**). This represented a reflection by UK funding bodies that technical graduates needed to extend their first discipline not only in technical areas but widen the scope of their understanding of business (The *TCE* quote again?).

In common with a number of industry specific packages in this scheme, we offer a mix of Technology, Business Management and Information Technology with an underlying principle of work based application that allow delegates to demonstrate their learning for the benefit of their companies. This allows a match between their learning, and industrial based assignment with "our expert" advice on the application of theory in their company. It is Masters level material that they apply, but with this very much work-based learning approach. This is a common approach across all IGDS programmes as is a requirement to have an industrial input into the course design. Our industrially based Management Committee was formed from the original individuals who came to us with the BEng concept and renewed our **Industrial Partnership** here. They were very much in favour of this approach, and the design and development of the course used an industrial liaison approach as a major source of both content and application. As a result, the course development became a partnership between industry and academia, and gave us a series of modules with course material we were deliver rather than material we knew sufficiently about to deliver. We then had to source our own experts and as a result brought in internal and external partners into the programme.

This creates our own multi-disciplinary team and **Academic Partnership,** which is both internal and external, since apart material developed within our own department, we extended our sources into:

Topic	**Partner**
• **Manufacturing Technology**	Dept. of Design and Manufacturing Engineering,
• **Analytical Methods & Process Automation**	Dept. Pure & Applied Chemistry,
• **Management Functions**	Graduate Business School,
• **IT Strategy**	IT Associates Company
(*All University of Strathclyde)*	
• **Batch Processing**	UMIST, Manchester
• **Process Control**	University of Edinburgh
• **Managing of Technological Innovation**	Royal Society of Chemistry

as examples of that collaborative approach.

Our model for the **Masters Programme** is similar to the BEng DL form of learning.

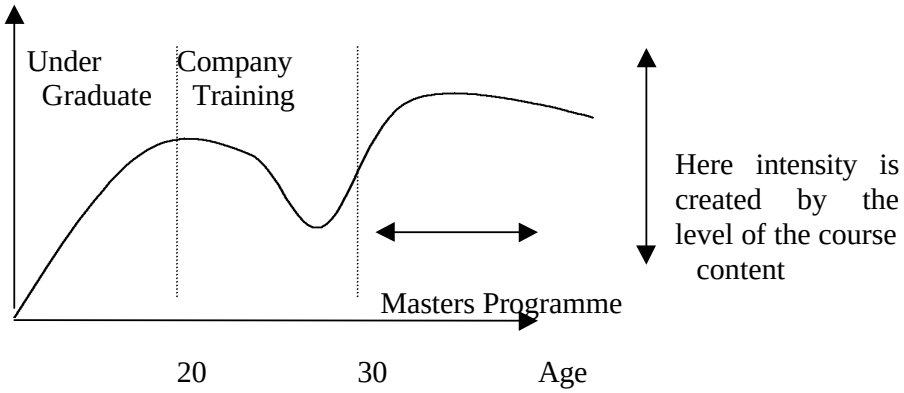

Fig 3: Post -Graduate Learning

The programme has been described as a Technical MBA, since it mixes advanced technical subjects with business management. Its particular success is a final Major Project that requires students to link the components of Technology, Business Management & IT.

The course first intake was 1997 and by November 2002, we will have taken 160 delegates through one of two Masters level degree courses: *MSc in Process Technology & Management* and *MSc in Chemical Technology & Management* and have awarded 35 post-graduate Masters degrees.

The teaching format is again **"Supported distance learning**" with the same level of student/lecturer interaction and pastoral care as the BEng DL course. We also wanted to introduce a greater emphasis on **team based problem solving** in these programmes yet we did not wish to increase the amount of time students were required to be released from the work place. As a result, an e-conferencing format using *First Class* software was introduced. This format allows **geographically dispersed students** to investigated their own company's approach to a problem, share it in asynchronous conference and for the group to review the different approaches before agreeing a common response. Since the software can be accessed either by "desktop" or "Internet, it allows open access from any location, overcoming travelling from base or firewall at base issues to be overcome. The approach has been so successful that all communications to students are now delivered via this route using bulletin boards. (There are two real advantages here, the vagaries of the postal system are defeated and students cant "lose" timetables and hence miss submission dates.)

Our experience to date confirms that the output from the **work based approach** to assignment and assessment can have substantial impact on the student's company. From 50% of the taught modules using this approach and allowing for choice of electives, students could have two thirds of their material as work based application. In addition, the Major project (equivalent to three modules), not only asks students to apply the application of Technology, Business & IT, but must have a relevance to their organisation.

It is assessed using the following criteria:

- The scope of the project in terms of looking at the whole business environment (20%)
- The use of course concepts in both width and depth across all three parts of the course (30%)
- A demonstration that there has been an involvement/interaction with the other parts of their organisation. (15%)
- Takes into consideration published material in relation to the core course topics (10%)
- Demonstrated benefit to the employer, backed up with independent supporting evidence (15%).
- The general format and layout of the report is set out as per the published guidelines (10%)

The fifteen Major Projects produced to date have all had differing outputs, but typical **case study** examples are:

- A "conventional" effluent treatment analysis, found previously un-recognised toxic hazards
- A review of potential new product applications will probably save substantial costs by not taking what would have been a wrong direction.
- The "conventional" design reduced throughput & quality as it was duplicated on a world-wide basis, since "convention" was taken as "standard & best", rather than what is was "at best average".

These examples perhaps don't seem startling but the issues had never been addressed until the student ask his/her Line Manager for a project topic and got the response:

> *"well, we have been needing to look at this for some time"*

The experiences of students across both individual modules and course completion are just as varied and sometimes unusual;

> GS: Wrote a report on improving customer service from material in *Manufacturing Technology*, his MD liked what he read, implemented it across all the company sites and now Graham is in charge of Plant in Holland – The drawback- **being sent to a monastery** ……..for 2 weeks intensive training in Dutch.
>
> C D: Needed to write a report on his organisation's Safety Systems as the main assignment for *Safety and Environment* and his recommendations are now Standard Operating Practice– and he got paid a bonus for achieving this.
>
> JMcG: Used his Major project report on "Decommissioning Off-shore Oil Platforms" to convince a prospective employer that he was a valuable asset as a new employee having spent after 15 years as a contract Project Electrical Engineer.

PR: Had his annual review "I am about to finish my MSc – what next?" and he is now Plant Manager in Alaska. More importantly, with access to a "*green card*" and a permanent post in Houston.

Not all the students have such dramatic events, but since with a large part of both courses having work based assignments, recent research amongst the 90+ students active in the programme, suggest that 4/5 modules will have an immediate impact on the student's company - more than paying for the whole course. It's a double payback really for students – assistance with career development and demonstrating your worth to the organisation at the same time. (This anecdotal set of findings is now subject to a formal review across all IGDS course topics by one of the authors).

It is however the industry's judgement as to whether the programmes are of value and Alan Smith, President of the Industrial Affairs Division of the Royal Society of Chemistry makes two comments on the Masters Programme:

For the programme in Chemical Technology & Management,
"*Chemists need to move on from their original disciplines, the initiative between RSC and University of Strathclyde allows chemists to interact with other companies, other disciplines and hear/learn other views on the world at work.*"
Whereas the Process Technology & Management course,
"*Expands the narrow view of first degrees in engineering or science. The match of advanced technical skills and management material from Strathclyde's MBA Programme really makes a difference to individuals*."

3. CONCLUSIONS

What are the lessons here from this approach to learning? We would suggest that:

- It forces a multi-disciplinary/multi-organisation approach on student
- It builds multi-skilled individuals
- Work based assignments build competencies
- It provides support in career development
- It offers a CPD opportunity to the Chemical Engineering Community
- There is measurable payback to sponsoring organisations
- It enhances our own university learning
- There are opportunities for international sharing of knowledge and experience
- Partnership is a successful design approach for CPD courses

And these are just some of the companies testing that out:

Abbot Laboratories, Aker Oil and Gas, AstraZeneca, BJ Services, BNFL, BP Chemicals, BP Exploration, British Sugar, Cabot Carbon, Calcarb, Chemdal, Chirex, Colgate Palmolive,

Croda International, CSC Forest Products, Elementis Specialities, Esso Petroleum, Fidelity Printers & Refiners, FMC Corporation, Glaxo Wellcome, Kodak, Kvaerner, McDermott, Merck Sharp & Dohm, Nycomed Amersham, Pall Filtration, Pfizer, Precision Process Technology, Puremalt Products, Ricoh UK, Roche Products, Rohm and Haas, Royal Ordnance, Scotia Pharmaceuticals, SEPA, Smith Kline Beecham, Squibb Manufacturing, Stone and Webster, Synetix Tioxide.

Are the programmes successful? The number of companies who provide a regular flow of students would suggest that is the case. Since there is no funding other than fee income stream nor now a guaranteed student intake, they need to be self- sustainable and the BEng DL programme is ten years old and the Masters Programme is five years old. This would suggest success is the case, but some metrics help put this in perspective.

- The annual BEng intake represents ~ 67% of the mean intake on any BEng Undergraduate UK based school leaver programme in 2000 (Source IChemE documents), i.e. there is a market demand comparable with post-school leaver chemical engineering education.
- The IGDS Master programme intake compares favourably with the University of Warwick Manufacturing IGDS programme, yet draws its delegates from a narrower industry sector than Warwick.
- The "drop out rate" on all three courses is 12-15% of intake compared with 30-50% for U.K. distance learning programmes (source: Open University documents), i.e. the format is successful. The high level of pastoral care provided by the Course Administrators achieves much of this success, according to evaluation questionnaires.
- 25% of annual intake will be "repeat" business i.e. companies can see the benefit in sponsoring their employees to a value of £10,000 and up to 20 days release from work as part of the individuals personal development.

What are the lessons for the Chemical Engineering community?

Our experience (and those of from parallel industry IGDS courses) of learning suggests that most of the UK Chemical Engineering population struggle with the concept of lifelong learning and that outside some very valid areas of specialist subjects, most Chemical Engineers seem to give up. Yet both our BEng and Masters Programmes feature Chemists and Mechanical Engineers, who want to become or learn about Chemical Engineering and understand how their business operates across a broad base of disciplines.
They don't stop at the basic level – in our programmes, they begin to understand where the role of Chemical Engineering lies in the business model within their company, and use their learning to move their careers forward, demonstrating their worth to their organisation.
The view therefore presented here, is that with the correct and valid form of teaching for industry based professionals it may be possible to generate a culture beyond the conventional approach to offering access to learning.

This may have a particularly important **implication** to IChemE, who in line with other Engineering Institutions, moves to the requirement for a Master level qualification to meet academic requirements for Chartered status. Not all under-graduates will complete that requirement with their first degree and a route through our BEng DL and IGDS programmes may provide industry with a more balanced business-orientated graduate rather than one taking the MEng direct route straight from leaving school.

In finishing this paper, it may be worthwhile and probably necessary to return to the Human Resource Department's agenda of Learning Organisations – one where

- Autonomy,
- Risk taking,
- Tolerance of mistakes,
- Sharing experience
- Gaining new skills

produced competitive advantage, and for many organisations (if not all) that is the over-riding objective of all that we are required to do for those with an interest in CPD.

Learning & Knowledge can play a substantial part in that business objective:

> "*Competitive advantage is more likely to arise from the intangible firm-specific knowledge which enables it to add value* "
> Spender, J. C. `Making knowledge the basis of a dynamic theory of the firm', [11]
>
> "*Firms exist to facilitate the acquisition, creation, exploitation and transfer of knowledge, with advantage being gained by the `speed and efficiency of the creation and transfer of knowledge'*
> Kogut, B. and Zander, U. `What do firms do? Co-ordination, identity and learning', [12]

The University of Strathclyde gives the Chemical Engineering Community that support through our Distance Learning and Integrated Graduate Development Scheme Programmes by providing the opportunity for individuals to learn new skills, and then have an impact on their business.

4. REFERENCES

1. December 1996 The Chemical Engineer, IChemE
2. Personnel Today Jan 2001, Reed Business Information Ltd, for IPD.
3. Nonaka, I. and Takeuchi, H. 1995 The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation Oxford University Press New York
4. Institute of Personnel and Development, Issuesb in People Management No.22 1998
5. P.Senge 1990 The Fifth Discipline Double-day New York
6. Nonaka ibid
7. Drucker The Coming of the New Organisation Havard Business Review January 1988

8. Brown, J. S. and Duguid, P. (1991) `Organisational learning and communities of practice: towards a unified view of working, learning and organisation', Organisation Science, Vol. 2, No. 1.
9. Peters T. and Waterman R. In Search of Excellence Harper Row New York
10. Garvin D. Building a Learning Organisation Harvard Business Review July 1993
11. Spender, J. C. 1996 `Making knowledge the basis of a dynamic theory of the firm', Strategic Management Journal, Vol. 17
12. Kogut, B. and Zander, U. 1996 `What do firms do? Co-ordination, identity and learning', Organisation Science, Vol. 7.