PREPARING GRADUATES FOR THE REAL SAFETY WORLD – THE PAST AND THE FUTURE

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The paper describes the evolution of teaching in UK Schools of Chemical Engineering since the mid-1980s. The paper also describes the evolution of a Safety and Loss Prevention teaching in a British University undergraduate course at both Bachelor and Master levels. It describes the barriers to learning due to limitations in educational resources, the acquired knowledge and understanding of the students as well as limitations in the perspectives of those delivering the course.

The development of a realistic "virtual process plant" which can be used to both show the form of a process plant to first year students as well as audit skills to final year students is described. The use of this and the analysis of case studies can bring a reality to the safety teaching and become a source of discovery or self learning (self teaching).

Finally some of the issues which have to be addressed to retain safety as a fully integrated element of and within the Chemical engineering syllabus and to prepare the students for the challenges of student's placement and the full time occupation are highlighted.

KEYWORDS: Teaching, Chemical Engineering, Safety, IChemE, AIChE, ABET.

INTRODUCTION AND BACKGROUND

In this paper the term "safety" includes Occupational Health, Safety and Loss Prevention/Safety Engineering and Environmental protection.

The teaching of safety in any undergraduate course is fundamental, as prescribed in IChemE Accreditation Guidelines. The knowledge gained during this period often lingers for a working lifetime. Knowledge gained after graduation is often fragmented and fragile, so it is easily forgotten. In any accident report it is normal to find reference to the lack of Management input and control of the safe working environment. (Baker 2006, Hopkins 2000, HSE 1987, Cullen 1992) It could be argued that the lack of or the poor building of the safety foundations at undergraduate level is one of the reasons for the repetition of basic accident causations in industry. This was confirmed by a series of inhouse safety training courses where qualifies engineers did not fully appreciate the "safety fundamentals" and did not know of a number of recent global events. These were revealing. If safety is not an integrated part of any undergraduate course it is likely that it will not be part of the graduate thinking.

There are a number of difficulties with teaching safety. First, it is not an academically "pure" subject and can be seen, erroneously, as a case of following rules, (regulations). Secondly the assessment of effects is determined by empirical equations. Thirdly it is difficult to recognise a potential hazard if that hazard is not in the memory banks or readily available and analysed in published scientific documents. It is also a subject that young academics do not aspire to teaching or researching. This will be discussed later in this paper.

IChemE Safety and Loss Prevention Study Group decided to make the problem of safety education a topic for one of its meetings at London University in 1986. In some respect this was preaching to the converted, however, the meeting did generate two significant outcomes. It identified the need for:

1. A training course called latterly "Teaching the Teachers Course".
2. The need for a safety curriculum which was integral to the undergraduate course.

The two "Teaching the Teachers" Courses were illustrated by a site on the Cromarty Firth which was used for the storage of white oils and butane/propane and took some months in preparation. It covered: Hazard Identification which covered the 8 main steps of Hazard Studies (Crawley 2003) and included HAZOP as a main study, quantification of the effects of the event and quantification of the frequency of the event. Clearly the hazardous events had to be credible and reasonably readily identified. However, a tutor could add their own ideas on "hazards" such as the stability or the soils under a recovered or land fill site, the proximity to a Site of Special Scientific Interest, the proximity to a bombing range and also a geological fault line. All four applied to the chosen site!!! In addition the HAZOP had to be relatively simple and tried to avoid the "as well as" elements. The quantification of effects relied on simple formulae available in the technical literature; the accuracy was not perfect and adequate for the exercise. The quantification of the frequency was by event trees as fault trees have many problems for those not skilled in their use.

The first course at which there was about 50% representation of schools of Chemical Engineering took place in Exeter University on 6/7/1988. Sadly during the preliminary workshops, lead by Trevor Kletz, there was the Piper Alpha disaster. This added focus to the need for such a course but the attention of those delivering the course was split between the course and the disaster. This course was re-run in Leeds in 1990 so giving nearly 100% coverage of Schools of Chemical Engineering.

The final package covered full lecture notes and worked examples, with drawing, involving at least 200 hours of effort. In other words it was a complete package with Drawing Office quality drawings covering before and after HAZOP, layout drawings and Hazardous Area Classifications.

After the first course a joint working party of the IChemE Safety and Loss Prevention and Education Study Groups drew up a safety curriculum targeting the main-stream modules to be taught. This curriculum was presented at Taormina (Crawley 1992). The paper stated both the student and academic perspectives.

1. Safety had to be an examined topic as the student perspective is that if a topic is not examinable it is a waste of time, this has been reiterated by ABET (ABET 2011) in USA.
2. The academic perspective is that safety is a complex set of integrated topics so it would be easier to teach "the Law" which may seem to be black and white. (In reality safety uses strategies appropriate to the hazard, which can be split out individually.)
3. The curriculum suggested that some of the "tools" such as audits and permit to work could be taught as sub-sets of "management" and that lay out could be a sub-set of "design". It was also believed that some of the phenomenology could be taught within core chemical engineering modules and reliability could be taught inside the mathematics module.
4. The paper did note of the difficulty of teaching HAZOP where there has be an understanding of failure modes of equipment and the model had to be simple.
5. The paper also noted "the student will not usually have the knowledge or experience to understand many of the engineering principles ..."

In retrospect the curriculum had some ideals which were difficult to achieve as they would require a restructuring of the main stream modules and the introduction, integration and understanding of the new ideas or topics. In particular it was assumed that all Chemical Engineering courses would have set topics on "management" and also "materials", this is now known to be inaccurate. While the original curriculum and time allocation was correct it did not become a standard for the reasons given above.

The American Institute of Chemical Engineers describes itself as providing leadership in advancing the chemical engineering profession. Chairperson Moure-Eraso said, "*The status of the recommendation reflects AIChE's outstanding response that surpassed the objectives envisioned by the Chemical Safety Board. If future chemical engineers are given the proper educational tools, they will be able to more fully comprehend and better manage the hazards in a chemical manufacturing process.*" (CSB 2012) He also formally commended AIChE for exceeding the CSB's recommended action resulting from the board's 2009 investigation report into the fatal reactive chemical accident at T2 Laboratories in Jacksonville, Florida.

As a result of the investigative findings the CSB had called on AIChE to work with the Accreditation Board for Engineering and Technology (ABET) to include reactive hazard awareness in college chemical engineering curriculum. AIChE proposed changes, which ABET approved in 2011, to require proficiency in not just reactive chemical hazards but in all chemical process hazards among a broad range of engineering disciplines. There is a lesson for the IChemE.

A NEW APPROACH

In spite of the good intentions of the UK curriculum outlined above (Crawley 1992) it became clear that a structure for the teaching of safety had to be developed as a core and not a bolt on subject. This evolved by answering the following question:

> "*What should an honours Bachelor's graduate know about safety when he/she starts the first job?*"
>
> This then asked: -
>
> "*What should an Integrated Master's graduate know about safety when he/she starts the first job?*"

The answers are different but again guidance is given in IChemE accreditation. The Master's graduate should have skills in management for safety as well as the Bachelor's skills.

In an effort to introduce the student to the concepts of safety it was found necessary to introduce the concepts slowly over a number of years. The Strathclyde University approach which covers a 5 year Integrated Master's course was as follows:

Year 1 Fundamental review of Science and Mathematical skills with an introduction to the Chemical Engineering principles including safety.

Year 2 More advanced Chemical Engineering principles including safety.

Year 3 A fully developed safety course which lays down the foundations for the more advanced course in year 5 but also teaches the safety principles that should be built into the Detailed Design in year 4.

Year 5 The Safety Management is taught in this year before the student carries out an industrial based project.

The integrated approach to the teaching of safety at Strathclyde University, discussed above lead, to two curricula. In the case of the Bachelor's course it includes: -

- A brief introduction and illustration of the key Acts in Safety and Environment

- Hazard identification including HAZOP
- Basic Safety Management Systems – Permit to Work, modification control
- Phenomenology – outflow, fires, explosions and dispersion
- Event trees (fault trees are too complex but event trees are quite simple)
- Design for Safety* – layout, pressure relief, simple Safety Instrumented Systems (SIS),
- Reactors in particular exothermic reactors
- Simple reliability which feeds into SIS
- Introduction to Inherent Safety
- Human vulnerability – this is very educational for 20 year olds!
- Equipment and hardware vulnerability.

The need for the section on Design for Safety* is self-evident as it is a key element which has to be integrated into the final design project and should be a part of the marking schedule. The safety design features are a blend of strategies or Defence in Depth, not all defences are appropriate to a specific situations. The student must understand which tools are available and which might be appropriate in specific circumstances. The strategies within the design itself are left open to the student but their strengths, weaknesses and applicability are described inside the course.
In the case of the Master's course it includes: -

- Safety Management – including styles and the employee response, aging and motivations and more advanced safety management systems
- Safety v environment
- Causes of errors (human error is really a sub-set of management error)
- Accident investigation
- Audits
- Inherent safety
- More advanced phenomenology

It is important that each topic in the Master's course is backed up by case studies which illustrates the issues and so as to reinforce the course notes. This adds a touch of reality to which the student can relate and learn. Longford, Piper Alpha and Texas City are excellent examples but most occurred before most students were born so the students find it difficult to relate to them.

> "*To know not what occurred before you were born is for ever to remain a child*" –Cicero

The feed-back from students who entered placements in Offshore Oil and Gas companies is that they are told the major issues that arose from the Cullen Inquiry have now been resolved. The global evidence does not support this hypothesis, so by carrying out a detailed study of the Piper Disaster using both the Cullen Inquiry and the BBC video "*Spiral to Disaster*" (BBC Enterprises) the student can now challenge these statements from firsthand experience.

TEACHING STYLE

It is evident from the curricula that the Bachelor's course is more mathematically oriented and the Integrated Master's course is more management oriented. It is important that the Bachelor's course is not taught as number crunching alone but the undergraduate perspective is that the route to a successful completion of a degree course is by numbers. The recognition of the undergraduate perspective was quite a revelation! This requires a different approach to the teaching. The Bachelor's curriculum is aimed at "discovery". The needs of safety are the understanding of the causations, the preventative measures and only then the quantification. It follows that the course is taught in three steps:

1. How could it happen? How does the leak occur?
2. How could it be prevented? What protective systems, controls, maintenance, procedural or other are required?
3. What is the likely magnitude of the effect? If a sample point of 5mm diameter was left open how far might the flammable cloud travel on a) a still day and b) on a windy day?

The outcome of this approach is the (discovery) realisation that a relatively small leak, such as a leaking sample point can have significant implications and that the cold winter night is one of the most dangerous weather conditions. Buncefield is a case illustration.

The Integrated Master's course is taught more by using case histories and allowing the candidate to review their notes to discover why an event occurred. The curriculum is aimed at understanding what management should be doing to prevent the outcomes of the case studies, this includes the robustness of Safety Management Systems. How would the student prevent the accident at Buncefield?

As an example the Challenger Disaster (BBC Enterprises), while it does contain some inaccuracies, shows that one of the key team members who had all of the wear (erosion) data from the previous launches on the Solid Booster Rocket "O" rings was not invited to the meetings. The decision was made for commercial reasons and was based on opinion and not on solid facts (no pun intended!)

The two courses are taught at both undergraduate level (Bachelor's and Master's) and the same for mature students. The mature Bachelor's candidate will have a number of year's practical experience and a HNC or equivalent. The mature Master's candidate will have a first degree. This requires a slightly different delivery style which uses the knowledge already acquired from the mature students' experiences. The delivery uses the same course material and notes and is more interactive using techniques such as asking the mature student questions such as "*how does this relate to your experience*?"

THE VIRTUAL PLANT

Over the years it has become more and more difficult for students to obtain "first hand experience of chemical plant" for reasons of perceived safety and economics. To overcome this an interactive "virtual plant" was designed. The first year student can "see" what a process plant looks like without leaving the lecture theatre; it has pipe racks, pumps and equipment. During the tour the student is given both visual and sound/aural information. At the more advanced level the student can execute an audit or hazard identification study looking for potential problems or issues and then to propose actions which should be put in place to prevent a future event arising following the audit. The virtual plant allows the student to leave the perimeter path so as to look at the areas of concern in more detail. This teaches the "look, listen, feel" technique.

There are over 12 potential issues. Examples of issues built into the model are:

1. A cracked graphite bursting disc on a dust duct.
2. A pump hanging off a lifting frame with a damaged lifting eye and frayed rope.
3. An inaccessible valve (and 45 gallon drum).
4. Permit to Work which is issued by the production department to the production department!
5. A pump can be seen with a dripping seal
6. Nearby the site drains can be seen to be choked with debris.
7. Another pump which is not bunded.
8. A large storage tank with a damaged bund wall.
9. A hole in the site fence compromising security.
10. The loud noise from an air compressor is now heard
11. A skip filled with drums of oil and rags – the classic seat of a fire.
12. A sea container used as a construction hut with cylinders of cutting gas deep inside.

All of these have been seen during audits.

INTER-INSTITUTE APPROACH

In the mid-1990s an Inter-institute working party comprised of all branches of engineering, in conjunction with the HSE who supplied the "pump priming money", developed the introductory phase of an interactive "Hazard Identification" CD which was an attempt to devise a model, not unlike the virtual plant, but was based on a building site with the usual trip and access hazards. There were about 10 meetings leading up to the production of the prototype called "Engineering a Safer Future". The CD has not been completed as the participating Institutes did not complete the funding. It is reasonable to point out that the CD was trying to cover all engineering disciplines and may have been more appropriate to one or more and not to others, that is, the problem of being "all things to all people". The initial phase of the tool is available but is not ideal for Chemical Engineers.

USA BASED RESOURCES

SACHE (Safety and Chemical Engineering Education Program) is a collaboration between CCPS (Center for Chemical Process Safety) and universities to provide teaching materials and programs that incorporate elements of process safety with the education of undergraduate students and young practicing engineers. AIChE and CCPS recognize that the best way to improve safety in our plants and laboratories is through better process safety education. Although companies have extensive safety training programs experience has shown that presenting process safety concepts as part of the chemical engineering curriculum proves most effective. SAChE develops materials to facilitate the safety education. Students should recognize that this education proposed by CCPS is focused on fundamental technical subjects that should be integrated into the basic education of engineers. The proposed topics include calculating the size of relief valves, computing sources from ruptured vessels or pipelines, calculating downwind compositions of chemicals, understanding the flammable and explosive characteristics of chemicals and dusts, technical safety reviews, inherent safety, hazards of reactive chemicals, etc. (All of these have been covered for 15 years by the Strathclyde University Curriculum.) The products include PowerPoint slide/lecture sets, DVD movies, problem sets with solutions, and case histories. SAChE also trains chemical engineering faculty in total-immersion workshops, focusing on the engineering and management challenges of implementing process safety in a working chemical plant. Since 1996, SAChE has held an annual workshop for university faculty members at industrial sites. The workshop's objectives are to demonstrate the importance of chemical process safety for practicing engineers and to provide information and materials that can be directly used in academic classrooms. The workshop instructors are industrial experts in the area of chemical process safety. The workshops include technical lectures on safety topics, such as reactive chemicals, designs for safety, sizing relief valves, fault tree analyses, and safety reviews, and plant tours and laboratory demonstrations are included in the schedule to give the faculty members hands on experience concerning the theoretical materials that are covered in the lectures. The workshops are only possible as a result of the generous support of several US major organizations and companies.

LESSONS LEARNED

As a safety professional coming into an academic role a number of lessons have been learned. Not all were obvious when starting teaching over 25 years ago! The delivery style is very much individual.

"*Does it work for you and the students*?"

Some problem areas found come from the secondary education curriculum. It has been necessary to teach mathematical manipulation and also to develop some graphical/visual models, for example to show the heat balance round a flame and why a sooty flame is red and a clean flame is yellow.

The modern trends are towards pre-prepared notes/hand-outs; these take time to prepare, maybe three hundreds of hours in writing and then a similar amount arranging them into sets or topics with some visual aid models. However they must not be fixed in time as regulations change and the professional approach changes. The "talk-and-chalk" approach could be modified on a daily basis but written notes have to be reviewed every two years or else they will lose currency, this takes about twenty five hours. Such recent developments include Layer of Protection Analysis (LOPA) and Safety Integrity Level (SIL).

The course has to be real and not totally academic. It is fortunate that the delivery of the notes can be interspersed with personal experiences and so can be made more real.

"*Don't do this as I can tell you it won't work*!"

or

"*This event occurred on a process in my old company* ________"

There are those that might say these are war stories but they add an element of reality.

HAZOP is fundamental to process safety but it is not taught easily as the student has to have an understanding of failure modes of equipment and there effects on operation. If a car breaks down it is sent to a garage and a new plug in unit is fitted. The cause of the failure is never revealed so the driver (student) does not learn how it might be prevented in the future. Further the "as well as" guide words require some fairly lateral thinking and implied knowledge which is not necessarily available. The models that are used must be simple and based on every-day-life or experience. So an alternative is the simple car - refuelling process disguised as a simple fluid transfer activity.

The Chemical Safety Board Videos (CSB) can be used to visualise incidents and the issues surrounding them such as permit to work, fires & explosions, reactive hazards, effect on humans. The one drawback is the relationship to US Federal & State law which needs to be discounted from the case study recommendations and drawn back to UK legislation which may have prevented the incident in the first place. The T2 Laboratories (CSB) incident is a rich source of discussion since it is possible to recognise deficiencies in thermodynamics, heat transfer (foulant build up), fluid flow, scale-up, HAZOP, management of change, relief & control systems, emergency shutdown systems and economics from a chemical engineering syllabus. The UK equivalent of these case studies would be very advantageous.

EXAMINATION

The examination of the courses is imperative but it is not as easy as it might seem. There are only a limited set of possible questions, the art is disguising them! These are:

1. Hazard identification
2. Fires
3. Explosions
4. Dispersion
5. Design features
6. Performance of a SIS or a redundant 2 out of 3 fire-water system
7. Human vulnerability (this can be part of the identification section)
8. HAZOP
9. Analysis of Case Studies

The Future.

There are four main "stake holders" in safety education each have a role to play in maintaining the "Requirements & Resources" to ensure graduate chemical engineers can act as professionals:

1. IChemE
2. Academe
3. Safety Specialists
4. The Industry: Professional Engineers

IChemE sets out the "Requirements for" Safety Teaching through its accreditation procedures and the August 2011 IChemE Guidelines (IChemE 2011) for accreditation of chemical engineering degrees calls for Safety to be demonstrated in 2 specific ways:

- Design and design practice: The creation of a process, product or plant to meet a defined need.
- Students must display competence in chemical engineering design, which requires bringing together technical and other skills, the ability to define a problem and identify constraints, the employment of creativity and innovation. They must understand the concept of 'fitness for purpose' and the importance of delivery.
- University Departments should demonstrate high standards of appreciation of Safety, Health and Environment (SHE) within their teaching of design and related project work.
- SHE Students must acquire the knowledge and ability to handle broader implications of work as a chemical engineer. These include sustainability aspects; safety, health, environmental and other professional issues including ethics; commercial and economic considerations etc. They must be aware of typical legal requirements on personnel, processes, plants and products relating to health, safety and environment. It is expected that this material is consistently built upon and themes reinforced throughout the degree.
- In particular, IChemE expects that all accredited chemical engineering degrees must contain a minimum core content under the European credit transfer system (ECTS) of 5 ECTS of process safety materials, in order to ensure exposure of students to the key principles in this critical area. 5 ECTS consists of 100 hours of student learning which typically means 40 hours of lectures, 20 hours of course note reading, 20 hours for assignments and 20 hours of revision. This represents only 2% of an Integrated Masters course – the bench mark to meet the academic requirements for graduate chemical engineering.

The Strathclyde model represents 4% of examination content and plans are underway to move this to 6% of learning time.

One such content suggestion for IChemE is illustrated below, though it should not be considered definitive:

Programme/unit safety and loss prevention

Aims: To provide introduction to hazard identification and quantification as applicable to process plant.

Syllabus: (Described by department)

Learning outcomes:

Specific underpinning core chemical engineering. Understand the general tools used in designing safe processes. Able to perform simple hazard ID exercises. Able to make assessments of event frequency, magnitude and effect. Understand how risk assessment is carried out. Understand the concept of LOPA. Be aware of legislation governing safety in design and operation of chemical plant etc. Embedded learning (SHE, economic, societal, and ethical). Embedded transferable skill development (skills and personal qualities) Able to recognise and apply good and bad safety practice. Understand the need to lead by example.

IChemE have a number of valuable information in the form of case studies. These are to be found in Loss Prevention Bulletin, Hazard Workshops, BP Training Videos, ICI Safety Newsletters and the Accident Data Base. The latter is still of use but the messages are not easy to extract. Some of the case studies are sufficiently complex that they are not readily transferred into a teaching environment but it should be possible for a small team of "retired" Professional Engineers to distil some of the points that are made and to re-write the case study into a less complex and more readily analysed study. Names could be changed and scenarios simplified (or more information given) such that the undergraduates can identify the causations and make sound recommendations. The costs of all of these documents as new, coupled with the plethora of cases, make it impossible for academics to use them due to budget and skills base. Maybe only two dozen carefully chosen case studies would be needed which in turn could then be part of the examination process. This could be done in about two person week's work.

The IChemE have a duty to ensure that the accreditation process ensures that the team members are competent to assess the standards of the taught subject. It is necessary that the status of the safety element, the detail and the hours expended are reviewed during the accreditation visits. Maybe not all assessors can carry this out in detail.

Academe: They are in fact the "Resources" since it is through them that the "Requirements" are delivered, yet a disturbing picture is emerging of this.

A review of 12 UK and 12 US University Chemical Engineering Departments websites suggests at best 50% of universities feature safety and loss prevention as a named topic in their undergraduate chemical engineering programmes. (Dickson 2011). Taking this deeper, a survey of these same universities demonstrates two separate forms of teaching practices, with an approximate 50% split between those offering safety as a specialist subject and those that only integrate safety material into Unit Operations and other classes, although all those surveyed do confirm that they incorporate the safety topic into Design Projects too. Only three UK departments reported any specialist who was teaching and four using specialist staff, whereas the common practice is to rotate the subject across all teaching staff.

Why is this a problem? To understand this it is necessary to follow the Academic career progression and how to become a top academic:

Stage 1: Complete an Integrated Masters with a grade of 80%, be interested in research or not having found job, take up the offer of a PhD	Salary C£20 k
Stage 2 (3 years later): Become a Post – Doctoral Associate	Salary £25 k
Stage 3 (4 years later): Gain a post as a Grade 8 Lecturer	Salary £37 k
Stage 4 (4 years later): Gain a post as a Grade 9 Senior Lecturer	Salary £46 k
Stage 5 (4 years later): Gain a post as a Reader	Salary £58 k
Stage 6 (4 years later): Gain a post as a Professor	Salary £65 k

But there are few PhD posts in safety, limited research funds in safety; few post-Doctorate posts in safety, that is, there is no academic promotion in safety (save in 4 universities worldwide). For a high powered academic having an interest in safety the logical approach is to become an industrial safety specialist and earn £40–80k. The likely outcome of this is that in 10 years' time, there will be no safety specialist left in universities. Clearly the latter (academe) is in need of support and it is the other three parties who have to drive the progress, since they require an output of competent graduate chemical engineers.

The authors recommend a fresh approach to minimum requirements in safety teaching and an approach of a basic and advanced class should be mandatory. The rational for the delivery of two Safety classes is two-fold; firstly, by paralleling teaching process design and safety principles in Year 2 (3in Scotland), there is opportunity for collaboration and cross referencing material especially plant layout, control/alarm and relief systems. Safety is not therefore seen as a specialist subject and is an integral part of the chemical engineering discipline. It is also a preparatory class for the Year 3 (4 in Scotland) detailed Design Project where students face the challenge of the chemical engineering role of "*design & operate chemical processes efficiently, effectively and economically in a safe manner*" and continue what was applied in Year 4 with a demonstration of HAZOP in their design submission. Secondly, in Year 4 (5 in Scotland), we are preparing students for their future responsibilities as professional engineers and as suggested previously Safety Management is a core responsibility of all engineers no matter their grade, and the students have the opportunity of challenging current industry practice.

The Safety Specialist can make an invaluable input to any safety course. The outline given earlier seems to find agreement with other published documents (Pintar 1999). The specialist can vary this and add areas that might be more appropriate, for example exothermic reactions. The T2 Laboratories case is a classic example of a run-away reaction compounded by a poor design. However run-away reactions are a source of many fatal accidents in spite of venting regimes such as DIERS. It may be a significant step to introduce the concept of "run-away reactions" into a Chemical Engineering course as it may require a re-assessment of the Chemistry input restructuring of the Chemistry teaching, maybe the safety Specialist can devise a solution. The Safety Specialist can comment on the lecture notes once prepared and suggest corrections in detail or content. The safety specialist can also assist in delivering one-off lectures on HAZOP or another key tool. When the author gives such a lecture the students invariably comment that it is refreshing to have someone talking to them who has "seen it, done it and got the Tee shirt". More over it re-enforces the fact that safety is a job with a future and that there are people who have enjoyed the topic so much that they have made it a life-time occupation.

Finally the Safety Specialist can devise case studies for examination or class work. They must be simple and real to a 20 year old. Too much detail will only lead to confusion.

The Professional Engineer has a duty to encourage the next generation of engineers. Not only can they assist as the safety specialist but they can be investing time and effort that will be rewarded by a reduction of the repeated incidents. In some respects they are another layer of the safety specialist. It is beholden upon the experienced professional that there is a practical input to the teaching of safety in a Chemical Engineering course. This can be in various forms:

1. Giving a small series of tutorials to discuss cases
2. Assistance in formulating the course notes
3. Devising realistic examination questions

There is a fifth stake holder namely HSE. If the teaching is correct it should be possible to alter the mindset of the graduate such that every task (design and operation) will be analysed for the safety standpoint as well as economics. This should result in a reduction in "repeat events" and lead to an improvement in safety standards. This has been highlighted by the needs for in-house training of qualified engineers as mentioned in the introduction

PAPER FINALE

"I have but one lamp by which my feet are guided; and that is the lamp of experience. I know of no way of judging of the future but by the past." Patrick Henry 1775 from his famous "Give me Liberty, or give me Death!" speech. To which we would add, "My lamp of wisdom & knowledge has guided me round the pot holes that I passed, hopefully it will shine brightly to show the pot holes on the road ahead"

The final two sentences taken from Crawley 1992 read:

> "*For those who wish to follow the path outlined in this paper – and as responsible scientist/ engineers improvements must be made – it will be of benefit to recognise that all of the frustrating steps trodden in UK will have to be trodden elsewhere. There will have to be bridges built and converts made. The largest is the one between the teachers of chemical engineers and the final user of the product, industry*".

The proof of the pudding is always in the eating. It is a given fact that many of the Strathclyde graduates are recruited into their first job because they have been given a sound training/education in safety and many have made a career in safety as a result. Maybe the University is training the next generation of "safety thinkers".

> "*Give me a child before it is seven and it is mine for life*" – Jesuit Mantra

> "*Give me the student before it is twenty and it will think safety for the rest of its life*" – Authors Mantra

Recommendations:
What we recommend. Or is it a cry for help?

1. IChemE needs to increase the credit weighting of Safety & Loss Prevention to a taught component of 4% of credits at Masters level (and 2% at Bachelors)
2. All the IChemE resources should be free to accredited universities.
3. The IChemE accreditation team should include one safety specialist.
4. All Chemical Engineering courses should have an assessed HAZOP workshop led by a practitioner during the outcomes of the major design project.
5. There should be Safety specialist Visiting Professor in every university Chemical Engineering department

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