HSE
Health & Safety
Executive

EDUCATION OF UNDERGRADUATE ENGINEERS IN RISK CONCEPTS

SCOPING STUDY

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September 1999

Foreword

This report presents the results of a scoping study commissioned by the Health and Safety Executive from Mr John Lee. Prior to undertaking the study, Mr Lee was Head of the Construction, Plant and Machinery Unit of the Technology Division in the Executive's Directorate of Science and Technology.

The report is being published as a contribution to current discussions between the Executive, the Engineering Council, Professional Engineering Institutions and other interested parties on the education of future generations of engineering graduates in concepts of risk assessment and risk control. The study has relied on the willing cooperation of senior engineers in the institutions, industry, universities and regulatory bodies. The Health and Safety Executive is very grateful for the help given by all those who participated in the study. In accordance with the protocol agreed for the study, the anonymity of participants is preserved in the presentation of views.

The conclusions and recommendations offered by John Lee will be valuable in informing consultation on the way ahead. This will be undertaken by the Health and Safety Executive with various representative bodies. Comments by others on the report will be welcomed and should be sent to Head of Technology Division, Health and Safety Executive, Room 315, Magdalen House, Stanley Precinct, Bootle, Merseyside L20 3QZ.

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Executive Summary

In 1998, the Health and Safety Executive held a high level meeting with the Engineering Council to explore what should be done to equip engineers of the future to operate in harmony with the health and safety regulator. The regulatory regime for health and safety recognises that industry, as the creator of the hazards which expose people to risks, is in the best position to control those risks. The non-prescriptive, risk based approach of the regulatory regime is intended to enable industry to devise solutions appropriate to the problem at hand and to adapt these solutions as time goes on to reflect technological change. In seeking to fulfil their responsibilities, duty holders - those with duties under the law - rely heavily on the level of understanding of risk concepts and the practical application of that understanding by their engineers, both in management and in the engineering of products and processes.

The meeting with the Engineering Council considered how HSE could work together with the Council to ensure that engineers, in their education and subsequent professional development, are equipped to fulfil the requirements expected of them. This report represents the outcome of the first stage of that consideration.

The report is concerned solely with the education of engineers in the undergraduate phase of their formation. It presents the results of a study of the essential requirements of the education of engineering undergraduates in risk assessment and risk control concepts. The study sought information and views from structured interviews with a wide selection of representatives and individuals from different parts of the engineering community. The sampled population was necessarily small in view of the need for a comprehensive interview structure. The emphasis was on the quality of the participation rather than on quantity. There were no group discussions.

The study focussed on the gathering and collation of views on:

- the existing situation;
- the situation as desired by the interviewees;
- the extent to which SARTOR 3 standards were felt to reflect the needs and expectations of interviewees.

The main findings were:

- the concepts of hazard and risk are not well understood and differentiated by new graduates;

- each professional institution has interpreted SARTOR 3 in its own way and produced guidance to universities on course content although there are wide variations in the content of the guidance;

- the accreditation system operated by the professional institutions provides a generic assessment of compliance with SARTOR 3 requirements but is unsuited to assessment of the detailed coverage of risk concepts;

- the need to impart risk principles in the teaching of individual subjects should be proportionate to the degree to which uncertainty prevails in the practical application of the subject; a generic, modular presentation was felt to be of limited utility;

- the familiarity of teachers in universities with techniques of hazard identification and risk reduction is variable and many would welcome good source material for integration into subject presentations;

- the provision of such source material by HSE and industry is seen as essential to improvement in standards of presentation;

- the preferred medium for the source material is the Internet. A website giving details of case studies with lessons learned found universal favour;

- although there is much written material already available it was felt that HSE should produce a simple, straightforward leaflet explaining the fundamentals of hazard, risk and risk control aimed specifically at the expected undergraduate level of understanding;

- to be successful the subject must be presented in an intellectually challenging way and this will require the development of high quality teaching material drawing on the resources of all interests;

- computer aided learning using an interactive learning package was considered ideal if used with case studies and hard copy material;

- provision of training opportunities for teaching staff should be integrated with the development of teaching material;

- the provision of the necessary developmental finance is seen as an attractive proposition for industry and government in view of the benefits that will ensue;

- achievement of learning outcomes should be capable of assessment both in course work and in examinations;

- the point was made repeatedly that an understanding of risk issues and the handling of uncertainty is fundamental to the development of expertise in the exercise of sound judgement. This underpins the professional life of engineers and is not confined to health and safety matters.

In summary, there was an overwhelming belief that the material provided and the method of teaching must encourage students to think creatively from first principles and not rely on following codes, standards and rules. This is the intellectual challenge facing undergraduate engineers of the future and their teachers. Its achievement would do much to fit new graduates for the professional life that will face them in the new millennium. It will provide a sound foundation on which training in the course of Continuing Professional Development can build.

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Introduction

1. The philosophy underpinning UK health and safety law and its implementation leads the world in the importance attached to adaptability to technological change. Modern legislation is based on goal setting, with the state setting the standards to be achieved. This leaves considerable - though not total - freedom to the regulated to devise solutions. The non-prescriptive risk-based approach of our regulatory regime is intended to enable industry to devise solutions appropriate to the problem at hand and to adapt these solutions as time goes on to reflect technological change. Industry is required to assess the risks it creates and take action proportionate to those risks to reduce them to a level which is as low as is reasonably practicable. The overall aim must be to keep accidents and ill health to a minimum. To achieve this ideal requires all parts of industry actively to consider, appreciate and understand the importance of risk assessment and risk management as essential requirements of good management. In seeking to fulfil their responsibilities, dutyholders will rely heavily on the level of awareness of risk concepts amongst their engineers, both in management and in the engineering of products and processes - from design, through use and maintenance, to decommissioning.

2. The change to the regulatory regime from prescription to goal setting was initiated with the enactment of the Health and Safety at Work Act of 1974. Now, 25 years later, there is ample evidence that the education of engineers has not generally adapted to the nature of the change. Among the reasons most often advanced are:

- the excessive and relentlessly increasing pressure on the undergraduate curriculum;

- a lack of confidence in university teachers that they can present the subject, at least by comparison with traditional analytically-based subjects; and

- perhaps most importantly, a view that health and safety is not, anyway, an academic subject.

3. The latter reason is based on the belief that health and safety education is concerned with imparting knowledge about the detailed requirements of the law. The belief is, of course, unfounded. There can be no reasonable expectation that a general education can or should attempt to deal with the intricacies of the law and its application. Such an objective is properly reserved for the professional development phase of the engineer's formation, with the need being tailored to the requirements of the individual's role. However, such professional development does need a sound foundation, which includes an understanding and awareness of risk concepts, on which to build. It is proper that this foundation is provided during the education of undergraduate engineers.

4. The foundation needs to be designed so that a learning outcome, based on an understanding of the concept of risk, is achieved. It will thereby permeate the presentation of subjects in all disciplines where the optimum engineering solution is uncertain and, very often, a compromise between conflicting requirements. This is a defining characteristic of the engineer's exercise of professional judgement. The transparency of the resulting decision is improved by systematic and structured assessment of the risks of failure of the potential solutions. Such assessment leads naturally to the practical design of precautionary measures,

by designing out undesirable outcomes and including rigorous measures to defend against remaining risks. Importantly, this process is common for addressing risks to success in all dimensions so that the understanding of risk has much wider connotations than health and safety. In that wide sense, it seems quite proper that it should be fully integrated into the education of an engineer.

5. The study on which this report is based arose as a result of a high-level meeting in April 1998 between the Health and Safety Executive and the Engineering Council. The purpose of the meeting was to take stock of what should be done to equip 21st century engineers for the demands that will be placed on them, as reflected in the preceding paragraphs. The Engineering Council, established by Royal Charter to advance education in and promote the science and practice of engineering, produced a booklet in 1993 'Guidelines on Risk Issues' intended to help engineers to discharge their responsibilities in this area. This HSE study amongst other things took account of that part of the guidance relevant to further and higher education and compared it with the situation today. Little appears to have changed and this report makes recommendations which should lead to the subject being covered adequately in higher education thereby helping the various stakeholders with an interest. The HSE interest is the benefit to all those who might be affected by improved health and safety performance in industry. Employers have a considerable stake in this too and also in the collateral benefits from the improved ability of engineers to handle other aspects of business success. Engineers themselves have a stake since their future employment status may depend on their proven competence on health and safety issues, especially in relation to design. And the Engineering Council has a stake in 'enhancing, strengthening and maintaining a world class engineering work force with the latest skills to enable firms to compete in the United Kingdom and international markets' - a quotation from the Memorandum of Understanding between the Engineering Council and the Government.

6. The background to the study was fully explained in an article by HSE's Director General, Jenny Bacon, in the August 1998 issue of Engineering First distributed to all registrants of the Engineering Council.

7. The results of the study are presented in three Parts. Part 1 surveys the existing situation as represented by the requirements of the Engineering Council's publication, Standards and Routes to Registration (SARTOR) 3rd Edition 1997. Quality of education is monitored against these standards through nominated and licensed bodies, such as professional engineering institutions, who are able to assess candidates for registration and to accredit academic courses. The views of interviewees are presented on the way these arrangements are working in practice with particular reference to health and safety. Part 2 turns to exploring the situation as desired by interviewees. Part 3 draws together conclusions and recommendations for action.

PART 1 THE EXISTING SITUATION

Standards and Routes to Registration (SARTOR) 3rd Edition 1997

General

8. This edition, which is in two parts, introduces new standards of education and initial professional development required for registration with the Engineering Council. Three levels of registration are covered, Chartered Engineer (CEng), Incorporated Engineer (IEng) and Engineering Technician (Eng Tech).

Part 1

9. This is an overarching policy document and defines the criteria and main pathways to registration for all potential registrants across the profession as a whole. It is not expected to change, except after a thorough and infrequent review. There are a number of references to safety, for example Para 2.1, under the section '.......Roles and Responsibilities', states that for all three levels of registration **'All engineers have a responsibility to society with regard to safety and the ethical and environmental impact of their work'.** However this, and some other references, refer to general requirements to be fulfilled by registrants as conditions of initial and continuing registration. These requirements are reflected appropriately in the standards of educational formation, continuing professional development and of professional practice. For the purposes of this scoping study it is the standards applicable just to the educational phase that will be considered.

10. Information on the educational base requirements is given in section 4 of Part 1. For all sections of the register there is a stated requirement that 'The educational base should be founded in the appropriate branch of technology, supplemented by communication skills, use of information technology, business and management, **and health, safety and environmental work'.** When addressing each of the sections of the register in turn further reference to health and safety is found only in the section for incorporated engineers which states that a degree designed for accreditation against the IEng requirement should cultivate (among other things) '**A professional attitude towards** matters such as the design, reliability and maintenance, product quality and value, marketing, and **safety'**. Much greater detail is found in Part 2.

Part 2

11. Part 2 gives a detailed picture of the current registration procedures and requirements and is issued in three separate sets of documents, one each for CEng, IEng and Eng Tech. Since Part 2 is intended to take account of the changing contemporary scene it will need revision more often than Part 1. This provision means that the conclusions of this scoping study and any other projects which HSE may care to carry out relevant to the standards and the means for accreditation could be used to influence future issues.

12. Each set, under the section on roles and responsibilities, more or less repeats the statement made in Part 1. **'All engineers have a responsibility to society with regard to safety, to their legal and contractual obligations, and for the ethical and environmental impact of their work'.** The only difference is the additional reference to legal and contractual obligations. But as with Part 1 this statement refers to a condition relevant to registrants and

not specifically to a level of attainment by a graduating engineer. There are further standards referring to health and safety in other sections on 'competence and commitment' but for the purposes of this study only those references under the heading of 'Educational Base' will be examined.

<u>Chartered Engineer</u>

13. The requirements for registration as a Chartered Engineer contain both direct and indirect references to health and safety risk management.

14. Under the heading 'standards and expectations' it is stated that an accredited degree course is expected (among other things) **'to ensure that the social, legal, economic and political contexts within which engineers operate are understood'**. Clearly this must include safety although it is not mentioned explicitly.

15. Under the heading 'Course content, structure and balance' there is a further list of items which are more explicit in their relevance to safety. These are '**<u>An understanding of</u>: constraints in applying technology to create products**. **<u>A knowledge of</u>: the methods of providing information to others within engineering. <u>An awareness of</u>: Quality systems and management in engineering; requirements and responsibilities of leadership; obligations to work safely and to apply safe systems of work** (this appears to be an expected behaviour rather than a safety awareness for a design engineer); **risk analysis; the financial, economic, social and environmental factors of significance to engineering; the relevant legal, statutory and contractual obligations; and the broader obligations of engineers to society.**

16. Perhaps the most significant statement is made in a paragraph which amplifies the content of MEng compared to BEng courses. This states that there would be **'a broader and more general educational base in the MEng to provide an educational foundation for leadership, social and business awareness and for a wider appreciation of risk, environmental, health and safety and political issues'.** A graduate from a BEng course would need to achieve this broader and more general educational base by undertaking a suitable Matching Section of not less than one year's duration.

<u>Incorporated Engineer</u>

17. The references to issues relevant to H&S risk management are not very different to those for Chartered Engineer.

18. Under the heading 'standards and expectations' the words are identical.

19. Under the heading 'Course content, structure and balance' the list is similar but excludes **requirements and responsibilities of leadership** and **risk analysis.**

20. It is noted that the same words are used to differentiate BEng degree courses and HND courses as were used to differentiate MEng and BEng courses. Because HND courses are judged to be likely to be deficient in providing the **'wider appreciation of risk, environment, health and safety and political issues'** students successfully completing their HND would need to take an additional year of study before they were adjudged ready for registration as an Incorporated Engineer.

Engineering Technician

21. This report does not cover Engineering Technician, the educational base for which is not a university degree. However some of the conclusions drawn could apply equally to BTEC, GNVQ and equivalent courses.

Summary

22. The above covers the extent to which SARTOR 3 specifically refers to health, safety or risk. However, the SARTOR 3 document does point out that it contains only general statements about the technical and non technical content which should be present in engineering degrees. Appropriate institutions are charged with preparing a specification for each discipline giving guidance on the knowledge, understanding, abilities and awareness expected to be developed through an accredited course. The way in which institutions have responded will now be examined .

Professional Engineering Institutions

General

23. Engineering institutions may be either nominated or nominated and licensed by the Engineering Council. A nominated body is one which is recognised by the Engineering Council to propose suitably qualified persons for registration. Licensed bodies may, in addition, accredit educational courses and arrangements for initial professional development which meet the Council's criteria. It is a selection of those from this second group which were examined for the purposes of this study. Those selected were:

> The Institution of Chemical Engineers;
> The Institution of Electrical Engineers;
> The Institution of Mechanical Engineers;
> Those institutions, including the Institution of Civil Engineers and the Institution of Structural Engineers, whose course accreditation is overseen by The Joint Board of Moderators; and
> The Institution of Incorporated Engineers.

24. The next paragraphs cover institutions' guidelines to universities for courses starting on 1 September 1999, the first date the SARTOR 3 standard applies. To date each institution has interpreted SARTOR 3 in isolation. However the largest institutions are, through membership of the Inter-Institution Collaboration on Health and Safety Group, developing a Template for use by all those in the process of course design and accreditation of engineering courses. This study complements that Template.

Institution of Chemical Engineers

25. The I Chem E guidelines on the accreditation of chemical engineering first degree courses contain fairly explicit advice on the expected safety content. **'A substantial and fully integrated design project........which should include.......safety, environmental and energy factors'** is described in the section relevant to the MEng course although nothing so specific is quoted for the BEng course. For illustrative purposes only, an example outline for a MEng and BEng course is provided showing the number of credits assigned to each topic. In both courses **20 credits are allotted to 'safety and environment' with a further up to 40 credits for the project out of a course total of 360 credits.**

26. There is more detail in the December 1998 edition of the guide for assessors and university departments entitled 'Accreditation of University Chemical Engineering Degree Courses'. In this document the following general references are made relevant to health and safety:

> a) 'The teaching of the course must develop **an awareness of the necessity of safe design.....;**
> b) Fundamental technologies must be complemented by and integrated with appropriate studies **including the legal framework,............and quantitative risk analysis;**
> c) **To ensure that an understanding of safety and loss prevention pervades the undergraduate course, it is considered necessary to include a short series of lectures in the first year'.**

27. Specifically under the design project the guidelines indicate that the project should serve (amongst other things) to encourage the application of chemical engineering principles to problems of current and future industrial relevance including safety and environmental issues. This is expanded by requiring reference to be made **'to Health and Safety at Work Act' with six very specific safety related issues under the heading 'Operability, Reliability and Hazard Analysis'.**

28. The paragraphs in the Guidance on **teaching of safety and loss prevention** is included in this report at Appendix 1.

<u>Institution of Electrical Engineers</u>

29. In contrast to the I Chem E there is very little expansion in IEE's accreditation guidelines 'Accreditation of Engineering Degree Courses - IEE's response to SARTOR 3rd Edition'. There are four lists under the headings Understanding, Knowledge, Skills and Awareness. The only reference to health and safety comes under the latter which says **'relevant legal, statutory and contractual framework, including health and safety and employment law'.**

30. In another document 'Membership Brief M5 - Training Requirements' there is a section referring to health and safety. However, these are requirements for membership which could be gained during the period of initial professional development and not necessarily during the degree course.

<u>Institution of Mechanical Engineers</u>

31. I Mech E's interpretation of SARTOR 3 educational requirements contained in a document entitled 'The Educational Base' mentions health and safety and associated subjects

in a number of sections but without any detail. The requirements differ little between MEng and BEng programmes.

32. The first reference is made under the sub heading ‘The output’. This is divided into four lists for knowledge, understanding, ability and awareness. Under ‘awareness’ three separate references are made as follows;

> **obligations to work safely and apply safe systems of work;**
> **risk analysis techniques;**
> **relevant legal, statutory and contractual obligations.**

33. The second reference comes under the sub heading ‘Programme design’. Again there are a number of headings below this such as broad education; versatility; depth of understanding; imagination, creativity and innovation; and finally leadership. It is under the last heading that the statement is made ‘**To enable the graduate to progress rapidly to a position of leadership, business and management are essential components of the degree that need integrating with the technical topics. The aim is to develop the student’s AWARENESS of the organisation of industry, finance, human behaviour, and the engineer’s responsibility for health, safety and environmental issues’.**

34. The final reference is found under the list of mandatory subjects in the section on ‘programme content’. Included are **human behaviour; health and safety and environmental issues.** The final sentence differentiates between MEng and BEng degrees with the words ‘In the MEng programme these subjects should be taken to a greater depth than in the BEng (Hons) degree’.

35. In summary I Mech E are advising that for a mechanical engineering first degree to be accredited it must have content which will provide the student with an awareness of health and safety issues. How this is interpreted by Universities and Accreditation Boards will be investigated later.

<u>Those Institutions, including the Institution of Civil Engineers and Institution of Structural Engineers, covered by the Joint Board of Moderators</u>

36. Content and accreditation of engineering degrees for the above group of Institutions is undertaken by the Joint Board of Moderators(JBM). In contrast to the I Mech E and IEE guidelines the JBM guidelines give, in considerable detail, the expected content of courses and differentiate quite clearly between MEng and BEng courses.

37. There are general guidelines and a number of annexes. In the general guidelines under academic requirements for both MEng and BEng courses it says **‘ A deep understanding of health and safety issues and the need to operate safe systems is mandatory for practicing engineers and courses must expose students to these issues and seek to extend the analysis to the legal requirements as well as to risk analysis’.**

38. What outcomes are expected in support of the statement are listed in an annex entitled **‘Guidelines for the teaching of safety issues to undergraduates’.** This is very detailed and is reproduced at appendix 2. The interpretation of its content was examined by interviews with University lecturers to be discussed later.

Institution of Incorporated Engineers

39 Compared with the institutions covered so far, the Institution of Incorporated Engineers is very new. It was formed in 1998 by the amalgamation of The Institution of Electronics and Electrical Incorporated Engineers, The Institute of Engineers and Technicians and The Institution of Mechanical Incorporated Engineers.

40. SARTOR 3 very clearly differentiates between Chartered and Incorporated Engineers. This Institution and its role will, therefore, be of great significance in determining the way this differentiation of future Incorporated Engineers fulfils the expectations of SARTOR 3.

41. Their guidelines on degree programmes for Incorporated Engineers make scant reference to health and safety. A single statement is made, **‘The Institution supports The Engineering Council’s view that the most important aims of degree courses for Incorporated Engineers should be to develop..........a professional attitude towards.............safety.’**

42. There are no other direct references but health and safety could indirectly be covered by the catch all of ‘management studies’ and ‘a substantive engineering project’. This was pursued in interviews with members of the Joint Accreditation Board of which the IIE is a Member Body.

Summary

43. It will be clear from the above that the guidelines provided by professional engineering institutions on the extent to which health and safety risk concepts should be covered by an accredited degree programme vary considerably. The way in which the university system interprets the guidelines and the effectiveness of accreditation boards in ensuring the guidelines are met will now be examined.

Universities and the Accreditation System

General

44. During the study comments were received from both academic and industrial members of Institution Accreditation Boards or Panels. University professors on the receiving end of accreditation visits were also invited to comment.

45. The system varied from institution to institution. Accreditation visits are usually made by a team consisting of independent academics and at least one industrialist. Course content, facilities and staff interviews take place some on a predetermined basis others on a random audit where Universities are informed of those aspects that would be examined only the night before.

46. The difficulty faced with regard to any assessment of whether risk issues are incorporated satisfactorily is the great variety of courses offered even within a single discipline. This is less difficult for chemical engineering courses where accreditation details are quite specific. For many electrical and mechanical engineering courses, the focus of which can vary considerably, the current accreditation guidance and practice is not sufficiently detailed to ensure courses cover health, safety and risk adequately. There are exceptions, for example electrical

engineering courses on safety critical systems naturally devote a considerable period on risk. For construction related courses accredited by the Joint Board of Moderators considerable work has gone into producing detailed guidelines against which courses starting in September 1999 can be assessed.

Summary

47. Accreditation guidelines cannot be generic because of the huge variety of different courses. However, advances have been made in response to SARTOR 3 although courses for accreditation to the new standard only start in September 1999. Furthermore, the results of this study would be expected to give an improved focus on health and safety requirements and associated learning outcomes in terms of risk concepts. In particular the recommendations relating to the provision of teaching material and case studies should enable the accreditation system to better address risk issues than has been possible in the past. This material will, together with the Template produced by the Inter-Institutional group on Health and Safety, make a considerable contribution to improving the hazard and risk concept content in engineering courses.

PART 2 _THE SITUATION AS DESIRED BY INDUSTRY, THE INSTITUTIONS, REGULATORS AND OTHERS

Scope and Structure of the Study

48. Information on the extent to which risk concepts are currently covered in courses, the expectations of industry and the extent that SARTOR 3 might influence changes, was sought from representatives of institutions and their accreditation boards and also from individuals working in industry and universities. Views were also obtained from independent consultants and from those employed by regulators.

49. SARTOR 3 standards and the subsequent guidance produced by institutions in response to this 3rd edition are relevant only for courses starting September 1999. Thus the information from this study mainly reflects the perceptions of interviewees on what they desire to see rather than what will (eventually) be achieved when SARTOR 3 has taken full effect.

50. To ensure the discussions were structured a general question set was developed and agreed by limited consultation both within and outside HSE. A letter of introduction and the question set, see appendix 3, were then sent to selected individuals drawn from interest groups as described above. The wording varied slightly depending on the interest group.

51. In all 35 persons were interviewed from 1 or more interest groups as shown in table 1.

	Chem	Civ/Struct	Mech	Elec	Marine	Other	**Total**	Accred[1]	IEng[1]
University	3	5	2	2		1	**13**	*6*	*3*
Industry[2]	1	1	1	3	1	4	**11**	*2*	*1*
Regulators[3]		1		1	2		**4**		
Consultants	4	1	1	1			**7**		
Total	**8**	**8**	**4**	**7**	**3**	**5**	**35**	*8*	*4*

Table 1

Notes to table 1

1. The numbers in the ‘Accred’ and ‘IEng’ columns indicate additional interests and are not included in the ‘Total’ column;
2. Industry was classified by its predominant discipline;
3. Regulators were not discipline specific

52. The context for the study as set out in Jenny Bacon’s article in Engineering First was provided to all interviewees in advance. Those interviewed, with the exception of the Chemical Engineers, were almost unanimous in support of the statement ‘that many engineers were graduating without a basic awareness of the importance of health and safety and an understanding of risk concepts’. Chemical Engineers do cover hazard and risk extensively but some of the comments made could well be useful for Chemical Engineers to consider. A selection of the most pertinent comments made during the interviews are listed below.

Perceptions from Universities

53. A selection of the most pertinent comments made during interviews with University staff are listed below:

- ‘We have worked hard to interpret SARTOR 3. Detailed guidelines are now available for both IEng and CEng courses but it will be some time before any effects are felt as new courses start in September 1999.’

- ‘Universities educate, industry trains.’

- ‘On accreditation visits it is invariably the industrialist who will enquire about risk, health and safety’.

- ‘No chance of meeting your wishes to include it as a standard requirement; courses are already overloaded not least because of the poor standard of A level maths and the need to cover developing technology. Nevertheless we recognise that there are legal responsibilities on engineers and generally things could be improved’.

- ‘We have reservations as to the practicability. Syllabus is already full and there are pressures also to include quality and financial aspects. Also the content would vary as the knowledge required would be course dependent. The more industry could take on, leaving universities to teach the technical subject, the better’.

- ‘Our courses cover the sort of risk concepts referred to but not explicitly. Perhaps greater effort is needed to make students aware that what they are doing is in fact a risk assessment. This is particularly appropriate during project work’.

- ‘Ability to include risk concepts is very dependent on staff competencies. One way would be to encourage certain staff to become risk ‘champions’ ’.

- ‘From a chemical engineering viewpoint I found the article surprising. Thought I Chem E and their relevant groups had done a good job with course guidelines’.

- ‘90% of our chemical engineering students spend 12 months in industry almost certainly working on a safety case. This enabled theory taught during first 2 years to be put into the practical context’.

- ‘We run sandwich courses where the second year is spent in industry. This provides students with an excellent opportunity to appreciate the importance of understanding risk and their experience can be related to their remaining two years and their final year project’.
- ‘For everyone in engineering, space in the curriculum is extremely tight. There are various bodies trying to insist on material being included but it is just not possible’.

- ‘Risk education needs are very different between CEng and IEng. Having said that, in chemical engineering risk and risk control are covered pretty extensively’.

- ‘Difficult to teach risk concepts without experience of industry to put it into context. Some teachers have transferred from industry to teaching and are more able than those who, say, have been teaching for 20 years or more’.

- ‘We make use of local industries. There is an industrial liaison committee which is kept up to date by changing one third of the membership each year’.

<u>Perceptions from those outside Universities</u>

54. A selection of the most pertinent comments made during interviews with people outside University are listed below:

- ‘The best practical solution should involve risk minimisation but not at excessive cost. The engineer is required to assess risks and take action to reduce them to a level which is reasonably practicable’.

- ‘Article too focussed on innovation/manufacturing/design. Must be borne in mind that risk concepts are equally important to the Incorporated Engineer whose focus is more on maintenance and use’.

- ‘Engineering courses are heavily loaded with lectures and the technical material to be covered is extensive’.

- ‘It is not possible for Universities to provide a ‘ready to run product’ despite industry’s wish for such. Industry must play its own part by helping to put the theory into the practice that is relevant to the particular sector’.

- ‘The definition of ‘engineering’ is important. Universities are good at teaching engineering science but engineers in practice must constantly seek a solution that is a compromise dictated by the constraints in which they are working. Health and safety risk is one of many constraints and it is this aspect of engineering that the University teacher finds difficult to teach’.

- ‘Risk management is an underlying concept that underpins everything an engineer does’.

- ‘Managing risk is so fundamental to the work of every engineer (and indeed many other professions) that it could be argued that universities should teach this as a core subject instead of more specialised engineering science topics which may be relevant only to the few’.
- ‘Graduate engineers are very knowledgeable and can apply what they know well provided there is a standard, specification, rule or other formulated approach available. What they seem to lack is the ability to think from first principles’.

- ‘The fundamental problem is applying the theory in practice. The only chance a student gets is during project work and still there is too much emphasis on calculations’.

- ‘Courses should be designed so that undergraduates both learn the science of engineering, which the university teachers are equipped to do well, and the practice of engineering which generally can only be provided by external visitors from industry’.

- ‘Legislation that now requires safety cases to be produced highlights the inability of graduate engineers to think for themselves. The ‘what if’ question seems particularly perplexing for them’.

- ‘Whatever is included in courses on health and safety risk, it must be examinable otherwise students will just not do it’.

- ‘Graduates seem to lack a general understanding of what engineering is in practice. They should be more aware that just because the computer calculation produces a result to several decimal places this does not make the solution right. Methodologies are helpful but not absolute’.

- ‘A graduate engineer’s knowledge of hazard and risk varies from discipline to discipline and from university to university. Chemical engineering graduates are pretty good although they could perhaps know more about hazardous chemicals. Mechanical engineering graduates know very little’.

- ‘Safety regulation has changed and engineers need to be educated to cope with that change. Past practice was compliance with Codes of Practice and rules. The new goal setting practice requires engineers to think more carefully before they do anything. Safety case regime forces people to think’.

- ‘Risk is something appropriate to almost everything we do, not just engineering. Perhaps the concept could be introduced at primary school, followed up in secondary school and then taught in context at university. Expand the 3Rs to 4Rs’.

- ‘There is inadequate understanding of general principles such as ALARP. The required thought processes are not ingrained into the ‘bright young things’ ’.

<u>Universities’ Capability to Teach Risk Concepts</u>

55. There was unanimous agreement that Universities and industry each had an important role to play before an engineer would be able to effectively identify hazards, carry out a risk assessment and subsequently select the best solution. The study tried to determine the level to which it was practical for a university to educate students in risk concepts. Nobody expressed the opinion that a university could do any more than lay a basic foundation notwithstanding that chemical engineering courses were an exception in that regard. However, the consensus was that it is for industry to build on the educational foundation, developing the expertise that was necessary and pertinent to the particular sector or industry. **What was very clear from the responses was that students needed more skill in thinking for themselves**.

56. The other almost unanimous opinion expressed by both those in the system and those outside was that the current situation could be improved.

<u>Discrete Module v Unifying Theme</u>

57. Views from those teaching in universities differed over whether the teaching should be through discrete modules or as a unifying theme. A selection of typical responses with reasons for those responses were:

- ‘A discrete module would be necessary early in the course to explain the legal framework and the basic principles, then throughout the rest of the course the application of those principles would be explained if they were applicable to the particular lecture’.

- ‘It is impossible to be specific. The way risk concepts are taught would very much be course dependent’.

- ‘If a separate health and safety risk module was introduced it would be the kiss of death for the subject’.

- ‘Introduce the subject during the induction phase when all engineering students are following the same format. Then expand the subject as appropriate to the particular discipline when students specialise’.

- ‘The subject should be taught as a unifying theme. We have the good fortune to have an expert on campus’.

- ‘Teaching is different between a general degree and those specifically related to design. The latter have safety taught as a unifying theme. The second year is spent in industry and the experience gained is related to their project work and other studies’.

- ‘For all disciplines dispersal through the course would be preferred to a specific module. At the very least all students should end up with an awareness of the subject’.

- ‘For many universities it would be impractical to teach risk concepts as a unifying theme as this would require all teachers to be competent in the subject. Unfortunately many have no experience of industry and their lack of understanding of the work environment means that they would be unconvincing to the student’.

- ‘The basic principles of the subject should be introduced in an early lecture then those principles could be expanded and applied throughout the course as appropriate’.

- ‘The subject should be taught later in the degree course when the student has a better grasp of other considerations such as finance, economics, quality etc. Otherwise the subject will have little meaning to the student who will be unable to put it into context’.

- ‘Guest lectures by those who are expert on the subject would be better than trying to fudge it throughout the course when teaching quality is not good’.

- ‘An early basic module is necessary when things like consequences, likelihood, ALARP, risk v safety are planted into students’ brains quickly’.

- ‘It would be more beneficial to have a module on risk in the first year which is relevant to all aspiring engineers than a module on some specialist parts of engineering which may only be appropriate to the few’.

- ‘Irrespective of whether a separate module or unifying theme is preferred some time spent in industry during the course is essential. This may either be in the form of a sandwich course or vacation work or local agreements for placements in industry. This requires the co-operation of industry but they will not get the product they desire without making a contribution'.

- 'Teaching as a unifying theme would be preferred but those doing the teaching must be competent. If no such general competence is available then the module approach would be better. The module should be taken early on when the brighter students will be able to apply the concepts through the course'.

- 'There should be a discrete module on risk. However the desired outcomes need setting down clearly because currently there is no general understanding. It should be understood for example that in the short term risk assessments could cause cost escalation of a project'.

- 'Risk should be taught as a unifying theme but only after an introductory module which would cover other relevant risk issues such as quality, cost, environmental impact'.

- 'A bland module on health and safety would be useless. The message needs to be given by graphic illustration of what goes wrong and this is difficult without the incident being in context. Teaching ALARP is important'.

- 'A discrete module may be difficult but the subject could be included in Engineering Application 1(EA1) or the management module. Even then it would be desirable for a practising engineer to provide the teaching so that the subject can be put into context'.

<u>Relative Importance of Specific Aspects</u>

58. The next section of the study tried to obtain a view on what aspects of risk assessment were considered to be the most important for graduating engineers if risk concepts were to be taught. To do this opinion was sought as to whether graduating engineers should have an appreciation or an understanding of the following seven topics and whether anything had been omitted from the list.

1. The concepts of hazard and risk;
2. The principles underlying the process of hazard identification and risk assessment;
3. The methodologies involved in hazard identification and risk assessment;
4. The hierarchy of risk control;
5. The benefits and application of control concepts eg inherent safety, defence in depth, redundancy, diversity and any others;
6. The human behavioural aspects of risk management;
7. The criteria (legal, technological, economic, ethical) for making a balanced decision;
8. Any other topics not covered above.

59. The terms 'appreciation' and 'understanding' were used to distinguish two levels. 'Appreciation' was the lower level where students would have an awareness sufficient to be able to refer to something. 'Understanding', on the other hand, would require the student to have sufficient knowledge to be able to explain something.

60. The results were not conclusive although trends emerged. The table below shows the responses from academia separate to those from outside academia to try to ascertain whether there was a different view from each group. With one exception both groups responded

similarly. The other segregation of results was between those answering on behalf of CEng courses and those on behalf of IEng courses. All results are shown in table 2.

	Academia		Others		Total CEng		Total IEng		Overall total	
	A	U	A	U	A	U	A	U	A	U
1. Concepts of hazard & risk	2	11	5	17	6	25	1	3	7	***28***
2 Principles	3	10	7	15	8	23	2	2	10	***25***
3 Methodologies	9	4	15	7	20	11	4		***24***	11
4 Hierarchy of risk control	9	4	13	9	19	12	3	1	***22***	13
5 Benefits and application	5	8	15	7	17	14	3	1	***20***	15
6 Human behaviour	11	2	14	8	21	10	4		***25***	10
7 Balanced decision criteria	7	6	10	12	13	18	4		17	***18***
8 Other topics (see para 61)										

Table 2

61. During the course of the interviews, interviewees were asked whether any other topics might be included. The overwhelming majority believed the list was very comprehensive but there were some suggestions, as listed below, which are worthy of consideration in any subsequent work.

Corporate v individual risk - need to be aware of the difference between these two to fully understand an engineer's responsibility;

Raw risk v controlled risk - an understanding of the difference between the original risk (raw risk) and the residual risk when the raw risk has been controlled (controlled risk);

Human intervention in risk mitigation - an awareness that human action not only can lead to disasters but can contribute to risk mitigation;

Risks associated with creativity - an understanding that engineering creativity can not take place without introducing some risk, and

'What if' scenario exercises - would encourage students to think from first principles and under conditions of uncertainty.

62. There were a number of respondents who found generic responses difficult. They pointed out that, as with other aspects of the study, the level of appreciation of some of the above list of topics would be dependent on the subject of the course. Also for the fifth item on the list several respondents suggested students should understand the benefits but need only appreciate how to apply control concepts.

Improvements

63. It was generally accepted by both teachers and others that some improvement was desirable although some in chemical engineering expressed the opinion that they covered the subject adequately.

64. A general view was that producing a book on the subject specifically for teachers would not serve a useful purpose. Material had to be presented in a format which put the subject into context. Some teachers in university, for example those who have recently transferred from industry or those that have a close association with local industry, are familiar with the practice of hazard identification and risk reduction and can put their lectures into context. Many, however, are not and there was wide support for having available good source material on the subject.

65. The preferred medium for the source material was the Internet. A website giving details of case studies with lessons learned found universal favour. In addition it was also felt necessary for HSE to produce some simple, straightforward leaflet explaining the basic concepts of hazard, risk and risk control aimed specifically at the undergraduate expected level of understanding. It was accepted that there was much written material on the subject but that many found this too detailed and confusing.

66. It was considered desirable to have one day courses for teachers on the fundamentals of hazard identification, risk assessment and risk control at various locations, perhaps facilitated by HSE. In addition visiting lecturers from industry could provide the experience - based teaching not able to be provided by many teachers.

67. Computer aided learning with an interactive package had also been found useful in teaching other subjects and could be used in conjunction with or instead of any Internet material.

68. A period spent in industry had proved very worthwhile at some universities in enabling students to put the theory taught at the university into context and practice. Sandwich courses, where one year is spent in industry, provided the best opportunity but it is appreciated that this luxury was not possible for all students. At the least students should be encouraged to spend summer vacations carrying out some small project in industry to which they could apply the concepts of risk assessment. Maybe even a compromise between the year in industry and summer vacation work could be arranged. A three or four month industrial placement as part of the course could be considered.

69. To achieve the above, some investment both in time and money would be essential by both HSE and industry. Industry would need to further invest in making available suitable summer vacation work or work placements.

PART 3 _CONCLUSIONS AND RECOMMENDATIONS

Conclusions

70. The concepts of hazard and risk are not well understood and differentiated by new graduates and SARTOR 3 could give a more detailed steer. However compulsory module material would not be welcome.

71. Each professional institution has interpreted SARTOR 3 in its own way and produced guidance to universities on course content although there are wide variations in the content of the guidance.

72. The accreditation system operated by the professional institutions provides a generic assessment of compliance with SARTOR 3 requirements but is unsuited to assessment of the detailed coverage of risk concepts.

73. The need to impart risk principles in the teaching of individual subjects should be proportionate to the degree to which uncertainty prevails in the practical application of the subject; a generic, modular presentation was felt to be of limited utility.

74. The familiarity of teachers in university with techniques of hazard identification and risk reduction is variable and many would welcome good source material for integration into subject presentations.

75. The provision of such source materials by HSE and industry is seen as essential to improvement in standards of presentation.

76. The preferred medium for the source material is the Internet. A website giving details of case studies with lessons learned found universal favour.

77. Although there is much written material already available it was felt that HSE should produce a simple, straightforward leaflet explaining the fundamentals of hazard, risk and risk control aimed specifically at the expected undergraduate level of understanding.

78. To be successful the subject must be presented in an intellectually challenging way and this will require the development of high quality teaching material drawing on the resources of all interests.

79. Computer aided learning using an interactive learning package was considered ideal if used with case studies and hard copy material.

80. Provision of training opportunities for teaching staff should be integrated with the development of teaching material.

81. The provision of the necessary developmental finance is seen as an attractive proposition for industry and government in view of the benefits that will ensue.

82. Achievement of learning outcomes should be capable of assessment both in course work and in examinations.

83. The point was made repeatedly that an understanding of risk issues and the handling of uncertainty is fundamental to the development of expertise in the exercise of sound judgement. This underpins the professional life of engineers and is not confined to health and safety matters.

84. The material produced and the method of teaching must encourage students to think creatively from first principles and not rely on following codes, standards and rules. This is the intellectual challenge facing students and the universities and, if achieved, silence one of the frequent criticisms levelled by industry.

Recommendations

85. A working group consisting of representatives from HSE, institutions, universities and industry should be set up to produce the supporting material identified in the above conclusions. The work of the group should be managed by an independent interest such as the Hazards Forum.

86. A company should be identified and commissioned to convert the output from the above working group into high quality teaching material.

87. Funding for this work should be sought from government and industry as these benefit most from the improved level of understanding engineering graduates will have about risk concepts as they begin their careers.

88. The Engineering Council should provide a more detailed steer to institutions on the expected levels of understanding of concepts of hazard and risk in Part 2 of SARTOR 3 when it is next revised.

89. All professional institutions should review and revise if necessary their guidance to universities on the 'concepts of hazard and risk' content of courses in light of this report and the template produced by the Inter-Institution Collaboration on Health and Safety Group.

90. HSE should produce a simple, straightforward leaflet explaining the fundamentals of hazard identification, risk assessment and risk control aimed specifically at the expected undergraduate level of understanding.

91. HSE should consider the possibility of running one day courses for teachers on the fundamentals of hazard identification, risk assessment and risk control at various locations.

92. Universities and local industry should organise visiting lecturers to provide the experience based teaching not able to be provided by many teachers.

93. Universities and local industry should co-operate to provide industrial placements or summer vacation work so that a small project can be carried out when students could apply the concepts of risk assessment.

SUGGESTIONS FOR THE TEACHING OF SAFETY AND LOSS PREVENTION TO UNDERGRADUATES (By a joint IChemE safety and loss prevention and education working party)

The subject should be brought up early in a degree course so that the student develops an awareness of essential safety requirements. Unfortunately, at this stage the student will not usually have the necessary knowledge or experience to understand many of the engineering principles and equipment used in the process industries. It is therefore suggested that dedicated material should be taught in two stages:-

(a) Introductory Material

To ensure that an understanding of safety and loss prevention pervades the undergraduate course it is considered necessary to include a short series of lectures in the first year. These need not be taught as a separate subject but may be part of an "Introduction to Chemical Engineering" type course. Ideally they should be examinable, perhaps as one section in an exam paper. Topics to be included in this section are:-

- The management of safety
- The difference between safety and loss prevention
- Historical perspective
- Development of legislation
- New perspectives (societal risk, proactive approach, inherent safety)
- The interface between loss prevention regulation and profitability
- Environmental protection

The legal requirements should not be overstressed as they may limit the internationality of the degree qualification.

The required time for lecturing is believed to be between 3 and 5 hours and to ensure that a reasonable understanding is obtained a piece of course work, probably an essay, should be produced. A section of an exam paper could usefully relate to the subject.

(b) Detailed Material

The exact timing of this material will vary depending on the organisation of the individual undergraduate course. The student should have had some experience of industry and have opportunities to practice the techniques that will be taught, probably in the design project. The topics to be covered are:

> Legislation; Management of Safety; Product safety as a factor which affects design; Systematic identification and quantification of hazards, including hazard and operability studies; Human factors in safety containment of highly hazardous media including GMOs; Pressure relief venting; Emission and dispersion; Fire; flammability characteristics; Explosion; Toxicity and toxic release; Safety in plant operation, maintenance and modification; Electrical area classification; Measurement and control of noise and heat; Loss prevention; and Personal safety.

Assessors should satisfy themselves that students gain a reasonable understanding of most of the topics, while realising that individual universities will emphasise the areas in which they have specialised knowledge.

The guidance also includes a table which sets out topics to be included in undergraduate Chemical Engineering courses relating to Health, Safety and the Environment that the Institution considers to be required. It is in the form of a matrix that provides a check list for course designers.

GUIDELINES FOR THE TEACHING OF SAFETY ISSUES TO UNDERGRADUATES (taken from Annex C of the guidance provided by the Joint Board of Moderators)

1. *PRINCIPLES*

1.1 That teaching on safety and risk should as far as possible be an integral part of all other teaching, with particular emphasis in design and management studies.

1.2 That design concerns the design of systems (including people and organisational issues, life cycle management etc.) and is not just about the design of artefacts (e.g. a bridge).

1.3 That the JBM should concern itself with the achievement of learning outcomes rather than an adherence to some standardised syllabus.

1.4 That the learning outcomes be described in terms of levels of attainment as specified in the training objectives of graduate trainees of the ICE i.e. the JBM is concerned with four levels of knowing about safety and risk i.e.

Level	Description
A	**A**ppreciation and awareness, be able to refer to something
K	**K**nowledge and understanding, be able to explain something
E	**E**xperience, be able to do something with help and closely supervised
B	A**B**ility - be able to do something without supervision

1.5 That safety and risk issues involve deep and fundamental ideas concerning what we know and how we behave and they need to be related to the student's own experience.

2. *TEACHING AIMS AND LEARNING OUTCOMES*

Some suggested learning outcomes are set out in Section 4.

The overall aims of teaching in safety and risk should be to enable the student to understand that:

2.1 risk and safety issues are all pervasive,

2.2 safety is about safeguarding life and health

2.3 there are safety implications of risk being inherent in all decision making

2.4 risk and safety are complex i.e. that systems are not easily predictable and therefore must be monitored and managed to achieve purpose.

(Note that this is in contrast to the scientific ideal, implicit in much of our teaching, that some 'truth' is being predicted. This means that the approach is one of using formal techniques not only to predict but as (partial) evidence in the decision making process. Many accidents result from the unforeseen and unintended consequences of human action).

2.5 there may be safety and environmental risks

3. *COMMENTARY*

3.1 Engineering is about making systems that are fit for purpose (i.e- have quality).

3.2 A system is not fit for purpose if is unsafe

3.3 Safety is therefore part of quality. Management for safety is therefore part of management for quality.

3.4 The safety record of the construction industry must improve. The industry traditionally has a poor safety culture. Safety culture is 'the way we do things around here with respect to safety'.

3.5 Safety, risk and reliability theory is in its adolescence because we are gradually coming to terms with its inherent limitation (e.g. incompleteness, human and organisational factors).

3.6 There are, in simple terms, two (complementary) approaches to safety, the technical and the human/organisational.

3.7 The technical approach starts with safety factors, permissible stresses, load factors and limit state design (in structures) and develops into risk and reliability theory, probabilistic risk assessment (PRA), failure modes and effects analysis, fault and event tress. The problem for complex systems is that there are severe simplifying (often non-conservative) assumptions about dependencies in systems. The interpretation of subjective probabilities (needed when data is sparse) as statistics can be most misleading and potentially dangerous.

3.8 Risk concerns questions at the heart of what we know. It challenges us to describe the limits of our models. We have to justify what we do.

3.9 The relationship between risk source and accident is often not clear - there may not be a causal model. These 'soft' risk sources must be managed just as the hard risk sources.

3.10 The human/organisational approach to safety comes from the social sciences. There are two contrasting approaches - those concerned with individuals issues (i.e. psychology) and those concerned with collective (social). These two are currently merging. The issues are complex. Individual perceptions of risk and human error, whether slips, lapses or mistakes, are studied. Ways to manage safety culture within quality management ideas are being developed.

3.11 It is clear that accidents and failures rarely occur 'out of the blue'. Accidents incubate - a situation of an 'accident waiting to happen'. There are nearly always signs of impending doom - if only someone can read them. Risk management is probably more about reading those signs than performing PRA - it is a learning process. We must not fall into teaching more techniques at the expense of helping the students to grasp some of these ideas.

3.12 There is a distinct responsibility to teach students about their own responsibilities for themselves and those who, in the future, may work for and with them. When they go on a site visit or work in a laboratory or just cross the road or smoke etc. They need to see risk implicit in everyday life and have confidence, with humility, in the way we cope with it. Engineers must be aware of safety legislation and appreciate that they will be judged by the repercussions of their acts and their omissions because as professional engineers they will have a higher duty of care than members of the general public. We don't need to calculate risk to manage it - necessarily - but there are circumstances where calculations are helpful.

3.13 The civil engineering profession has lacked an emphasis on feedback and learning. It is imperative that we get our young engineers to understand the importance of learning from failure. How many people see failure as an opportunity to learn rather than an opportunity to blame?

4. *LEARNING OUTCOMES*

A graduate of an accredited course should be able to:
(with some amplification or examples in brackets)

	Learning Outcome	*level*
4.1	design simple engineering systems for safety (e-g- limit state design of structures)	E
4.2	define and discuss critically concepts of safety, risk, risk source (know that safety is everyone's responsibility)	K
4.3	describe how risk is part of every day life (e-g- crossing the road, smoking etc.)	B
4.4	define and discuss critically natural and man-made risk sources (think through the various demands on the capacity of a system)	E
4.5	explain the difference between 'hard' and 'soft' risk sources (e-g. tripping and falling off a scaffold, poor communications)	A

4.6 describe a systematic risk management process, including who owns a risk, as a learning process (e.g- as set out in HSE, CIRIA publications or similar) K

4.7 discuss critically the balance between risk and benefit (including financial, business, environmental and ethical issues) K

4.8 explain the interdisciplinary nature of safety (the role of other professionals, environmental issues) A

4.9 demonstrate that at least one case study has been studied in detail (e-g. Ronan Point) E

4.10 describe the basic issues in a number (say 5) of famous failures (recognise the importance of types of human error and that people are the most unpredictable risk source and that poor communication is the greatest risk source) K

4.11 explain the importance of learning from failure A (e.g. the hypothesis that all swans are white is true until you find a black one!)

4.12 explain that there are limits to what we know and what that may imply for safety A

4.13 explain some of the complexities of individual risk perception. (e.g. why do some people smoke when all the evidence is against?) A

4.14 explain some of the complexities of organisational issues (are Directors of companies culpable for accidents?) A

4.15 behave appropriately when on site (know about the dangers of working on site) E

4.16 describe relevant legal and professional responsibilities for safety (Health & Safety at Work, CDM) A

4.17 deflne safety culture and be aware of its influence on a project A ('macho' image, the way we do things around here, the no of accidents)

4.18 carry out a risk assessment (e.g. for the University labs) E

5. *SUGGESTED READING*

- . "Safety by Design - an Engineer's Responsibility for Safety", produced by the Hazards Forum.

APPENDIX 3

Skeleton letter and question set

Dear

Education of Undergraduate Engineers in Risk Concepts

I am writing to seek your help with a study, being undertaken by me on behalf of HSE, on what needs to be done to improve the education of engineering undergraduates in risk assessment and risk control concepts. Your name was passed to me by..................... as a member of .... and I hope you will not mind assisting me in this study. The context for the study is set out in an article (copy attached) by HSE's Director General in the August 1998 issue of the Engineering Council's publication 'Engineering First'.

The study is essentially the gathering and collation of information on:

(i) the existing situation, as derived from selective consultation with universities;

(ii) the situation as desired by industry, the professional institutions, regulators and others with an interest, with the information collected from consultation with appropriate bodies and individuals, and

(iii) the extent to which SARTOR 3 standards properly reflect the needs and expectations of clients.

Although our prime interest naturally lies in the application of the concepts to health and safety, we recognise that the concepts have much wider application, for example to the financial and environmental dimensions of engineering initiatives. There are obvious spin-off benefits from undergraduates being taught a) to apply the thinking processes for assessing proposals or projects in terms of the risk to success in all dimensions and b) measures to control or mitigate those risks at the design stage.

I am a Chartered Engineer, recently retired from HSE and they have sought my services to assist them with this project. Much of the information gathering I hope to do by telephone discussion, though with the option of a meeting if considered desirable. Clearly your experience as a .... provides an excellent opportunity for me to obtain your personal views on all three issues listed above. I am therefore writing to a number of ...., selected on the advice of the respective ....
Participation will involve a discussion with me in which I will explore with you the areas set out in the attachment.

Structure of discussion

Some general points:

- w your own perception of the issue: do you share the analysis in Jenny Bacon's article? Is there anything additional you would say, drawing on your own experience of teaching in university and sitting on an accreditation board?

- w whether in general terms the foundation in risk concepts should be laid in the undergraduate phase and the development of expertise in risk management should be through on-the-job training subsequent to graduation;

- w whether the approach to teaching should be through discrete modules on the subject or by integration as a unifying theme in the teaching of appropriate subjects or a balance between these two approaches.

Turning to specifics: if each of the following points were introduced into undergraduate teaching, what do you believe the relevant degree of emphasis should be in terms of outcomes on a two point scale of 'appreciation and awareness' or 'knowledge and understanding' for:

- the concepts of hazard and risk;
- the principles underlying the process of hazard and risk assessment;
- the methodology involved in hazard and risk assessment;
- the hierarchy of risk control;
- the benefits and application of control concepts eg inherent safety, defence in depth, redundancy, diversity and any others;
- the human behavioural aspects of risk management;
- the criteria (legal, technological, economic, ethical) for making a balanced decision;
- any others?

If at this stage we have identified areas for improvement, how might HSE, industry and the institutions operate together to help the university system bring about that improvement? For example:

- a training package for university staff;
- provision of case study material (both successes and failures) of risk assessment and management;
- a clearer statement of standards to be achieved in SARTOR 3 or institutions' guidance on accreditation requirements;
- a timetable (5 years?) for achievement of an improved formation of engineering graduates in risk concepts through implementation of restated SARTOR standards and accreditation requirements.

This report is available free of charge on request from Dr J McQuaid, Health & Safety Executive, Room 715, Rose Court, 2 Southwark Bridge, London SE1 9HS and is also available on HSE’s web site, http://www.open.gov.uk/hse/hsehome/htm.

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