HEALTH & SAFETY LABORATORY

THE UNIVERSITY of LIVERPOOL

# Risk Education in Engineering

## The development of a new syllabus

**HSL/2005/22**

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## PRIVACY MARKING

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# Executive Summary

## Objectives

The Health and Safety Executive (HSE) is committed to ensuring that 'safety-critical professionals receive adequate education in risk management' as part of its mandatory activities detailed in the Health and Safety Commission (HSC) strategic plan 2001/2004. However, there is an indication that across Higher Education courses, the content and extent of risk education varies, and is not always proportional to the level of risk that undergraduates could be responsible for managing in their future working life.

The overall aim of this project is to conduct preliminary work towards achieving the HSC's aims as stated above. The objectives of the project being to:

- Develop a set of risk education learning outcomes that will fulfil the needs of HSE and other relevant stakeholders, such as employers and the engineering institutions,
- Describe how these can be integrated into an engineering undergraduate three and four-year syllabus,
- Develop a questionnaire that can be used to ascertain the risk awareness of students, and
- Consider what further work will be required to enable this syllabus to be taught in practice.

## Main Findings

A set of risk education learning outcomes that can be incorporated into an undergraduate engineering course has been successfully developed. These outcomes take into account the opinions of a number of key stakeholders, in particular the topics that they identified as high priority. The number of outcomes was streamlined so as not to over-burden a curriculum already facing demands from competing topic areas.

A template for a new syllabus that incorporates these learning outcomes has been proposed at The University of Liverpool. This identifies modules that would need to be modified and others that would need to be completely revised. The current climate of change in the Department of Engineering at The University of Liverpool is ideal for implementing such a new syllabus over the next 2-3 years.

A risk awareness questionnaire has been developed that can be used to ascertain students' level of understanding of the key concepts of risk relating to the learning outcomes.

**Main Recommendations**

An appropriate person from HSE should give a presentation to staff in the Department of Engineering at The University of Liverpool in order to raise awareness of the importance of incorporating risk concepts into the undergraduate engineering course.

To deliver the learning outcomes, a substantial amount of new materials and web-based resources needs to be developed (i.e. lectures, notes, case studies, assessments, projects, assignments, etc.).

The risk awareness questionnaire should be used to ascertain students' level of understanding of the key concepts contained within each learning outcome to ensure that the teaching materials are pitched at an appropriate level.

To inform staff more fully about risk education and the proposed materials, a training workshop should be held. In order to ensure that a new syllabus can be delivered to first year students in the next academic year this will need to take place before the end of May 2005, the deadline for module specification updates to be finalised.

The successful implementation of the new syllabus needs to be evaluated in terms of its success in delivering the learning outcomes.

The new syllabus needs to be promoted to other educational institutions on the basis of its successful implementation.

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## 1. Introduction

An understanding of risk concepts is seen as increasingly important to negotiate the non-prescriptive risk based approach of the regulatory regime, especially within the engineering related professions [1]. The need to educate undergraduates in aspects of risk relevant to their degree is recognised by various professional institutions and degree accrediting bodies. Over a third of respondents from the Health and Safety Commission's (HSC) consultation exercise "Revitalising Health and Safety" [2] specifically mentioned the importance of covering health and safety issues in further and higher education. In addition, 25% of respondents stated that standards of designed-in-safety would be improved if there was more focus on health and safety during design courses and if standards required for CE and other 'kite' markings were clarified.

The Health and Safety Executive (HSE) is committed to ensuring that 'safety-critical professionals receive adequate education in risk management' as part of its mandatory activities detailed in the HSC strategic plan 2001/2004. However, there is an indication that across Higher Education courses the content and extent of risk education varies, and is not always proportional to the level of risk that undergraduates could be responsible for managing in their future working life. Higher Education institutions generally do not interpret the accrediting bodies' guidelines for the content and extent of risk education uniformly [1]. The lack of detailed prescription for risk education learning outcomes and course content is one of the main barriers preventing universities addressing risk education in a more comprehensive way. A literature review scoping Risk Education in Higher Education indicates that the uptake of risk education in the UK is in its infancy and has not yet been formally implemented in any comprehensive manner across degree courses [1].

The need for formal implementation is addressed directly by HSE's strategic business aims. Action point 34 states, 'The government and HSC will act to ensure that safety-critical professionals such as architects and engineers receive adequate education in risk management. This will be delivered through a program of direct approaches to relevant higher and further education institutions and professional institutions' [2].

The overall aim of this project is to conduct preliminary work towards achieving the HSC's aims as stated above. The objectives of the project being to:

- Develop a set of risk education learning outcomes that will fulfil the needs of HSE and other relevant stakeholders, such as employers and the engineering institutions,

- Describe how these can be integrated into an engineering undergraduate three and four-year syllabus,
- Develop a questionnaire that can be used to ascertain the risk awareness of students, and
- Consider what further work will be required to enable this syllabus to be taught in practice.

This report describes the work carried out jointly by the University of Liverpool and the Health and Safety Laboratory (HSL) in co-operation with the HSE who has funded the project.

## 2. Current developments at the University of Liverpool

This project takes advantage of an ideal window of opportunity as it complements and coincides with changes within the Department of Engineering at the University of Liverpool. Over the next 5 years the department plans to develop a range of new taught programmes relevant to $21^{st}$ century engineering, building on the department's multi-disciplinary strengths and 5* RAE standing. This will require a radically redesigned curriculum for virtually all programmes, producing a new kind of engineering graduate that has been branded locally as "The Liverpool Engineer". To this end, the University of Liverpool is making a single-institution bid for a 'Centre of Excellence in Active Learning in Engineering'. Its aim is to develop and exemplify a range of learning and teaching methodologies, appropriate to engineering, which involve the active participation of the learner. The vision towards which the Department of Engineering at Liverpool is moving, and which it believes the award of a 'Centre of Excellence in Teaching and Learning' (CETL) will greatly accelerate, is of a new breed of engineering graduate for the $21^{st}$ century. This graduate will find team-working completely natural, will have a strong analytical basis for knowledge and understanding, be able to tackle problems from a multi-disciplinary perspective and will have already taken control of his/her own learning and professional development. Such a graduate will be a professional and immensely employable.

The Centre will lead the further development and holistic implementation of active and interactive learning and teaching methods, across all years of taught programmes in the Department of Engineering (more than 500 students in programmes leading to BEng, MEng, BSc and MSc). These activities will engage engineering students to take full responsibility for their learning, through problem and solution-oriented approaches. These developments will be extended to influence more than 1000 students in the other engineering departments at Liverpool and beyond, throughout the UK.

A major investment by the University (>£4M) in the building of a new flexible laboratory for active learning will provide a suitable environment and showcase for these developments. The CETL funding will provide facilities and support for the active engagement, by embryonic engineers, in their own learning and professional development.

The aims of the 'Liverpool Engineer' project are clearly complementary to the aims of the risk education project and both are seen to benefit each other in the creation of a new learning environment at Liverpool. In this, students will experience more closely what it is like to be a practising engineer akin to how medical and law students receive direct professional experience in their undergraduate training.

## 3. Development of Learning Outcomes

Drawing upon other relevant work in the field of risk education, a proposed set of risk education topic areas was developed for undergraduates. These were grounded on current professional requirements of the engineering institutions, legislation, and best practice described in relevant HSE publications and current academic courses. These topics were circulated to a number of key stakeholders in HSE, academia and the engineering institutions to obtain their opinion. These opinions were incorporated into a final template of topic areas as shown in appendix A. From this the learning outcomes, given below, that can be embedded in an undergraduate engineering course were developed. These learning outcomes balance the necessary knowledge of risk concepts for graduate engineers on entering the professional arena with the competing demands of other new topics, such as sustainability, on the curriculum. They also incorporate those areas that were identified during the consultation as high priority e.g. personal safety and the importance of using appropriate design standards.

Risk education learning outcomes (aimed at programme level):

On successful completion of the programme, students should be able to demonstrate knowledge and understanding of:

- (i) The concepts of hazard, safety and risk as part of everyday life,
- (ii) The engineer's professional responsibilities for safety and managing risk (moral and legal obligations, and financial and human factors relating to safety),
- (iii) The principles of hazard identification and risk assessment relevant to the discipline,
- (iv) The methods of hazard identification and risk assessment (both qualitative and quantitative) relevant to the discipline and how to apply them in familiar situations,

(v) The techniques for reducing and controlling risk and how to apply them in familiar situations,
(vi) Potential exposure to hazards and risk in the workplace, and
(vii) Underlying causes of accidents and failures (through case studies).

On successful completion of the programme, students should be able to demonstrate ability in applying knowledge of the above topics acquired through the learning and teaching strategies in the following:

(i) Can design simple engineering systems for safety accounting for uncertainties,
(ii) Can perform a risk assessment using appropriate methods, avoiding some of the common pitfalls, and implement, where necessary, effective risk reduction measures,
(iii) Can learn from documented failures and accidents the underlying hazard, safety and risk issues and relate this knowledge to their future professional responsibilities, and
(iv) Can identify and control safety hazards to themselves and others in the course of work activities.

## 4. Undergraduate Risk Awareness Questionnaire

The purpose of this questionnaire is to ascertain students' level of understanding of the risk education learning outcomes prior to receiving formal tuition in them. Therefore, the questions were designed to test understanding of concepts not knowledge of facts relating to a taught course. The key concepts for each learning outcome were first agreed by the project team and questions then developed to examine these. Due to the limited time-frame, (the questionnaire needed to be ready for delivery at the beginning of the academic year 2004/05), there was no formal testing of the validity of the questionnaire. The face validity of the questionnaire was judged according to the experience and knowledge of the project team. It may be possible to explore the discriminant and construct the validity of the questionnaire at a later date.

A multiple-choice style of question was adopted as this would eliminate the subjective element of marking a large number of open-ended answers and would better facilitate comparisons between levels of understanding across the learning outcomes. Due to time-constraints there was only a limited piloting of the questionnaire. The key concepts on which the questionnaire is based are given in appendix B.

The questionnaire is intended to help decide the appropriate level at which to pitch formal learning and teaching and the content of supporting materials. The questionnaire is also expected to provide a useful benchmark against which to gauge anticipated improvements in students' knowledge of risk concepts once the risk education learning outcomes have been incorporated into the engineering undergraduate curriculum.

## 5. Risk Education Syllabus

The engineering taught programmes at the University of Liverpool are aimed at developing to Honours degree level the knowledge, skills and understanding of their graduates to meet the needs of industry. The mechanical engineering taught programme (which is typical of the engineering taught programmes at Liverpool) aims to provide graduates with a sound understanding of engineering principles and the ability to undertake teamwork and communicate ideas. Graduates should also understand the engineer's role within industry in the UK and Europe. The 4-year MEng programme provides a greater depth of understanding through specialist options and opportunities to develop innovation and leadership skills through group design work and an enhanced project.

The MEng programmes in mechanical engineering are designed to meet the full MEng requirements defined by SARTOR97. The programme aims, which go beyond those of the 3-year BEng programmes given in the previous paragraph, are:

- To develop the students' academic knowledge in certain engineering topics to an advanced level beyond that of the final-year BEng level,
- To develop further knowledge and understanding of aspects of management of the technical function, and
- To develop further knowledge and understanding of European matters relevant to engineers, or to develop language skills.

The 'With Business' programme has the further aims of developing knowledge and understanding of industrial management topics.

The 'Mechanical Systems and Design Engineering' programme has the further aim of developing knowledge of the systems approach to engineering problems and its application in design.

The aim in embedding risk education into the engineering programmes described above is to enable engineering students to graduate with

(i) An understanding, as professional engineers in carrying out their own activities, of their responsibility for the safety of others, and

(ii) An understanding of safety and risk issues relevant to their own specific discipline.

## 5.1 Incorporating risk education into the curriculum

The following topics were proposed as an outline template for a risk education syllabus in an undergraduate engineering programme.

(i) **Basic introduction**

Aims and objectives (including expected student input and assessment). Definitions and terminology. Engineering as a 'safety-critical' profession. Hazard and risk as part of everyday life. Fundamental concepts of safety, hazard, likelihood, probability and risk. Examples. Case studies. Bibliography (including web sites).

(ii) **Management of personal risk**

How to control risks associated with the main hazards that a student is likely to come across during lab/project work and later in the workplace. Use of personal protective equipment and emergency procedures. Examples.

(iii) **Risk modelling and quantification**

Hazard identification and preliminary hazard analysis. Treatment of uncertainties. Qualitative and quantitative risk assessment. Limitations and potential pitfalls of risk assessment. Failure modes and effects analysis. Fault and event trees. Human error. Assessing the consequences of a specified hazard. Acceptability and tolerability of risk. Cost benefit analysis. Examples. Case studies.

(iv) **Professional responsibilities including legal requirements**

Legal framework. The Health and Safety at Work Act etc 1974. UK regulations and European directives. Legislation enforcement. Prescriptive versus goal setting philosophy. Professional engineering codes of conduct. Examples. Case studies.

(v) **Management of risk**

Safety culture and climate. Safety management systems. Examples.

(vi) **Safety in the design process**

Human and organisational factors including basic ergonomics and human error. Inherently safe design. Attitude to safer design. Use of best practice and standards. Examples.

(vii) **Risk reduction and control**

Prevention. Mitigation and control strategies. Examples.

The above template could be integrated into a 3 and 4-year engineering programme by embedding the key topics into relevant core modules and optional specialist modules. This will require new material to be developed that can slot into some of these modules without displacing much of the existing syllabus or detracting from the coherence of the module. Other modules may need to be completely revised to accommodate some of the risk topics. The aim is to build up the student's knowledge and awareness of risk concepts, techniques and current approaches over the duration of the programme (three years for the BEng programme and four years for the MEng programme) with a view to becoming professionally responsible for their own safety and the safety of others. This strategy is considered the most effective, as students will be exposed to the subject as an over-arching theme rather than an isolated topic. It also allows a wider variety of approaches to learning and teaching to be employed. However, it does require the co-operation and support of several members of staff, some of whom may need to be convinced of the need to implant further topics into an already packed curriculum and timetable. Furthermore, 'risk' is but one of several modern topics (e.g. sustainable development) competing for time on the curriculum.

It does help, however, that professional ethics and UK law on health and safety are already being covered in modules taught in year 3 of the mechanical engineering taught programme, Organisational Behaviour (MNGT301) and Management of Design (MNGT313). However, the majority of topics are not directly taught in one or more of the core subject modules (e.g. Thermodynamics and Mechanics of Solids) although some reference to safety in the context of the module subject will be made. The current mechanical engineering taught programme structure is given in appendix C.

The basic concepts of risk can be taught in the first year through case studies and specialist lectures focusing on the year 1 core modules 'Mechanics of Solids' and 'Design' where the risk theme and topics will integrate well. The essence of 'Mechanics of Solids' is structural integrity and avoiding failures. Safety and reliability are important elements of 'Design'. The risk theme can be carried through in ‘Design’ in year 2 where the basic concepts can be reinforced through project work. The new flexible laboratory for active learning will provide scope for further development of risk education. Practical activities can be devised for teams of students to analyse bench-top safety modules (to be developed and supported with the award of CETL funding). The aim of this activity is to demonstrate key principles concerned with hazards and safety and the application of risk concepts. All students undertake a substantial project in their final year (years 3 and 4 in the case of MEng students) that currently involves a rather superficial risk assessment at the commencement of their project. Procedures for students to carry out a more thorough risk assessment based on the techniques covered in previous years can be developed. For those students wishing to pursue risk management as a specialist topic, an advanced level module could be offered in the final year. Explosion hazards and evaluation is taught as a specialist subject in year 4. This is due for review and there is therefore an opportunity to completely revise this module and introduce risk management topics at an advanced level. How this new overall strategy could look is illustrated schematically in Figure 1.

## 6. Conclusions

A set of risk education learning outcomes that can be incorporated into an undergraduate engineering course has been successfully developed. These outcomes take into account the opinions of a number of key stakeholders, in particular the topics that they identified as high priority. The number of outcomes was streamlined so as not to over-burden a curriculum already facing demands from competing topic areas.

A template for a new syllabus that incorporates these learning outcomes has been proposed. This identifies certain modules that would need to be modified and others that would need to be completely revised. The current climate of change in the Department of Engineering at the University of Liverpool is ideal for implementing such a new syllabus over the next 2-3 years.

However the successful implementation of any new syllabus relies upon those who will help develop the materials and teach them, both in terms of their knowledge of the new topics and their motivation to deliver it in the face of many competing demands on the curriculum and resources.

A risk awareness questionnaire has been developed that can be used to ascertain students’ level of understanding of key concepts of risk. The list of key concepts produced, as part of this process, will provide a useful aid to identifying suitable sources of information on which to base these materials.

To achieve the HSC goal of ensuring that ‘safety-critical professionals receive adequate education in risk management’ [3], the new syllabus needs to be adopted widely throughout other higher education institutions. This is unlikely to happen unless it can be demonstrated that the new syllabus can be successfully delivered to achieve the learning outcomes.

## 7. Recommendations

All the objectives of this project have been achieved. In doing so, a template for a new risk education syllabus has been developed. This is a positive step forward towards HSC’s goal in ensuring that ‘safety-critical professionals receive adequate education in risk management’ [3]. The collaboration between HSL and the University of Liverpool has worked well in bringing together the expertise in risk assessment with that in teaching engineering to undergraduate students. To fully capitalise on the work so far the following recommendations are made.

- A presentation should be given to staff in the Department of Engineering at the University of Liverpool by an appropriate person from HSE in order to raise awareness of the importance of incorporating risk concepts into undergraduate engineering courses. This can be done through the Department’sUniversity’s ongoing Research Seminar Program held on Wednesday afternoons.
- To deliver the learning outcomes, a substantial amount of new materials and web-based resources need to be developed (i.e. lectures, notes, case studies, assessments, projects, assignments, etc.). The relevant expertise of both HSL and the University of Liverpool is needed for the successful development of these materials, as is the continuing support of HSE.
- The risk awareness questionnaire should be used to ascertain students’ level of understanding of the key concepts contained within each learning outcome. This should be used to ensure that the teaching materials are pitched at an appropriate level taking into account overall differences in understanding across the learning outcomes.
- When new materials have been drafted, a training workshop should be held to familiarise staff with how to use them to deliver the risk education learning outcomes. In order to ensure that a new risk syllabus can be delivered to first year students in the next academic year this will need to take place before the end of May 2005 to fit in with the module specification updates.
- The successful implementation of the new risk syllabus needs to be evaluated in terms of its success in delivering the learning outcomes.

- The new risk syllabus needs to be promoted to other educational institutions on the basis of its successful implementation.

## References


1. Lee JF, ‘Education of undergraduate engineers in risk concepts - Scoping study’, HSE Books C2.5 10/99, 1999.
2. HSE and DETR, ‘Revitalizing Health and Safety - Strategy Statement’, HMSO OSCSG0390, 2000.
3. HSC, ‘A strategy for workplace health and safety in Great Britain to 2010 and beyond’, HSE Books MISC643 C100, 2004.

## Appendix A: Elements of Risk Education Learning Outcomes – post consultation

| |
|---|
| **1. The concepts of hazard and risk as part of everyday life**<br>The fundamental concepts of hazard, likelihood, probability and risk<br>Definition of terms<br>The trade-offs we make between risk and benefit<br>Personal/professional responsibility for effects of our actions on the health and safety of others |
| **2. Personal health and safety in the workplace**<br>Hazards from machinery (operation, maintenance and testing)<br>Hazards from workplace transport and equipment (operation and maintenance)<br>Hazards from pressure systems and pressurised equipment (operation, inspection and maintenance)<br>Hazards from Electricity<br>Hazards from workplace environment – noise and vibration, slips trips and falls, chemicals (health, fire and explosion), lifting and carrying, fire safety<br>Use of personal protective equipment (PPE)<br>Emergency procedures |
| **3. The principles of hazard identification and risk assessment**<br>Hazard identification, preliminary hazard analysis, consequence analysis and human error<br>The use of data and information in risk assessment<br>Criteria for assessing risk within broad social, political and economic frameworks<br>HSE's tolerability of risk (TOR) approach – SFAIRP, ALARP, the use of good practice and how this differs to the Environment Agency's BATNEEQ (best available technology not entailing excessive cost)<br>Cost-benefit analysis – value of life issues<br>An appreciation of the public's view of risk (societal concerns) and what underlies this (perception, social amplification and cultural bias) |
| **4. The methods of hazard identification and risk assessment**<br>How to complete a basic risk assessment –HSE's 5 steps to risk assessment<br>How to estimate risks through the use of qualitative and quantitative tools and techniques<br>The main hazards and risks associated with a number of specified systems and processes appropriate to the discipline<br>The evaluation of risk to determine tolerability |
| **5. Techniques for quantifying risk**<br>Risk graphs, fault trees, event trees, failure modes and effects<br>Appropriate sources for failure rates and associated uncertainties<br>Simple task analysis and their use to estimate human error probability<br>Statistical models for predicting human error HEART and THERP<br>To assess the consequences (injuries and damage to health) and associated likelihood and uncertainties for a specified hazard |
| **6. The pitfalls of risk assessment**<br>Dangers associated with the inappropriate or incorrect use of risk assessment techniques illustrated by case studies<br>Dealing with uncertainties and assumptions<br>Know that there are limitations to underlying mathematical models<br>Advantages and disadvantages of formal quantitative risk assessment<br>How to critically assess risk assessments |

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| **7. Principles of risk reduction and hierarchy of control measures**<br>How to implement standard risk control concepts and measures appropriate to the discipline<br>Importance of relating control measures to the risk assessment<br>How to assess the effectiveness of risk mitigation and risk control strategies<br>How to take account of common cause (mode) failure<br>How to set up the systems required to implement the risk assessment |
| **8. Risk considerations for design**<br>Importance of accounting for human behaviour, capacity and organisational factors in the design process, basic ergonomics<br>How to design against human error (including appreciation of different types of human error)<br>Inherent safety approach to design<br>Scientific principles used in design for safety and engineering safe operation<br>Concept of serial and parallel systems<br>Safety redundancy and conditional failures<br>The significance of EU directives, regulations and the role of harmonised standards in ensuring compliance |
| **9. Understanding underlying causes of accidents and ill health, and the link between hazards, accidents and risk management**<br>Knowledge and understanding of the causes of major accidents<br>Learning from accidents and disasters, e.g. documented failures such as Three Mile Island, Chernobyl, Flixborough, Piper Alpha, and the Kings Cross Fire, shuttle disasters,<br>A case study for management of risk that is appropriate to the discipline |
| **10. The influence of safety culture**<br>Definitions of safety culture and climate, its importance and effects<br>Characteristics of good and poor safety cultures<br>The relationship between culture, system and safety |
| **11. Risk Management**<br>Introduction to safety management systems and HSE's HSG 65 model<br>Key elements of a safety management system and their functions<br>The four C's – Communication, Competence, Co-operation and Control<br>Importance of human behaviour and organisational factors (including management commitment) in the management of health and safety risks |
| **12. Measuring and reviewing occupational health and safety performance**<br>To understand accident and safety performance data, and use this data as a measure of safety performance<br>Financial implications of poor occupational health and safety performance |
| **13. Professional responsibilities for managing risk**<br>Introduction to main elements of UK and European legal systems, and their relationship<br>The institutions of health and safety law, e.g. role of government, duties and powers of Health and Safety Commission (HSC) and Health and Safety Executive (HSE) and others such as Local Authorities and Employment Medical Advisory Service (EMAS)<br>The philosophy, key elements, institutions and legal requirements of the Health and Safety at Work Act etc. 1974 (HSWA)<br>Regulations, Standards and Approved Codes of Practice (ACOP) under HSWA<br>Introduction to key legislation relevant to the discipline such as: Management of Health and Management of Safety at Work Regulations, 1999, Provision and Use of Work Equipment Regulations 1998 (PUWER), and Control of Substances Hazardous to Health 1999 (COSHH) etc<br>Professional codes of conduct and ethics |

## Appendix B: Key concepts of learning outcomes to be tested

1. **Concepts of hazard, safety and risk as part of everyday life**
    - The difference between hazard and risk
    - Definitions of hazard and risk
    - The trade-offs between risk and benefit in everyday life
    - Absolute safety as not possible, but an ideal
    - Dealing with uncertainty in terms of risk decision making
    - Risk not just as consequence, but due to likelihood and exposure
    - High severity does not automatically mean high risk
    - Concept of exposure to risk
    - Concept of likelihood

2. **Engineer's professional responsibilities for safety and managing risk**
    - Understanding there are codes of conduct
    - Understanding the purpose of the codes of conduct
    - The institutional role of the E.C., e.g. accreditation of courses, purpose of charter ship in relation to risk education
    - Legal duty – professional practice underpinned by law
    - Relationship of safety to other business objectives – integral to business, not an 'add on'. Relevance of 'good health is good business' case
    - Concept of role and importance of standards, and importance of compliance to them
    - The concept of 'reasonably practicable'
    - Professional responsibility under HSWA
    - Responsibility of designer towards the end user
    - Impact of design decisions on user, through the lifecycle of the product

3. **Principles of hazard identification and risk assessment relevant to the discipline**
    - Idea of risk assessment as a process – steps, iterative, systematic approach
    - Techniques for risk assessment – the range that exist and the reasons for them
    - The purpose of risk assessment
    - When to do a risk assessment – the ongoing nature, a dynamic process
    - Hazard identification
    - Appreciation that things do fail, e.g. a guarded hazard is not an eliminated hazard
    - Risk assessments should take account of uncertainty and what is not known

**4. Techniques for reducing and controlling risk**

- The Hierarchy of risk control – elimination and reduction
- Measuring how effective risk controls are
- How to decide ‘safe enough’, e.g. when to stop
- The concept of ALARP
- The requirement for risk reduction measures to be practical and useable, not a technical exercise, but related to broader business aims.

**5. Potential exposure to hazards and risk in the workplace**

- Personal responsibility for H&S
- The results of an individual’s actions on the H&S of others
- Understanding of rules and procedures for H&S in the workplace
- Appreciation of human error
- Awareness of hazards in the workplace
- Employer’s responsibility for the welfare of employees
- Safety and health. The difference between chronic and acute exposure – danger of accumulative exposure

**6. Underlying causes of accidents and failures**

- Link between hazards, accidents and risk management
- Fundamental causes of accidents
- Multiple causes – chain of events

## Appendix C: Mechanical Engineering taught programme structure

| **BEng/MEng Year 1:** | | Credit Value | Level | Semester | Exam:CW |
|---|---|---|---|---|---|
| MECH101 | Thermodynamics and Mechanics of Fluids | 15 | 1 | 1+2 | 75:25 |
| MECH102 | Mechanics of Solids | 15 | 1 | 1+2 | 75:25 |
| MATH197 | Mathematics for Engineers | 22.5 | 1 | 1+2 | 70:30 |
| *or* | | | | | |
| MATH199 | Mathematical Techniques for Engineers | 22.5 | 1 | 1+2 | 70:30 |
| MECH131 | Design 1 | 7.5 | 1 | 1 | 0:100 |
| ELEC101 | Digital Electronics | 7.5 | 1 | 1 | 70:30 |
| MATS114 | Electrical and Magnetic Properties of Materials *(not Aerospace Engineering with Pilot Studies)* | 7.5 | 1 | 1 | 70:30 |
| AERO131 | Pilot Studies I *(Aerospace Engineering with Pilot Studies only)* | 7.5 | 1 | 1 | 0:100 |
| MECH104 | Introduction to Computing | 7.5 | 1 | 1 | 0:100 |
| MECH141 | Design 2 | 7.5 | 1 | 2 | 30:70 |
| ELEC108 | Electromechanics of Drives and Actuators | 7.5 | 1 | 2 | 70:30 |
| ELEC121 | Electrical Circuits and Systems | 7.5 | 1 | 2 | 70:30 |
| MATS112 | Mechanical Properties and Microstructure of Metals | 7.5 | 1 | 2 | 70:30 |
| *And:* | | | | | |
| *Aerospace Engineering programmes only:* | | | | | |
| AERO110 | Introduction to Aerospace Engineering | 7.5 | 1 | 2 | 70:30 |
| *Integrated Engineering and Systems Engineering programmes only:* | | | | | |
| INTE100 | Engineering Applications | 7.5 | 1 | 2 | 0:100 |
| *Materials Engineering programmes only:* | | | | | |
| MATS109 | What's it made of? | 7.5 | 1 | 2 | 70:30 |
| *Mechanical Engineering programmes only:* | | | | | |
| MECH110 | Computational Methods in Mechanical Engineering | 7.5 | 1 | 2 | 0:100 |

| **Year 2:** | | Credit Value | Level | Semester | Exam:CW |
|---|---|---|---|---|---|
| AERO213 | Aeroengines | 15 | 2 | 1+2 | 90:10 |
| MECH218 | Mechanics of Solids | 15 | 2 | 1+2 | 90:10 |
| MECH217 | Thermodynamics | 15 | 2 | 1+2 | 80:20 |
| MECH215 | Dynamic Systems | 15 | 2 | 1+2 | 90:10 |
| MATS214 | Materials Processing and Selection I | 7.5 | 2 | 1 | 80:20 |
| MATS210 | Materials Processing and Selection II | 7.5 | 2 | 2 | 80:20 |
| MECH210 | Design 3 | 7.5 | 2 | 1 | 0:100 |
| MECH211 | Design 4 | 7.5 | 2 | 2 | 0:100 |
| MATH295 | Engineering Analysis | 7.5 | 2 | 1 | 80:20 |
| MNGT203 | Industrial and European Studies | 7.5 | 2 | 1 | 100:0 |
| *H300, H301, HH37 and HH73:* | | | | | |
| MECH214 | Mechatronics | 7.5 | 2 | 1 | 90:10 |
| MECH213 | Numerical Analysis | 7.5 | 2 | 2 | 70:30 |
| *H3N2 and H3NF* | | | | | |
| MNGT202 | Cost and Project Management | 7.5 | 2 | 2 | 100:0 |
| MNGT204 | Industrial Marketing I | 7.5 | 2 | 2 | 80:20 |

| **Year 3 BEng:** | | Credit Value | Level | Semester | Exam:CW |
|---|---|---|---|---|---|
| ENGG341 | Project | 30 | 3 | 1+2 | 0:100 |
| MECH301 | Heat Transfer | 15 | 3 | 1+2 | 100:0 |
| MECH313 | Viscous Fluid Flow | 15 | 3 | 1+2 | 100:0 |
| MECH303 | Vibration and Control | 15 | 3 | 1+2 | 100:0 |
| MECH304 | Structural Failure Modes | 15 | 3 | 1 | 100:0 |
| MECH308 | Introduction to the Finite Element Method | 7.5 | 3 | 1 | 70:30 |
| MECH306 | Design 5 | 7.5 | 3 | 1 | 0:100 |
| MECH309 | Applied Finite Element Method | 7.5 | 3 | 2 | 0:100 |
| *H300:* | | | | | |
| MNGT202 | Cost and Project Management | 7.5 | 2 | 2 | 100:0 |
| *H3N2:* | | | | | |
| MNGT301 | Organisational Behaviour I | 7.5 | 3 | 1 | 85:15 |
| *Replace one of MECH301, MECH313, MECH303 or MECH304 with two modules (not more than one in semester 1) from:* | | | | | |
| MNGT309 | Manufacturing Strategy | 7.5 | 3 | 1 | 100:0 |
| MNGT311 | Management of Product Development I | 7.5 | 3 | 1 | 100:0 |
| EBUS302 | Total Quality Management I | 7.5 | 3 | 2 | 100:0 |
| MNGT313 | Management of Design | 7.5 | 3 | 2 | 100:0 |
| *HH37:* | | | | | |
| MNGT202 | Cost and Project Management | 7.5 | 2 | 2 | 100:0 |
| *Replace one of MECH301, MECH313, MECH303 or MECH304 with:* | | | | | |
| MECH310 | Engineering Systems | 7.5 | 3 | 1 | 70:30 |
| MECH311 | Engineering Systems Modelling | 7.5 | 3 | 2 | 0:100 |

| **Year 3 MEng:** | | Credit Value | Level | Semester | Exam:CW |
|---|---|---|---|---|---|
| ENGG342 | Project Part 1 | 22.5 | 3 | 1+2 | 0:100 |
| MECH313 | Viscous Fluid Flow | 15 | 3 | 1+2 | 100:0 |
| MECH304 | Structural Failure Modes | 15 | 3 | 1 | 100:0 |
| MECH308 | Introduction to the Finite Element Method | 7.5 | 3 | 1 | 70:30 |
| MNGT301 | Organisational Behaviour I | 7.5 | 3 | 1 | 85:15 |
| MNGT309 | Manufacturing Strategy | 7.5 | 3 | 1 | 100:0 |
| MECH309 | Applied Finite Element Method | 7.5 | 3 | 2 | 0:100 |
| MNGT313 | Management of Design | 7.5 | 3 | 2 | 100:0 |
| MATS311 | Composite Materials | 7.5 | 3 | 2 | 90:10 |
| TLLC025 | Contemporary European Studies II | 7.5 | 3 | 2 | 100:0 |
| *H301: one of:* | | | | | |
| MECH301 | Heat Transfer | 15 | 3 | 1+2 | 100:0 |
| MECH303 | Vibration and Control | 15 | 3 | 1+2 | 100:0 |
| *H3NF:* | | | | | |
| MNGT311 | Management of Product Development I | 7.5 | 3 | 1 | 100:0 |
| EBUS302 | Total Quality Management I | 7.5 | 3 | 2 | 100:0 |
| *HH73:* | | | | | |
| MECH310 | Engineering Systems | 7.5 | 3 | 1 | 70:30 |
| MECH311 | Engineering Systems Modelling | 7.5 | 3 | 2 | 0:100 |

| Year 4 MEng: | | Credit Value | Level | Semester | Exam:CW |
|---|---|---|---|---|---|
| ENGG442 | Project Part 2 | 22.5 | M | 1+2 | 0:100 |
| MECH402 | Group Design Project | 22.5 | M | 1+2 | 0:100 |
| MECH418 | Computational Fluid Dynamics | 15 | M | 1+2 | 40:60 |
| MECH406 | Impact and Blast Performance of Structures and Systems | 15 | M | 1+2 | 100:0 |
| MNGT309 | Manufacturing Strategy *(2004/05 only)* | 7.5 | 3 | 1 | 100:0 |
| *Options totalling 37.5 credits (between 7.5 and 22.5 credits in semester 1)(45 credits from 2005/06), subject to the approval of the Programme Director, from:* | | | | | |
| AERO316 | Aerodynamics | 15 | 3 | 1+2 | 100:0 |
| MECH301 | Heat Transfer | 15 | 3 | 1+2 | 100:0 |
| MECH303 | Vibration and Control | 15 | 3 | 1+2 | 100:0 |
| MECH312 | Advanced Manufacturing Processes | 7.5 | 3 | 1 | 100:0 |
| MECH315 | Laser Materials Processing | 15 | 3 | 1 | 100:0 |
| MNFG308 | Rapid Prototyping | 7.5 | 3 | 1 | 80:20 |
| MNGT311 | Management of Product Development I | 7.5 | 3 | 1 | 100:0 |
| TLLC023 | Advanced German for Engineers | 7.5 | 3 | 1 | 0:100 |
| MATS310 | Ceramics | 7.5 | 3 | 2 | 90:10 |
| MATS312 | Surface Engineering | 7.5 | 3 | 2 | 90:10 |
| MATS315 | Smart Materials | 7.5 | 3 | 2 | 90:10 |
| MATS411 | Advanced Composite Materials | 7.5 | M | 2 | 90:10 |
| MNFG301 | Computer Integrated Manufacturing | 7.5 | 3 | 2 | 50:50 |
| MNFG309 | Industrial Robotics and Automated Assembly | 15 | 3 | 2 | 0:100 |
| MNFG313 | Design for Manufacture and Assembly | 7.5 | 3 | 2 | 0:100 |
| EBUS209 | Operational Management II | 15 | 2 | 2 | 70:30 |
| EBUS302 | Total Quality Management I | 7.5 | 3 | 2 | 100:0 |
| *or* | | | | | |
| EBUS303 | Total Quality Management II *(not H3NC)* | 15 | 3 | 2 | 60:40 |

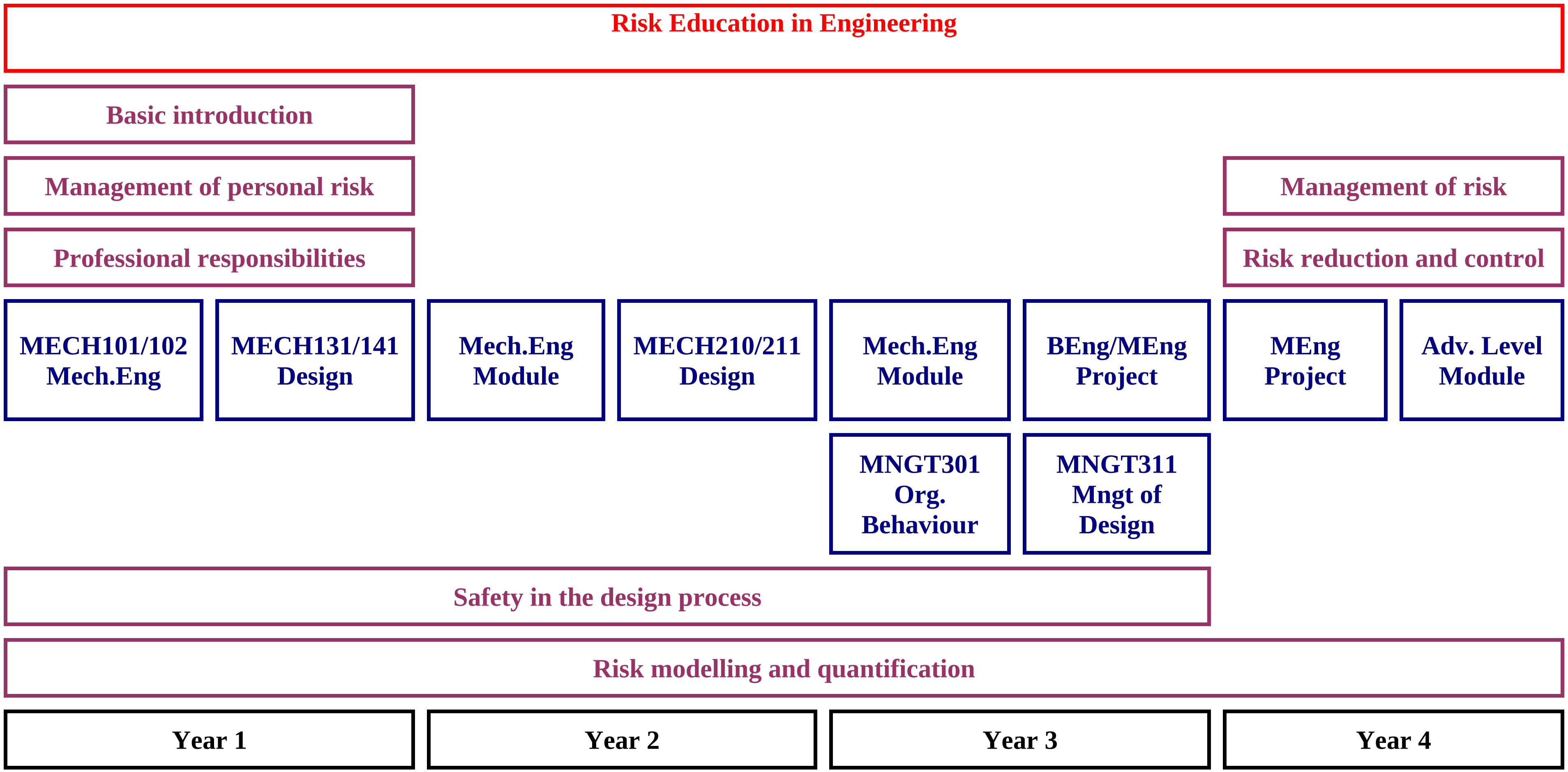


**Figure 1: Possible template for integrating risk syllabus into mechanical engineering programme**