Teaching health and safety in undergraduate engineering courses

Project summary

Our research and development programme

IOSH, the Chartered body for health and safety professionals, is committed to evidence-based practice in workplace health and safety. We maintain a Research and Development Fund to support research, lead debate and inspire innovation as part of our work as a thought leader in health and safety.

In this document, you'll find a summary of the study we commissioned to reassess the teaching of health and safety in undergraduate engineering courses. This report looks at the teaching material on health and safety principles and practice available to lecturers in the UK higher education sector, and forms part of our activities around embedding health and safety in professional and vocational education.

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Undergraduate health and safety risk teaching

What's the problem?

The principles and practice of health and safety are crucial to the engineering industry. The Inter-Institutional Group on Health and Safety (IIG)* has been concerned about the shortage of health and safety teaching material available to the UK higher education sector. This shortage could lead to many young engineers leaving university with an inadequate understanding of the subject. There's an identified need, therefore, to provide engineering undergraduates (and perhaps others undertaking engineering courses) with a common basic understanding of health, safety and related risk issues.

Previous work was carried out by the IIG and Health and Safety Executive (HSE)† to provide a package of teaching materials on health and safety aimed at undergraduate engineers. The material was originally envisaged in terms of four project-based modules, delivered using a gaming approach in which each student user would be part of a virtual team. A demonstration CD was developed,‡ including examples of e-learning tutorial material, an example of a video gaming approach to spotting and understanding hazards, and a further example taking students through the steps of a risk assessment based on the hazard-spotting video game.

The demonstration CD was widely distributed and generated considerable interest, as a result of which the team gave many presentations on the project. Discussions were held with around 30 organisations, including major industrial companies, universities, engineering bodies and charitable trusts, generating feedback, ideas and views on the potential for further funding to build the complete teaching package. The 'gaming', team-based approach has significant benefits in making learning about health and safety more memorable than some more conventional approaches, but several difficulties were identified with the full use of the approach as initially envisaged:

- it would be difficult to provide gaming material of a standard that students would find acceptable and the material could become 'dated'
- there were high costs involved in ensuring continued realism across all the modules
- the approach made it less easy for the material to be used in other teaching environments, such as schools and industrial training centres
- there was a need to ensure that, while producing a 'common basis' for all engineering students, the teaching material might be regarded as more relevant if some of it could be focused on specific engineering disciplines, such as civil or mechanical engineering.
- despite wide support from engineering institutions, universities and industry, it was difficult to be confident of obtaining sufficient funding for the project based on the proposed approach.

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* IIG members include the major engineering institutions, IOSH, the HSE, the Engineering Council, the Hazards Forum and several other smaller institutions with a strong interest in health, safety and risk.

† Taylor R H, Bell D and Smyth V. *Development of an IIG/HSE e-learning health and safety risk education package for engineering undergraduates.* Research Report 452. HSE, 2006.

‡ Taylor R H, Stacey N, Cummings R, Vallance S, Bellenger D and Smyth V. *Further development of an IIG/HSE e-learning health and safety risk education package for engineering undergraduates.* Research Report 482. HSE, 2006.

These issues needed to be addressed in order to re-establish the momentum and enthusiasm generated by the first phases of the work. We commissioned Professor Dick Taylor (RHT Risk Management, Visiting Professor at Bristol and City Universities and Chairman of the IIG) to reassess the previous IIG–HSE approach to developing teaching materials for undergraduate engineers and find out whether this might be done in a simpler and more cost-effective way while retaining many of the concepts and e-learning benefits in the original approach. Nicola Stacey of the Health and Safety Laboratory (HSL) provided valuable input and advice to the review.

The research had three key goals:

- to develop a common framework of material for teaching undergraduate engineers about health and safety risks in a way that would interest students of all engineering disciplines
- to design a modular package enabling universities to teach the material as a single course or use elements of it as required
- to assess how the package might be designed so it could be used in other learning environments, such as schools, colleges and in-company training, without significant rework.

What did our researcher do?

Professor Taylor set out to restructure the content of the teaching material for undergraduate engineers, while retaining coverage of the topics agreed by the IIG. He revisited the original content of the material to consider how it could be presented at a lower overall cost or in a form that might attract funding, or sponsorship in kind, from more sources.

Professor Taylor met with IOSH and the HSL to consider issues that needed to be addressed and to identify organisations that could be approached for further discussion of those issues.

While the new material would be aimed primarily at undergraduate engineers, our researcher wanted to know if it could also be used in a wider context without major adaptation. Therefore, each section was reviewed in the light of previous feedback to consider if it might be of use in schools, further education, other undergraduate teaching, employee training and overseas.

As simulation materials relating to hazards and accident sequences would be difficult and costly to produce at an acceptable quality, Professor Taylor looked at other options, including videos, animations and other interactive tools. He identified a range of existing teaching materials that might be included in the revised package, including a simulation of the Port of Ramsgate walkway collapse – which was developed in collaboration with the University of Liverpool* – as well as material from the HSL.

The teaching materials and associated learning outcomes were restructured into five modules, each with different sections (A1, A2, B1, B2 and so on) that represent the individual blocks of course content (see Table 1). In addition to the course content, there was a need to ensure that some or all of the material is subject to assessment, and that supporting references and suggestions for tutorials and discussion topics are available.

* Stacey N, Simpson K and Schleyer G. *Integrating risk concepts into undergraduate engineering courses.* Research Report 702. HSE, 2009.

What did our researcher find out?

Professor Taylor found that a new modular structure (designed to interface with a learning management system) would enable wider use of the tutorial material, with the potential for each module to be used separately as required. By focusing the material in some sections (eg C3 and D3) on a specific engineering discipline and environment, the package can provide choice and strong links with the more specific, discipline-related learning needs of undergraduate engineers, while its modular content will enable more opportunities for it to be used in other teaching environments.

Sections from the demonstration CD could be modified using the existing scripts to ensure strong presentational uniformity across the package, at a cost of around £2,000 for each section. Further material would need to be scripted, designed and produced in an interactive format at an estimated cost of between £5,000 and £10,000 for each section, depending on its length and complexity.

Several modules have been identified as ideal for early development, constituting a 'core' of material that will help to demonstrate early success and generate enthusiasm (see Table 1). Some of these modules are from the demonstration CD, while some are new sections.

Working closely with industry would help to achieve realism and relevance in simulation and animation, particularly in sections such as C3 and D3. Development of these sections could be led by the individual engineering institutions, with potential industry sponsorship for which participants would be suitably recognised on the teaching material as providing direct funding, resources or existing materials.

Wider use

Some sections of the package could be useful in further education or other areas of higher education. Any development of the material should attempt to reflect the possible needs of engineering technicians on non-degree courses, as well as those of undergraduate engineers.

Feedback and discussion about the concepts and wider use of the material with teaching support bodies and others suggested that some of the conceptual material on risk (such as risk statistics, the difference between hazard and risk, and what shapes perceptions of risk) might be of use to teachers of sixth form students. Some material may also be of interest to providers of the new Engineering Diploma and the Diploma in Construction and the Built Environment, which are aimed at 14–19 year olds, and the Science, Technology, Engineering and Mathematics Network.

Organisation and funding

As part of the reassessment, discussions with experts in e-learning material development allowed a preliminary estimate to be made of various elements of the costs in developing a package of teaching material. This included redevelopment of the material on the demonstration CD, the development of new modules to cover the material outlined in the table, and the need for the whole project to be managed within a common framework. It was estimated that developing a preliminary package of 'core' material (excluding project management costs) might amount to £80,000–£90,000. This would enable the project to 'get off the ground' and form a basis for further material to be developed against the background of a good track record and evidence of successful use. Developing the total package as currently conceived might cost about three times this figure and industrial sponsorship might be sought. Issues such as the potential for the material to be available more widely – on a licensing basis – were also mentioned as a possible means to offset some of the development and future maintenance costs.

The proposed approach would entail material being developed and possibly funded by a range of sources. A project advisory board should be set up to align and meet the requirements of the various stakeholders and to ensure that the material is consistent with a common presentational framework, is delivered and used effectively, and that commercial issues and future opportunities are explored and addressed.

Module	Section
A. Introduction	**A1: Why health and safety is important to engineers*** Based on material on the demonstration CD, including video clips of disasters and personal stories. Would be extended with further explanatory material.
	A2: The ethical requirements on engineers and what they mean in practice* New material based on those currently produced by the Engineering Council or Royal Academy of Engineering, or by other institutions and professional bodies.
B. General risk issues	**B1: Appreciating the risks that we run in day-to-day living and calculating and comparing their magnitude*** Material is available on the demonstration CD, but the section may need to be developed from scratch based on HSE risk statistics. Could be made more interactive.
	B2: Understanding the difference between 'hazard' and 'risk'* Examples from the demonstration CD could be transferred with little change.
	B3: Understanding the assumptions involved in risk statistics and doing simple calculations based on typical activities* Using material from the demonstration CD to compare the risks involved in various activities and look critically at how risk statistics are formulated.
	B4: Risk perception – why people have different perceptions about risks and the need to understand the views of stakeholders in making decisions* Using material from the demonstration CD, including further work on profiling users.
	B5: Appreciating that absolute safety is unobtainable – how safe is safe enough?* New material, including simple calculations of costs/benefits and general concepts.
	B6: Concepts of tolerability of risk and AFAIRP/ALARP* Basic concepts based on the HSE document *Reducing risks: protecting people*.

** Core materials that could be developed first without significant amounts of discussion and planning.*

Table 1
Proposed structure of the revised learning material

Module	Section
C. Understanding health and safety requirements, identifying the risks and controlling them	**C1: The basics of UK health and safety legal requirements and the risks being controlled*** New material, possibly based on HSE documents and various training manuals. Need to find ways to present material in an engaging way while retaining its 'formal' nature.
	C2: Fundamentals of occupational health New material based on the priority that the HSE, IOSH and IIG attach to the issue.
	C3: Specific examples of workplace risks illustrated with interactive material Similar to material on the demonstration CD, with options relevant to each engineering discipline (eg construction site, factory, chemical plant, electrical installation) but not necessarily in a virtual reality environment. The development of sector-specific material could be led by individual institutions.
	C4: How do we control the risks? – the principles of risk assessment* Expanding on the material on the demonstration CD, which is based on the HSE's *Five steps to risk assessment*, using an interactive approach.
D. The causes of accidents and the costs involved	**D1: The difference between 'individual' and 'organisational' accidents*** New material, possibly based on Reason's Swiss Cheese Model and using illustrative examples of how successive 'layers' can be breached.
	D2: The costs of accidents – human, financial and reputational* New section, building on section D1.
	D3: The causes of organisational accidents – some practical examples for assessment and analysis based on examples taken from each engineering discipline New material to develop awareness of human, organisational and cultural issues and the need for good engineering design, project management and operations. The development of sector-specific material could be led by individual institutions.
	D4: Human performance, ergonomics and the man–machine interface New material that could be led by the Institute of Ergonomics & Human Factors on issues relating to good ergonomic design and more general human factors.
	D5: Dealing with risks in projects from 'cradle to grave' – using systems thinking New material emphasising the impact of poor design and the need to see any part of engineering in the context of the whole life cycle.

** Core materials that could be developed first without significant amounts of discussion and planning.*

Table 1 *Continued*

Module	Section
D. The causes of accidents and the costs involved	**D6: The importance of safety culture and safety management*** New material emphasising the role of safety culture and management, eg the importance of leadership and the role of the individual in leading by example.
	D7: Learning from experience – the need for reporting of events and near-hits, appropriate investigation and using the learning New material, which may include a simulation where the student is involved in a team investigation of a reported event and follow-up implementation of the output. The development of sector-specific material could be led by individual institutions.
E. Overall summary – what we have learnt	High-level summary of key points in the package, providing an opportunity to reinforce the main messages using inputs such as cartoons, memorable quotes and so on.

** Core materials that could be developed first without significant amounts of discussion and planning.*

Table 1 *Continued*

Module section*	Schools	Further education	Other higher education	Companies	Overseas
A1	●	●	●	●	●
A2	○	○	–	●	●
B1	●	●	●	○	○
B2	●	●	●	○	●
B3	●	●	●	○	○
B4	●	●	●	●	○
B5	●	●	●	●	●
B6	●	●	●	●	–
C1	○	●	○	●	–
C2	○	●	○	●	○
C3	○	●	○	●	●
C4	●	●	●	●	●
D1	○	○	○	●	●
D2	○	○	○	●	●
D3	–	○	–	●	●
D4	–	○	–	●	●
D5	–	○	–	●	●
D6	–	○	–	●	●

** For each specific audience, sections with the potential for good applicability are marked with an a black circle. Sections with limited or uncertain applicability, or which might need significant adaptation, are designated by a white circle. Dashes indicate sections that are not likely to be transferrable.*

Table 2
Potential for wider use of the revised learning material

What does the research mean?

The proposed approach to developing the tutorial material will enable it to be used more widely while lowering production costs and increasing the possibilities for funding and support. The phased development of the material means that if the project proceeds more slowly than anticipated or doesn't deliver the full range of outputs, the material that has already been developed could still be used successfully.

It's important to discuss the research in order to agree the next steps, and to ensure adequate funding as well as competent management of the project. The requirement to 'trial' material, and to develop a learning management system and more teaching support, including assessment requirements, also needs to be established in greater detail.

Dialogue with potential sponsors should be reopened, and there is a need to develop a clear statement of project intent and a generic proposal. Using a phased approach to developing the package will enable a core of material to be made available for use before the entire package is completed, providing an early 'track record' that can be used to attract further sponsorship.

More statements of support are needed from engineering institutions, the Engineering Council, the Higher Education Academy and universities interested in piloting the material, and to re-engage with university engineering departments that would be willing to trial all or part of the material and to develop a network of users with opportunities to share and update teaching materials as they are further developed.

The material holds potential for wider use and this should be pursued while considering its implications for development. Commercial experts from IOSH, the HSL and other organisations should be engaged to consider commercial opportunities and issues.

Don't forget

Like most studies, it was recognised that this one had some limitations. The study proposes a new approach to producing the tutorial package, and new materials will need to be trialled by users to establish their usefulness to engineering undergraduates and in other learning environments.

It was only possible to provide a broad indication of the overall costs of developing the tutorial package because costs will be highly dependent on the type of e-learning material developed. However, better cost estimates will need to be developed early in further development work in order to establish the level of funding needed to produce the package, and to attract support and funding from organisations that may be prepared to be involved in the next phase of development.

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IOSH is the Chartered body for health and safety professionals. With more than 40,000 members in 85 countries, we're the world's largest professional health and safety organisation.

We set standards, and support, develop and connect our members with resources, guidance, events and training. We're the voice of the profession, and campaign on issues that affect millions of working people.

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