

A Health and Safety Risk Education e-Learning Package for Undergraduate Engineers

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Abstract

This paper describes the production, content and use of a demonstration CD containing a sample of e-learning material designed to form a basis for the teaching of health and safety risk management to young engineers. The material builds on concepts and content developed in preparatory work by a sub-group of the Inter-institutional Group on Health and Safety (the IIG), which defined learning outcomes and made suggestions for technical content. The paper will explain how these were developed to 'proof of concept' stage with feedback from a wide range of stakeholders.

The demonstration CD includes eye-catching introductory real-life material such as video-clips of personal stories and major disasters. A construction site 'spot-the-hazard' exercise has been developed in a virtual reality environment. Briefing materials and interactive tutorials have been produced covering: the difference between hazard and risk, why people view risk differently, comparison of risks, quantitative and qualitative risk assessment. These are designed to involve the user in simple but thought provoking exercises with feedback on their answers. The CD also contains a presentation of the background to and overall aims of the project, plus the full list of learning outcomes.

Introduction

The Inter-institutional Group (IIG) on Health and Safetyⁱ has been working with the Health and Safety Executive (HSE) and the Health and Safety Laboratory, various universities and industry to develop a package of memorable, stimulating and thought-provoking teaching materials to provide a basis for teaching risk to undergraduate engineers, particularly in the context of health and safety. The goal is to ensure that all students who complete their engineering course have sufficient understanding of risk issues relevant to their specific course of professional study and future working life.

As the late John Lee (1999) stated in his scoping study, which considered the education of undergraduate engineers in risk concepts:

“Modern legislation [in the UK] 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 recognises that industry, as the creator of the hazards which expose people to risks, is in the best position to control those risks and 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 fulfill their responsibilities, duty-holders 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.”

The work of the authors of this paper, thus far, has involved defining draft learning outcomes, developing scenarios and a structure against which the teaching could be developed. The proposed approach has been discussed with a wide range of stakeholders, including the IIG and its member institutions, Engineering Council (UK), Royal Academy of Engineering, Higher Education Academy (HEA) Engineering Subject Centre, several university departments (including students) and the Engineering Professors' Council. It has also been discussed with several major industrial companies. In all cases, the overall response has been positive, particularly to the idea of a modular, layered structure and the use of a strongly interactive 'gaming' approach. As a result, a demonstration CD has been produced containing a representative sample of the proposed material for further discussion with potential funding organisations and end-users; copies of the CD are available on request from Nicola Stacey.

The sections below explain why and how this subset of material was chosen and the process used to deliver the material in an attractive format on the CD. Recommendations are made for the immediate next steps to be taken before proceeding (given continued interest, commitment and resources) to the development of a full teaching package.

Concept of proposed e-learning package 'Engineering a Safer Future'

To help undergraduates appreciate the importance of effective health and safety risk management, high quality, engaging and inspiring teaching and learning materials must be available to universities, professional institutions and employers. The e-learning package 'Engineering a Safer Future' aims to meet that need. Unfortunately, introducing health and safety issues to students is often done by focusing on the legal requirements. The project team recognises that this is not a good way of engaging the interest of engineering students or for that matter academics. Instead this package aims to teach the more holistic topic of risk management by highlighting the professional responsibilities of a practising engineer with reference to simulated projects. The broad concepts of health and safety regulation can then be shown to be an essential input which enables them to fulfill these responsibilities along-side the importance of communication, team working, leadership and decision-making.

Three layers of material are proposed which students can use semi-independently as part of an engineering undergraduate course or graduate training programme. The first will be simulated projects, using interactive video or virtual reality, of a team of three young engineers undertaking a range of projects as part of their graduate training with a major company. In carrying out these projects, they address and discuss risk issues. The second layer will consist of briefing material, interactive tutorial exercises and assessments to reinforce the concepts covered in the simulations. The third layer, will be accessible from the same user interface, but would be populated by university departments to meet their specific needs.

In each project, the student will encounter health and safety issues through interaction with simulated people and processes, which will raise questions for the student to think about, debate and address. The briefing materials and interactive tutorials will support this process at appropriate points in a simulated journey from one project to another. The briefing materials and tutorials can also be used as stand-alone exercises. The package will be able to be run in self-assessment mode to provide automatic feedback, or supervised mode so that students submit their work to a tutor who then provides feedback. The package would be designed to be modular and used in the form of a toolkit. Learning outcomes will be explicitly linked to the different modules so that university departments can tailor the journey to support project or course work, rather than be a specific extra part of the curriculum.

The intention of the simulated projects is that they should not be overly concerned with engineering detail, but should be sufficiently broad to be of interest to all engineering disciplines. They should be challenging to capable students but not too daunting for less able students.

Using computer based simulations allows students to learn in virtual environments, to network with fellow learners regardless of geography and to participate in realistic scenarios, practicing and applying skills they can transfer to the workplace. This prepares them to fulfil their professional responsibilities for managing health and safety risk before experiencing risk for real.

Learning outcomes

The overarching learning outcome hoped to be achieved by the full 'Engineering a Safer Future' e-learning package is a fundamental understanding of the concept of risk and its role in an engineer's exercise of professional judgment in a wide variety of topics and disciplines, but in particular health and safety. The IIG (2001) published a template for course design and accreditation, with defined learning outcomes, following a scoping study (Lee 1999) that considered the education of undergraduate engineers in risk concepts, the current situation, drivers in terms of accreditation requirements and collated views of what is desirable. The learning outcomes were categorized in accordance with four levels of capability:

- 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/or closely supervised
- B** **A**Bility : be able to do something without supervision

Based on this template, the IIG (2003) Health and Safety sub-group proposed an outline of undergraduate engineering teaching materials. Following on-going discussions with various stakeholders a proposed set of learning outcomes according to this categorization has been further defined and published (Taylor, Bell & Smyth 2006). These can also be accessed from the demonstration CD. In order to achieve

the defined learning outcomes it is proposed to link key concepts, which address and test the learning outcomes, to different simulated projects. Suitable projects are suggested below. These are open for discussion, and therefore subject to change before final agreement.

1 – Process or Manufacturing Plant such as an Oil Platform

- Terminology – the difference between the terms ‘hazard ‘ and ‘ risk’
- Engineering and human issues relating to working in a high hazard environment
- Relative risks of different activities and occupations
- Perception of risk – why people view risks differently
- How safe is safe enough – achieving the balance between safety and cost

2 – Construction Site

- Identifying hazards
- Controlling risks - carrying out a risk assessment
- Costs of accidents and occupational health
- Legal framework for health and safety in the UK
- Personal and professional responsibilities – ethics, codes of conduct, dealing with the “people” aspects of workplace health and safety

3 – Community project (e.g. design, construction and operation of a wind-turbine for electricity generation in a remote location or developing country)

- Managing health and safety risks throughout a project – ‘cradle to grave’
- Assessing and deciding on the balance of safety, sustainability issues and costs
- Taking account of human behaviour and reliability
- Actual examples of success and failure in the management of health and safety risks

4 – Learning from accidents

- Key elements in an accident investigation
- Importance of management systems and controls and organisational issues in safety
- Need for “defence in depth” and the complex nature of causes of accidents with reference to latent failures and Reason’s “Swiss Cheese model”
- Concept of safety culture and our role in contributing to it (through leadership, good communication, encouraging learning and in promoting a questioning attitude).

Content of demonstration CD

The demonstration CD that has been produced shows how the concept for ‘Engineering a Safer Future’ might be achieved. It contains a sample of presentations, learning activities and resources. These draw upon content agreed previously, and illustrate the various types of content that are possible and which might appear in a full teaching package. This allows the concept described above to be demonstrated to potential users, stakeholders and organisations who could fund further development of a truly modular and flexible teaching package. It has been

designed to give further confidence in the effectiveness of the approach and methods suggested and to generate support for the proposed production of a fully developed package. The CD therefore also includes explanatory material to inform stakeholders about the background to the project and its intent.

The package is designed to run on a PC with Windows 2000 or later, minimum screen resolution of 1024 by 768 with 16 bit colour, sound capability, and 256 mb of RAM.

A scene-setting audio-visual presentation auto-runs on first starting the package. This explains the importance of managing health and safety risk and the engineer's role. It uses powerful images such as the one shown in figure 1, video clips of major disasters and interviews with people directly affected by accidents at work alongside hard-hitting accident statistics for example as shown in figure 2. The auto-run presentation can be skipped on subsequent uses of the package to go directly to the welcome page. In the description below the text found on the click buttons of the demonstration package is shown in bold.

From the welcome page an audio-visual presentation can be opened which explains the **background** to the 'Engineering a Safer Future' project, its aspirations and how the viewer may get involved. A guidance sheet can also be opened to explain **how to use** the packages. This can be expanded to contain detailed help and tutorials for the teacher. From here the complete list of **learning outcomes**, which the full package will cover, can be accessed. The intention is to more clearly link the learning outcomes with specific resources.

From the welcome page the user can then access the main menu of sample teaching resources. These include:

- **Real life stories** which are fuller video clips of the major disasters and personal stories used in the auto-run scene-setting presentation which can be called up individually. These not only explain the circumstances of the accident, but its impact on the lives of the victim(s), their colleagues and their family.
- **Tutorials** composed of audio-visual briefings, and interactive exercises on comparing risks, factors affecting risk perception, an introduction to terminology (specifically 'risk' and 'hazard') and an example of supporting background reading (in this case on the concept of 'reasonable practicability'). These can be related to the simulations or used as stand-alone exercises.
- **Interactive scenarios** that contain ideas for various simulations, such as an accident investigation and a sustainability related community design project, how they might be realized and which learning outcomes they would deliver. Within this section there is a construction site virtual reality environment, which the user can navigate like a video-game in order to spot hazards. At the end of the 'game' the user gets feedback on how they have done. The user also has access to an audio-visual briefing on the HSE 5-steps to risk assessment. They are led through a risk assessment of part of the simulated construction site. After this the user can access risk assessment forms that can then be used to conduct a risk assessment of their own.
- **Next steps** outlines various ideas about how the full 'Engineering a Safer Future' e-learning package might be further developed and used in practice.

On exiting the package a final screen invites the user to give feedback and contribute to further development with contact details before closing.

The CD can be used in various ways. A viewer who is pressed for time can just watch the auto-run scene-setting material and then look at the short audio-visual presentation explaining the **background to the project**. Otherwise the viewer can imagine that they are a potential student user and explore the interactive material for themselves using the menu options as described above. The overall structure of the demonstration CD is shown in figure 3.

The next section explains why and how this subset of material was chosen and the process used to develop the material in an attractive format on the CD.

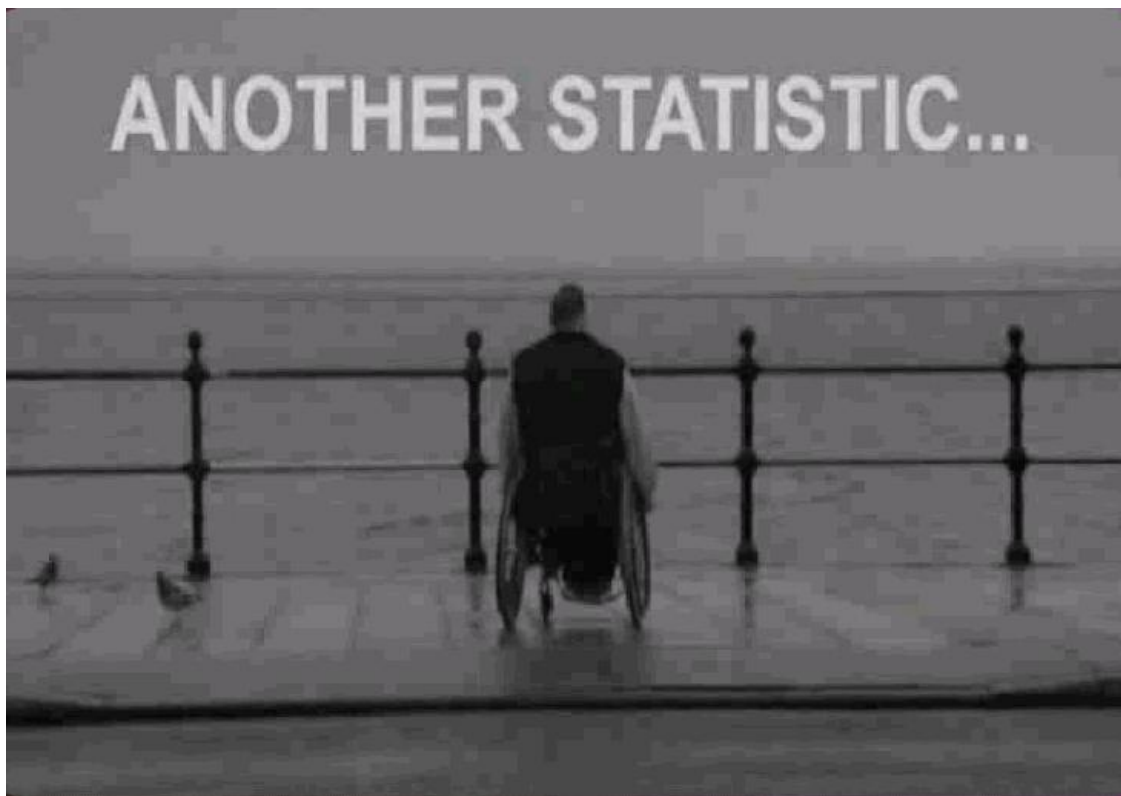


Figure 1 – Powerful image used in opening sequence

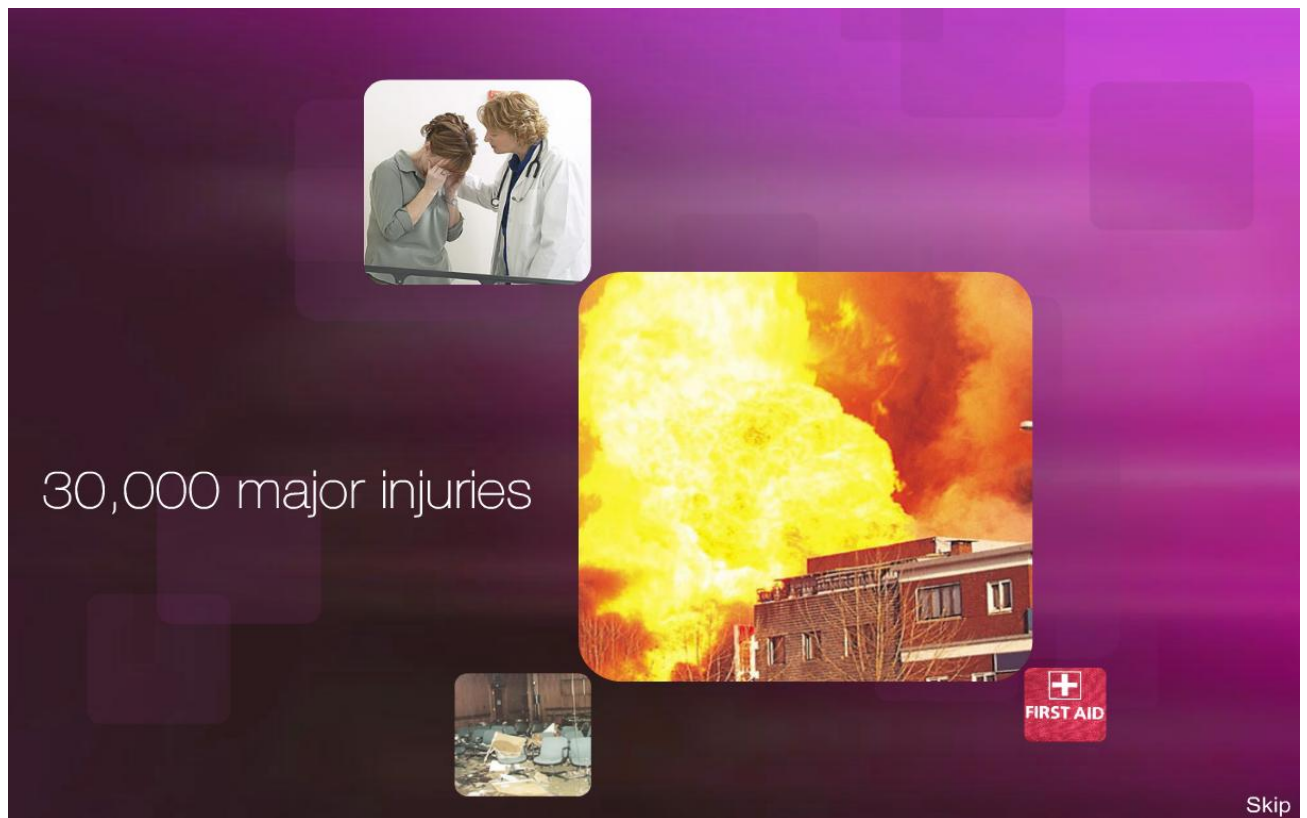


Figure 2 – Hard-hitting statistics used in opening sequence

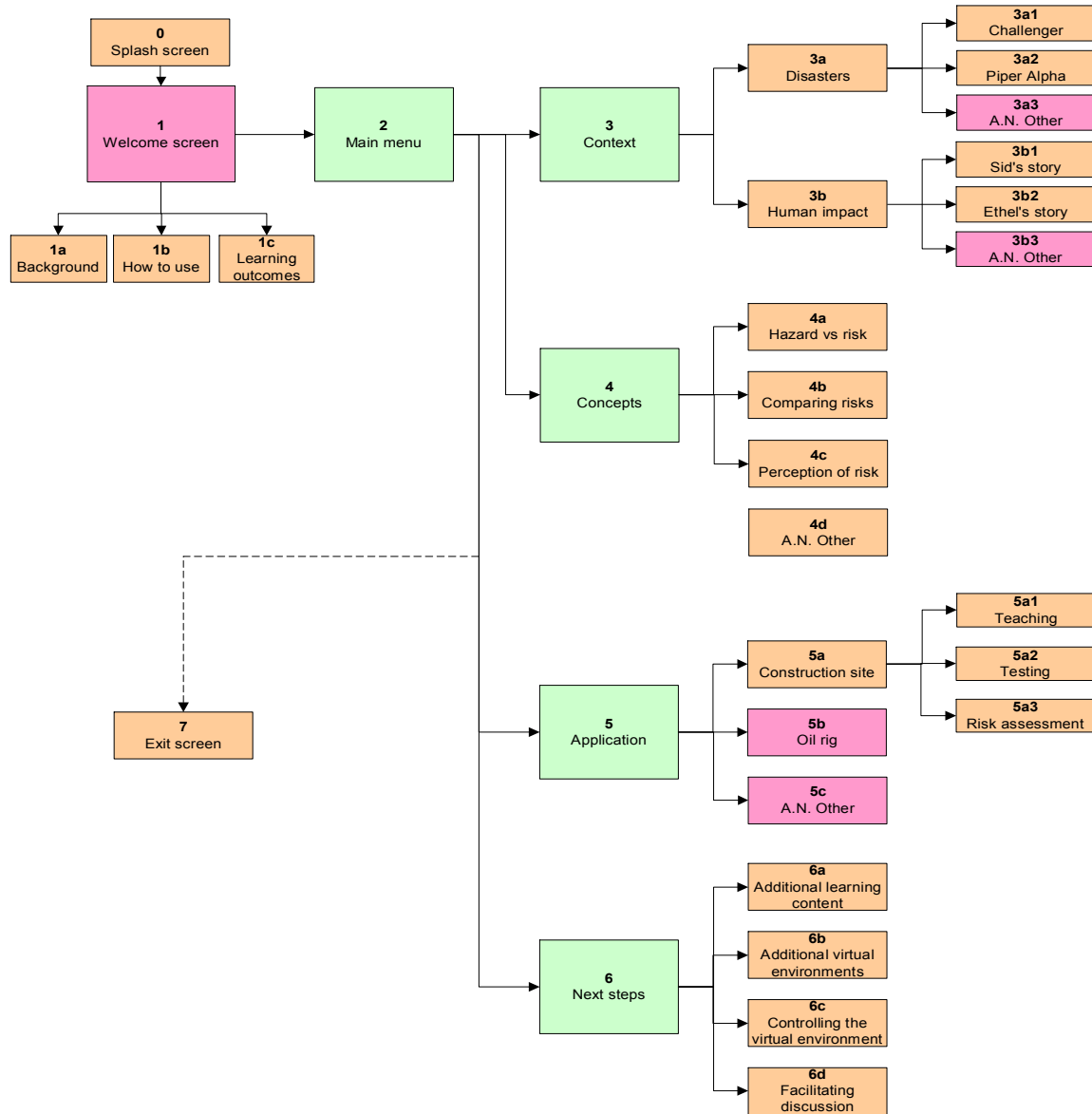


Figure 3 - overall structure of the demonstration CD

Development of ‘Engineering a Safer Future’ e-learning package

Initial work of the IIG (2001) on health and safety considered and defined learning outcomes as described above and identified source material. This was followed up by the production of a document by a sub-group involving academics, HSE and other experts, which summarised the range of topics which might be included in teaching material (IIG 2003).

These documents received strong support from the Engineering Institutions, the HSE (who regarded it as an opportunity to raise awareness of such issues in an educational context with reference to related objectives in its “Revitalising Health and Safety” strategy document (HSE 2000)), and the Engineering Council UK (who saw it as a potential source for meeting accreditation requirements) as well as the Engineering Professors’ Council (EPC) and several universities. Although not aimed directly at industry, major companies to which the summary report was submitted, reinforced both the need for the material and offered general support. In two cases, they saw the material as a potential source for internal training.

It was soon recognised that an appropriate delivery mechanism needed to be found that would enable as many university engineering departments as possible to teach the concepts of health and safety risk management. This would need to recognise that many academics lack familiarity with risk concepts and techniques for managing risk and moreover have limited industrial experience to put them into context so as to engage students. An e-learning package with teaching support was therefore chosen as the best way forward.

With financial support from the HSE, with the IIG Sub-group continuing to offer oversight on behalf of the Engineering Institutions and the Engineering Council (UK) the concept described above was developed and a detailed definition published (Taylor, Bell & Smyth 2006) of requirements, content and approaches for actual e-learning teaching material. This benefited from the involvement of a company (Logica CMG through their HSE IT support organisation, "Refit") with a strong track record in providing similar material in an e-learning format for a variety of government and industry applications.

In order to move the project forward, HSE funded the authors and CMG Logica to develop a CD that would demonstrate the concept using a sample of the proposed content (Taylor, Stacey & others 2006). The sample was chosen to illustrate, within the financial and time constraints, as wide a range of topics and media types as possible. Whilst the financial constraints did not allow for the sample to be fully flexible and modular it is presented in such a way as to demonstrate how this might feel and work. In this way, key elements of the proposed full e-learning package have been assembled to make the intended approach clear to stakeholders. This will allow feedback to be obtained and potential partners to be identified in order to take the project forward.

The approach taken to the development of the sample content was for topic expert(s) to write briefing notes, which Logica CMG turned into scripts and these were checked by the topic expert before coding. A psychologist with experience of user-interface design advised on the overall layout, presentation and routes through the material.

Following a pause to evaluate the package, it is now intended to try to develop the full package. Discussions are therefore now taking place with industrial companies and representative bodies (e.g. trade associations), with academic funding bodies and with charitable foundations. Discussions are also continuing with the engineering institutions and with universities.

For example, the authors are optimistic that work could soon begin with the development of an improved simulation of a construction site (in a similar interactive gaming context as demonstrated at a lower level of quality on the demonstration CD) or activities relating to health and safety risks on an oil platform and relevant tutorial material would be 'enabled' by these, together with any identified teaching support material. The scenarios discussed above could be adapted depending on stakeholder needs and potential sources of funding and/or technical input. For example, the proposed oil platform scenario could be adapted to other types of process or manufacturing plant and further tutorial material developed in this context.

The discussions currently taking place have three primary objectives:

- Obtain feedback on the work so far so that further development can take account of this;
- Develop further ideas on how the project can be managed – particularly given the phasing envisaged, the likely need for technical and financial input from a

variety of stakeholders and the possibility that the material will be of interest to other users such as the FE sector and those concerned with training in companies and;

- Explore potential sources of funding. The HSE, which has funded all of the work thus far, understandably take the view that input from potential users is now required to take 'Engineering a Safer Future' to the next phase.

Conclusions and Recommendations

The primary intention of the work described in this paper was to produce an attractive, good quality 'sample' or 'demonstration' which would enable future contributors and/or funders of a full e-learning package to understand and see clearly what is intended and to have confidence that it can actually be achieved. A suitable sub-set of the material developed to 'proof of concept' has now been produced to meet this objective. This 'sample' is estimated to contain about a sixth of the material that would be needed to satisfy all the learning outcomes, as proposed by the IIG.

In order to fulfill this primary purpose, within financial and time constraints, the CD has not been produced to the same quality standards as would be required for a fully developed e-learning package. The project team is, therefore, aware that there will be some errors, over simplifications and omissions present. However it was felt that the timely circulation of 'sample' material for comment and feedback was more important than detailed quality checks and wider peer review. We invite users to bear this in mind in providing feedback and comments on the present material.

Nonetheless, the development of the demonstration CD has shown the care, clarity and control that is required to avoid substantial rework (and thus increase in cost) in a project of this sort. A process has been developed that should provide a basis for the efficient production of a complete teaching package in accordance with relevant standards. The use of such a process will add confidence to the estimates of cost and timescales and quality.

A flexible, modular structure is required to meet the needs of university engineering departments, possible accreditation for Chartered Engineer status, or graduate training schemes of companies in the engineering sector.

A full e-learning teaching package will need to be developed with a learning management system, compatible with Higher Education IT systems, to allow tracking of student progress, assessment and examination. The intention is that the content will be applicable to all engineering students irrespective of their specific engineering discipline.

Involvement of and promotion by professional institutions will be essential. Moreover clearer links need to be made with accreditation requirements. Also essential is the support, promotion and possible hosting of the package by academic institutions such as the Higher Education Engineering Subject Centre.

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ⁱ Consists of representatives of the expert groups and secretariats of the Institution of Engineering and Technology (IET, the former IEE), the Institution of Mechanical Engineers (IMechE), the Institution of Civil Engineers (ICE), the Institution of Chemical Engineers (IChemE), the Hazards Forum, the Institution of Occupational Safety and Health (IOSH), the Ergonomics Society, and the Safety and Reliability Society (SaRS). HSE and the Engineering Council (UK) are also members.